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3258

A MULTI-CHANNEL PULSE HEIGHT ANALYZER USING A CR STORAGE TUBE

by

James A. Cunningham
Radiation Physics Laboratory

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FOREWORD

This report describes a multi-channel pulse height analyzer developed during an investigation of the utility of memory devices in nucleonic instrumentation.

The research on this project was conducted as a part of a program of research and development in Basic Instrumentation, jointly sponsored by the Office of Naval Research, the Office of Scientific Research of ARDC, and the Atomic Energy Commission.

H. W. Koch, Chief
Betatron Section

A Multi-channel Pulse Height Analyzer Using a CR Storage Tube

James A. Cunningham
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Abstract

The pulse height analyzer described in this paper has been designed for use with pulsed accelerators such as the 50 Mev betatron and the 180 Mev synchrotron at the National Bureau of Standards. The analyzer utilizes the technique of storing the voltage pulses during the short output duration of the accelerators and then analyzing the information during the dead time. Pulse heights were converted into time intervals by means of an ordinary 3KP1 cathode ray tube used as a storing device. Simple time gates permitted the construction of a relatively compact multi-channel analyzer.

I. Introduction

Much of the research in nuclear physics involves the measurement of voltage pulse heights from some detector. Various pulse height analyzers have been proposed and constructed.[1/] These pulse height analyzers can be placed into three general classes: (1) electronic voltage discriminators, (2) electron beam deflection in a cathode ray tube, (3) electronic sweep comparison methods changing a pulse height into a time interval. The pulse height analyzer described in this paper uses the combination of the last two general classifications. It has been designed for use with pulsed accelerators such as the 50 Mev betatron and the 180 Mev synchrotron at NBS. The analyzer utilizes the technique of storing the voltage pulses during the short output duration of the accelerators and then

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1/ A. B. Van Rennes, Pulse-Amplitude Analysis in Nuclear Research, Nucleonics 10, No. 7 (1952).

analyzing the information during the dead time. With this technique it is possible to use simple electronic circuitry, resulting in a relatively compact unit. Discussed in the following sections of this paper are the cathode ray tube storage technique as applied to the pulse height analyzer, the pulse height analyzer circuits and characteristics, and the future application of this storage technique to other nucleonic instruments.

II. Cathode Ray Tube Storage Technique

The operation of the pulse height analyzer can best be explained by a description of the cathode ray tube storage process. A piece of wire screen or foil is placed on the face of the CR tube (see fig. 1). This screen forms one plate of a condenser and the phosphor coating forms the other plate. Any change in phosphor potential is capacitively coupled to the foil and an output signal is generated across "R" and fed into an amplifier. When the electron beam strikes the phosphor surface, a rain of secondary electrons is emitted from the phosphor at the beam position, leaving that spot positively charged. This rain of electrons falls on the grounded coating and on the surrounding phosphor area, charging it to a negative potential. The secondary electron emission will continue until the surface under the beam is charged positive. If a pulse to be analyzed is applied to a set of deflection plates, the beam is deflected across the face of the tube and returns to its normal position. The area bombarded by the beam is charged positively with respect to the surrounding area. If a sweep voltage is applied at a later time to the same set of deflection plates, the beam is deflected across the same path. As soon as the beam deflection exceeds that of the original pulse, the beam strikes an uncharged region of the phosphor, and secondary electrons are again emitted for the balance of the duration of the reading sweep. Since some of these electrons fall on the grounded coating of the tube, the average potential of the phosphor becomes positive, and an output signal is generated across "R". The time at which this output is generated after the start of the sweep is proportional to the peak voltage of the original pulse. The pulse that is originally recorded can be called the writing sweep, and the sweep that removes the information can be called the reading sweep. The writing sweep can be of a very short duration (3 milli-micro-seconds or greater) and the reading sweep can be of a relatively long duration (e.g., 1,000 μsec). If two or more writing sweeps are applied to the storage tube, they will create several phosphor discontinuities. When the reading sweep is applied, each discontinuity will produce an output pulse. The time of occurrence of each output pulse is proportional to the input pulse height. The output pulses occur during the interval from 0 to 1,000 μsec after the start of the sweep, and are distributed into appropriate time channels. Each of these time channels can be calibrated in terms of the original voltage pulse heights.

