AIP Review of Scientific Instruments

Chart Recording of Microsecond Pulse Amplitudes

J. T. Dewan and K. W. Allen

Citation: Review of Scientific Instruments **21**, 823 (1950); doi: 10.1063/1.1745437
View online: http://dx.doi.org/10.1063/1.1745437
View Table of Contents: http://scitation.aip.org/content/aip/journal/rsi/21/10?ver=pdfcov
Published by the AIP Publishing

THE REVIEW OF SCIENTIFIC INSTRUMENTS

VOLUME 21, NUMBER 10 OCTOBER, 1950

Chart Recording of Microsecond Pulse Amplitudes

J. T. DEWAN AND K. W. ALLEN
Atomic Energy Project, National Research Council of Canada, Chalk River, Ontario, Canada
(Received July 7, 1950)

A peak voltmeter circuit is described which will record, on an Esterline-Angus chart, the amplitudes of microsecond pulses generated at random in ionization chambers or similar counters. Slow response of the recording pen prohibits the resolution of pulses less than one second apart. Provision is made for selecting pulses coincident with some triggering event as the low counting rates suitable for the circuit are most often encountered in coincidence experiments. Coincidence resolving times as low as five microseconds may be attained, and the linearity is such that input pulse amplitudes from 2 to 100 volts are reproduced on the chart to within ±1 volt.

INTRODUCTION

In many instances it is necessary to obtain the distribution in size of microsecond pulses produced in ionization chambers or proportional counters and for this purpose a multi-channel pulse analyzer is normally utilized. However, when the pulses occur very infrequently, at an average rate of a few per minute, as is often the case in coincidence experiments, a high speed pulse analyzer is a much more complex instrument than is required. Its discriminating circuits may tend to drift during the long counting periods necessary to produce good statistics, and usually it has no provision for the selection of pulses coincident with other events. Consequently a circuit has been designed which will indicate, on the chart of an Esterline-Angus 1-ma pen recorder, the magnitudes of random pulses which may, if desired, be selected by coincidence with other events. It was originally used in the study of the energy distribution of long-range α-particles which are emitted occasionally in the fission process,[1] but subsequent experience has confirmed its usefulness in other applications. The rather slow response of the Esterline-Angus pen prohibits the resolution of pulses less than one second apart, although the coincidence resolving time may be as low as several microseconds. The circuit can be readily adjusted to handle input pulses ranging from microseconds to milliseconds in duration and will reproduce on the chart pulse amplitudes from 2 to 100 volts to within ±1 volt. It is, perhaps, somewhat tedious to translate the spectrum of pulses obtained on the chart into a differential or integral bias curve, but on the other hand a permanent record is obtained showing the actual time distribution of the pulses, a feature especially useful when deviations from randomness are suspected.

[1] K. W. Allen and J. T. Dewan, Phys. Rev. 80, 181 (1950).

DESCRIPTION OF THE CIRCUIT

The general operation of the circuit can be readily understood from the block diagram of Fig. 1. Pulses to be recorded, of positive sign and up to 100 volts in amplitude, are normally obtained from a linear amplifier. They are fed into the discriminator D_1, which eliminates amplifier noise and any small undesired pulses, and then into the coincidence gating circuit C. If a given pulse is coincident with one from the gate generator G it passes on with unchanged magnitude to the lengthener L; if not, it is suppressed in the coincidence circuit. The lengthener is a two-stage integrating circuit which, in the absence of the restorer R, would extend the duration of the input pulse from a few microseconds to several minutes thereby allowing the Esterline-Angus pen ample time to record the magnitude of

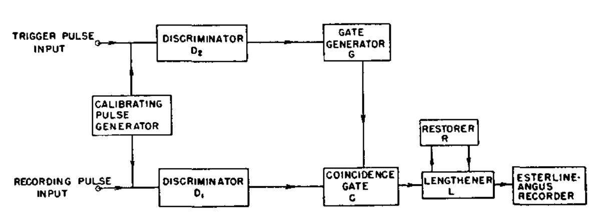

FIG. 1. Block diagram of the pulse amplitude recorder.