III. Pulse Height Analyzer Circuits

The circuits involved in this multichannel pulse height analyzer are mostly conventional. Except for the storage tube and the scaler (which employ Philips decade counter tubes), they consist of ordinary amplifiers, cathode followers, one shot multi-vibrators, and a pulse peak detector.

The operation of the analyzer can be explained briefly with the aid of a block diagram (fig. 2). The pulse to be analyzed is applied to a set of deflection plates of the cathode ray tube. A trigger pulse[2/] is sent into two delay trigger circuits that supply secondary trigger pulses after fixed delays. One secondary trigger pulse starts the reading sweep generator, which is applied to the same set of deflection plates, and it also starts the multivibrators that supply the time gates. The other secondary trigger pulse starts a gate pulse for the output amplifier. This gate is necessary to eliminate the pickup from the original pulse and the unwanted pulses at the start and end of the reading sweep.

The output signal is taken from the wire screen on the face of the CR tube and fed into an amplifier. From there the signal goes through a gating tube that also amplifies the pulse and sends it into a peak detector. The peak detector is a circuit designed to give a sharp pulse at the peak of a broader input pulse. This sharp pulse is amplified and fed through a cathode follower giving a low impedance output. The time gate channels used were a series of multivibrators triggered in sequence. Each multivibrator output is sent to a gating circuit. The output of the peak detector is fed to all of the gating circuits in parallel and only that gate which

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[2/] When the analyzer is used with the betatron, the trigger pulse used is the ejection pulse that precedes the X-ray burst by a few microseconds. When random pulses are analyzed a gate precedes the storage tube, allowing only a few pulses to enter the storage tube before the reading sweep is applied. The "trigger-in", under these circumstances, can be the same trigger that starts the gate.

is open when the pulse arrives passes the pulse to its respective scaler. The scaler unit is based on the Philips tube decade scaler.[3]

IV. Characteristics

1. Resolution of the Storage Tube and Detecting Circuitry

The resolution of the pulse height analyzer can be defined as the ratio of the uncertainty in the pulse height measurement to the maximum pulse height that can be analyzed. The resolution of this pulse height analyzer is determined by the storage tube, the peak detector, and the time gates.

Since the time of the output signal of the storage tube occurs as a smoothly varying function of the pulse height, the resolution of the CR tube can be determined by observing the time duration of the output signal. The expected output signal rise time depends upon the speed of the reading sweep, the sharpness of the reading sweep beam, and the sharpness of the phosphor potential discontinuity. The phosphor potential discontinuity is created by the edge of the primary electron beam; and, therefore, it depends on the sharpness of the beam. Assuming that the beam spot size is of the order 0.020" ÷ (reading sweep in in./μsec), then with the 1400 μsec 2 in. sweep used, the rise time should be approximately 14 μsec. The decay time of the output pulse is determined by the coupling RC time constant. The capacity between the phosphor and the foil is approximately 20 μμf and the "R" is 1 meg, so the decay time will be about 20 μsec. Figure 3 shows the output pulse on a 200 μsec time base, which appears to be about 40 μsec

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[3] Philips Research Report 7, 81-111 (April 1952).

out of a 1400 µsec reading sweep. This compares favorably with the sum of the rise and fall time expected, which is about 35 µsec.

Detection of the output signal by a pulse height discriminator was found to be unsatisfactory. The output signal essentially rides on top of a background signal created by the irregular phosphor density along the sweep path. The irregular phosphor density creates a varying amplitude output signal which, if detected by a pulse height discriminator, would affect the time at which the detecting signal would occur. If the reading beam should drift, changing the background signal, an error would be introduced. Errors due to irregular phosphor density are considerably reduced when the peak detector is used. The output pulses resulting from phosphor irregularities are of lower amplitude than the signal and are not as sharp as the signal. When an input pulse of constant amplitude is fed into the analyzer, an output signal is observed during a 1400 µsec reading sweep which varies in time approximately ±1.5 µsec. This gives the storage tube and peak detector an overall resolution of about .1%. The window width stability of the CR tube analyzer is determined by the variation of the time output signal divided by the width of the time gates.

The time gates were tested by observing their drift on an oscilloscope and using a random time pulse generator for observing gate widths. The reproducibility of the number of random pulses in each gate was within the statistical accuracy of 1 percent.

2. Comparison Test of the Analyzer

The entire analyzer was checked by using a NaI total absorption spectrometer[4] to examine the spectrum of gamma rays from a Zn^{65} and RaD-Be source. The measurements were taken continuously during a five-day period except for intervals taken to calibrate and test the analyzer with a precision pulser and sliding pulser. Figure 4 shows the spectra of Zn^{65} and RaD-Be plotted with an Atomic Instruments model 510 single channel analyzer. The spectra taken with the CR tube analyzer are in good agreement with those taken with the single channel analyzer. Both analyzer window widths were set at approximately 0.5 volts. The window width stability of the CR tube analyzer under the above conditions was about 5 percent.

During this investigation a 3KP1 CR tube was used and the preceding results were obtained. Recently, however, several tubes[5] have been produced specifically for the storage process used in computers. These tubes should have many advantages over the ordinary CR tube for use with this technique.

3. Input Pulse Shape Requirements

Since the pulse to be analyzed is applied to a single set of deflection plates, only the peak of the pulse will form a phosphor potential discontinuity. This means that any previous pulse shaping is not necessary. Pulses of 3 mμsec duration have been analyzed. It was found that several pulses could be stored on the face of the tube before a

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4/ R. S. Foote and H. W. Koch, Scintillation Spectrometers for Measuring the Total Energy of X-ray Photons, Rev. Sci. Instr. (1954), to be published.

5/ A. S. Jensen, J. P. Smith, M. H. Mesner, and L. E. Flory, Barrier Grid Storage Tube and Its Operation, RCA Review 9, No. 1 (1948).

reading sweep is applied. This enables the analyzer to accept several pulses during a short X-ray burst, permitting an increase in the rate at which data can be taken. The unwanted pulses at the beginning of the reading sweep of the 3KP1 CR tube destroyed the usefulness of approximately the first 7 percent of the reading sweep. It was found necessary to increase the gain of the amplifier preceding the analyzer to examine pulses that are in the lower 7 percent of a pulse height spectrum.

4. Power Supply Requirements

The output voltage of the CR tube power supply can drift more than 10 percent without a detectable error in the time of the output pulse, since the deflection sensitivity is the same for the writing sweep as it is for the reading sweep.

The storing, comparing, and amplifying circuits are equivalent to those of a normal 3 inch oscilloscope (see fig. 5). There are several methods for recording the time pulses by different circuitry. The counting rate one expects will determine the amount of circuitry. If one expects a slow counting rate (20 counts per minute), then a gated scaler and printer can be used. If the gated scaler counts at a 100 k cycle rate and a reading sweep of 1,000 µsec is used, the pulse heights will be divided into 100 channels.

For the higher counting rates expected from experiments with the NBS accelerators (about 180 pulses per sec) a conventional set of time gates was constructed, adjustable in time occurrence and width, providing eight channels that could be set to any voltage level and window width. Work is now being done on applying a beam switching tube[6] to greatly reduce the circuitry of the time gates used.

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[6] Electronic Design, Vol. II, No. 1 (Jan.1954). Tubes are produced by Burroughs Electronic Instrument Division.

V. Applications

1. Use with Radioactive Sources

When the analyzer was used to examine a spectrum of a source emitting particles at random times it was preceded by a gate. The gate can be opened allowing a few pulses to enter the storage tube and then be closed during the reading sweep. When the information is recorded and the sweep returns to its normal position the gate can be reopened and the series of operations repeated. The gating circuit[7] used was of the difference amplifier type passing pulse heights from 0.4 volt to 4 volts linearly.

2. Future Applications

During the development of the pulse height analyzer, it became evident that this principle could be applied to other nucleonic instrumentation problems. For example, it would be possible to record on the CR tube a number of pulses that occur during an extremely short time and to count them with conventional scalers during the reading sweep. This would be useful in the measurement of very short half lives or in time-of-flight experiments. The waveforms are indicated in figure 6.

If the sweep voltage of figure 6a is applied to the horizontal plates of a storage tube, and the voltage pulses to be counted are applied to the vertical plates, as shown in figure 6b, the pulses will be stored on the CR tube, as shown in figure 6c. During the retrace of the writing sweep, which lasts about 1000 μsec, the beam scans from right to left along the same base line. As the beam crosses the discontinuities of the phosphor potential created at the base of the voltage pulses, output pulses are created on the 1000 μsec sweep (fig. 6d).

7/ Linear Gate Circuit for Pulse Height Analysis by P.R. Chagnon. P.R. Chagnon, Rev. Sci. Instr. 24, p. 990 (1953).

The above process is equivalent to the storage of a series of pulses that occur during a 1 μsec duration and then expanding them on a longer time base. This technique permits the measurement of the information in a conventional manner with relatively slow circuitry.

VI. Conclusion

The principle of quick storage and leisurely analysis of data as described above permits the use of simple electronic equipment for some of the difficult problems of nucleonics instrumentation.

VII. Acknowledgment

The author wishes to acknowledge the assistance and discussions held with members of the Nucleonics Instrumentation and the Electronic Computor Sections of the National Bureau of Standards.

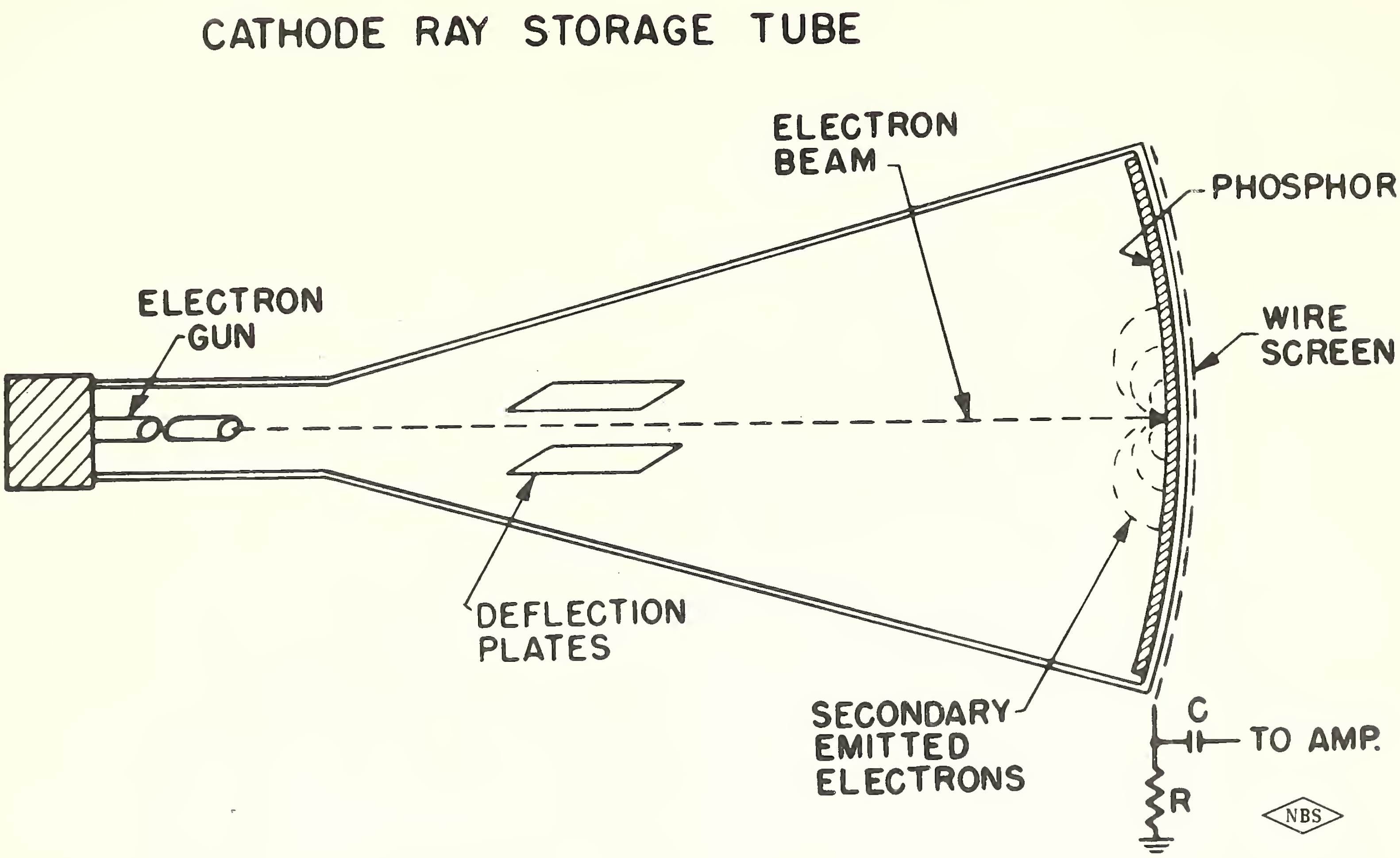

Figure 1. Cross-section of a CR tube used as a memory device, illustrating a method of removing pulse height and time information from deflected beam.

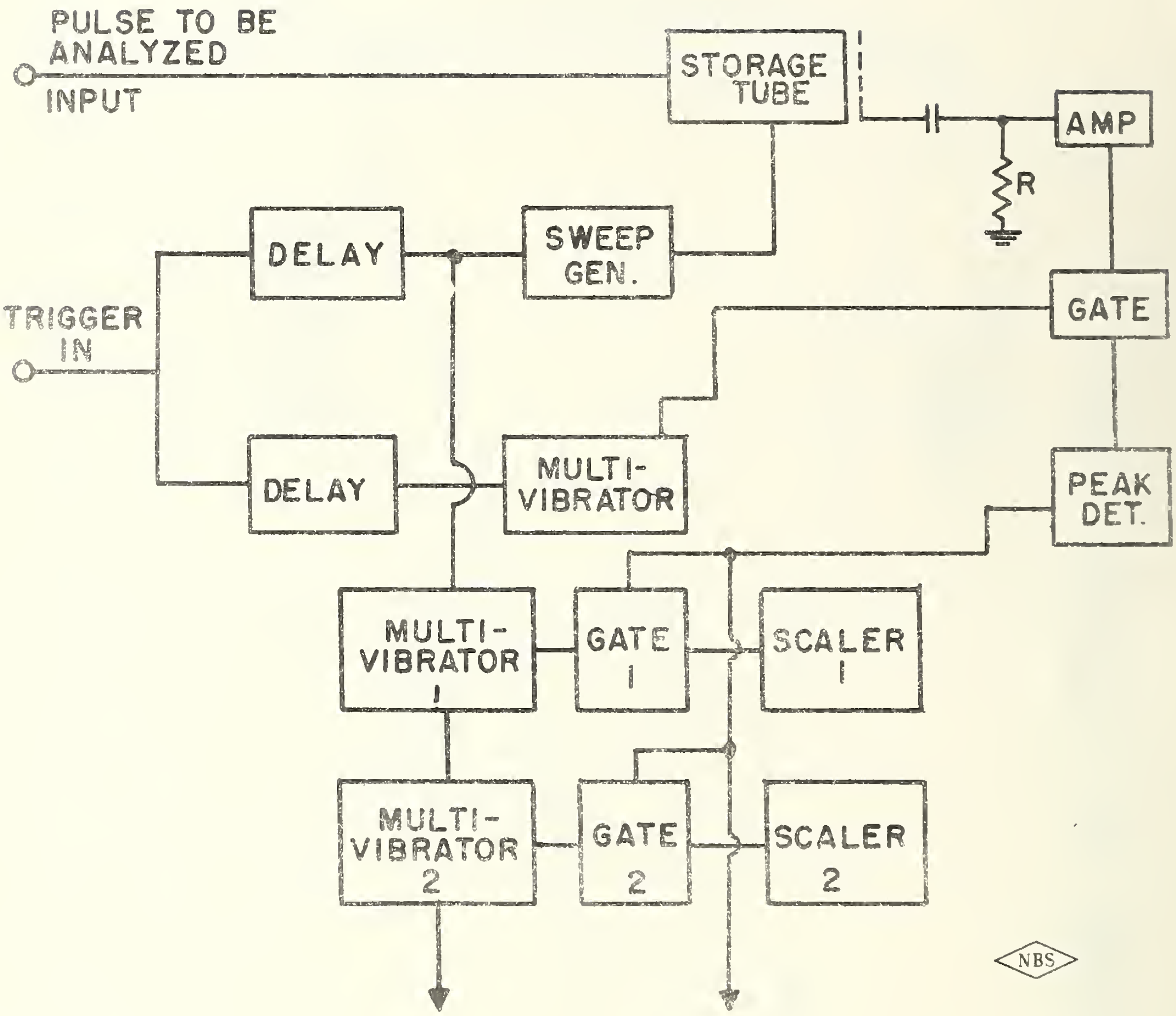

Figure 2. Block diagram of CR tube pulse height analyzer.

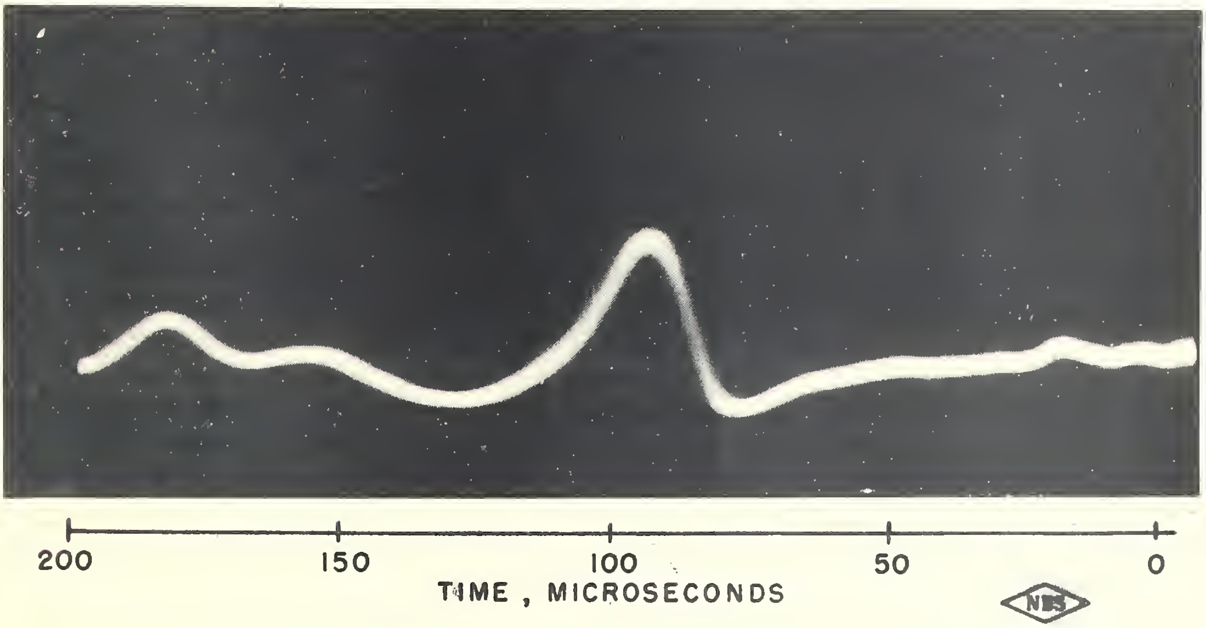

Figure 3. Output signal from CR tube pickup plate. This also shows the type of background from a tube.

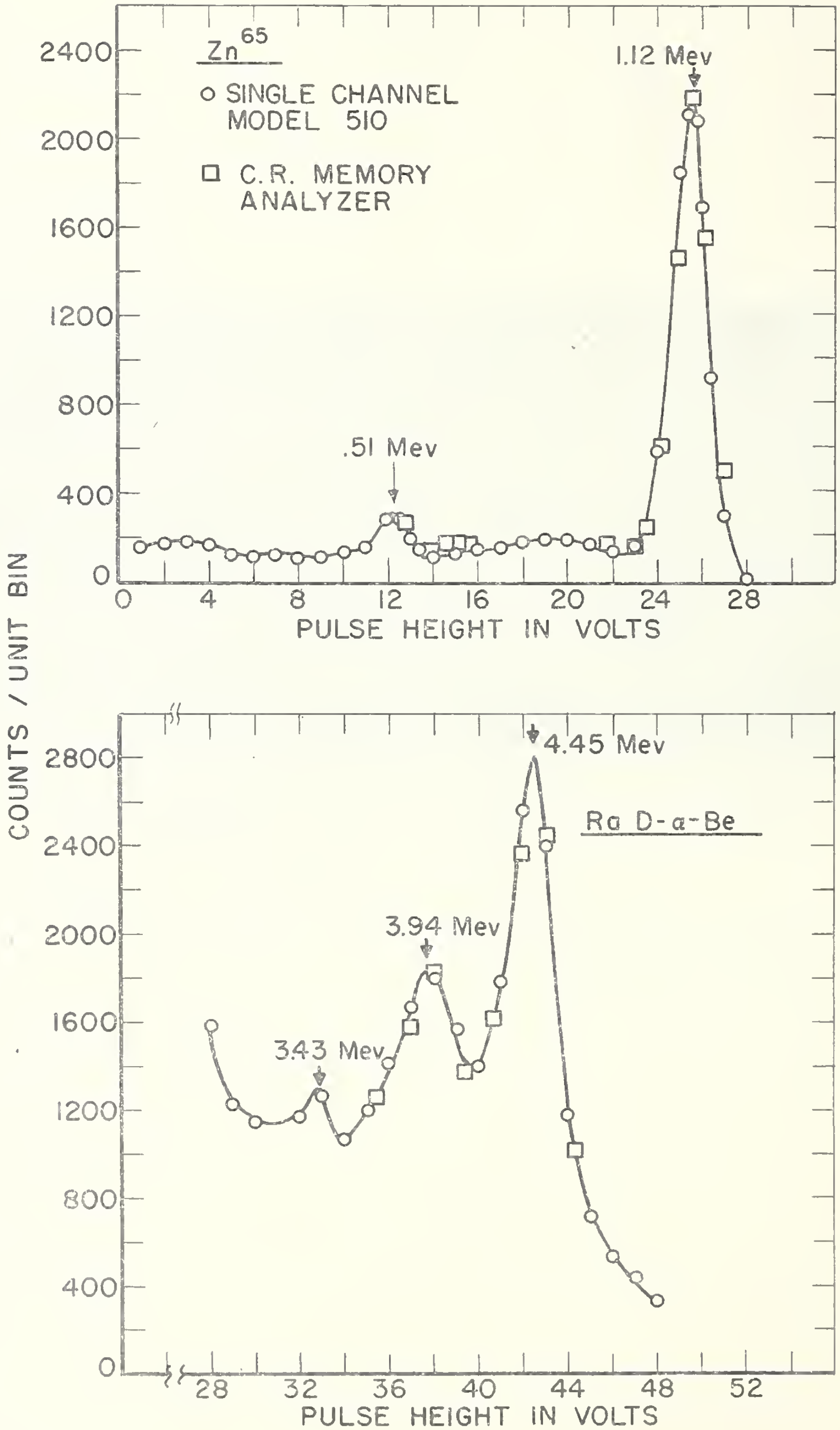

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Figure 4. A comparison of the gamma ray spectra of Zn^{65} and RaD-Be sources measured with a single channel analyzer and a CR tube pulse height analyzer.

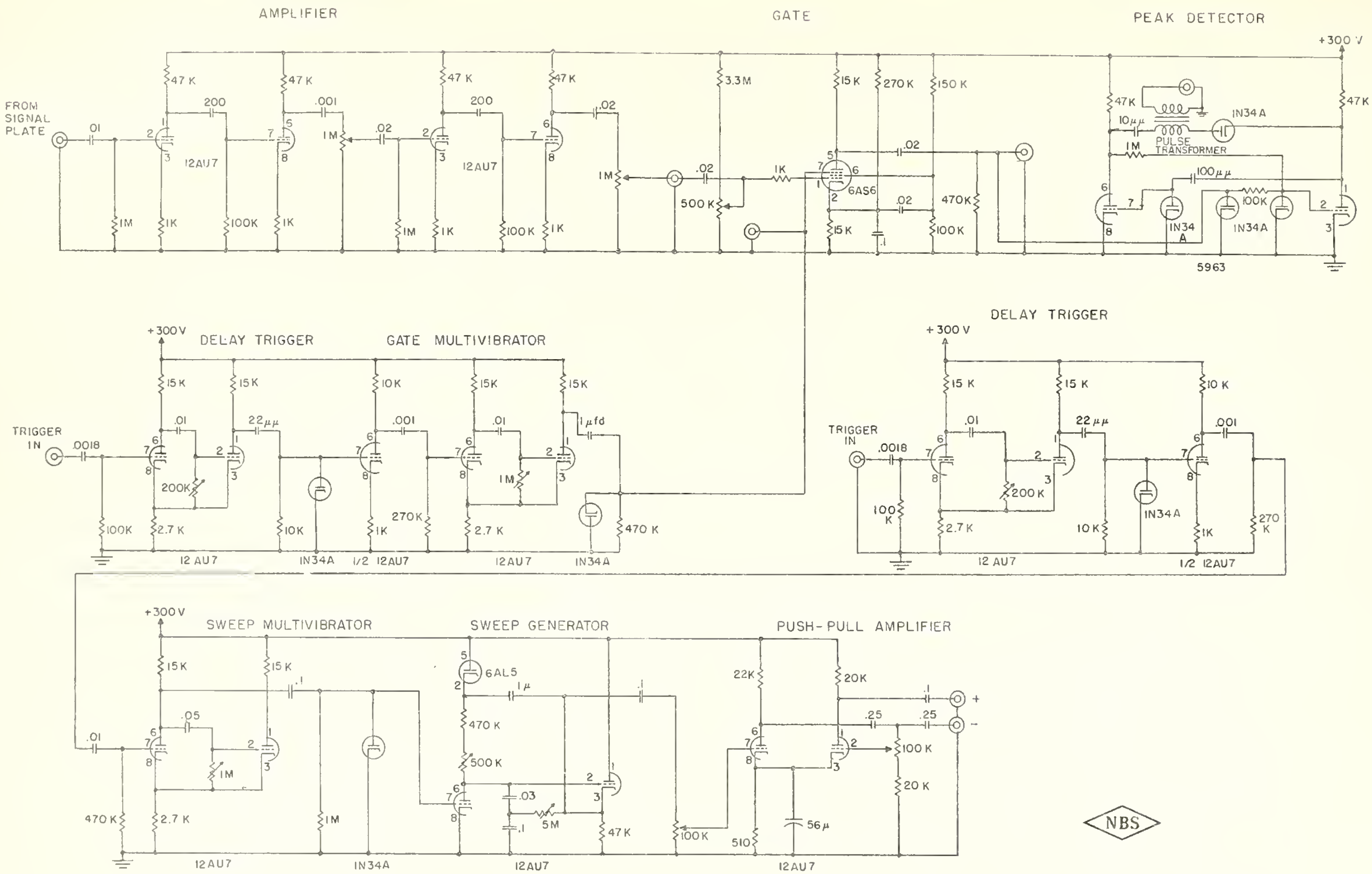

Figure 5. Circuit diagram of the delayed trigger, reading sweep, amplifiers, and peak detector of the CR tube pulse height analyzer.

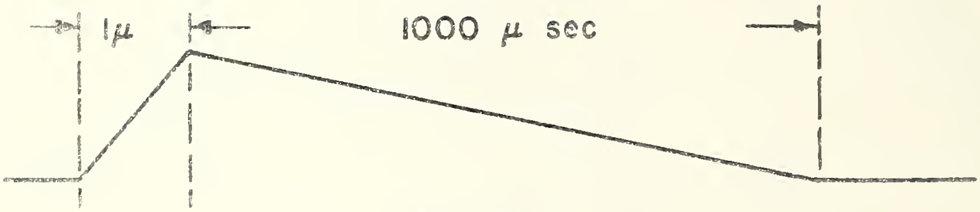

FIG. 6a

FIG. 6b

SWEEP ON CR TUBE FACE

FIG. 6c

OUTPUT PULSES OF PEAK DETECTOR ON 1000 μ sec TIME BASE

FIG. 6d

Figure 6. The waveforms applied to and generated from the CR tube when used as a fast scaler.

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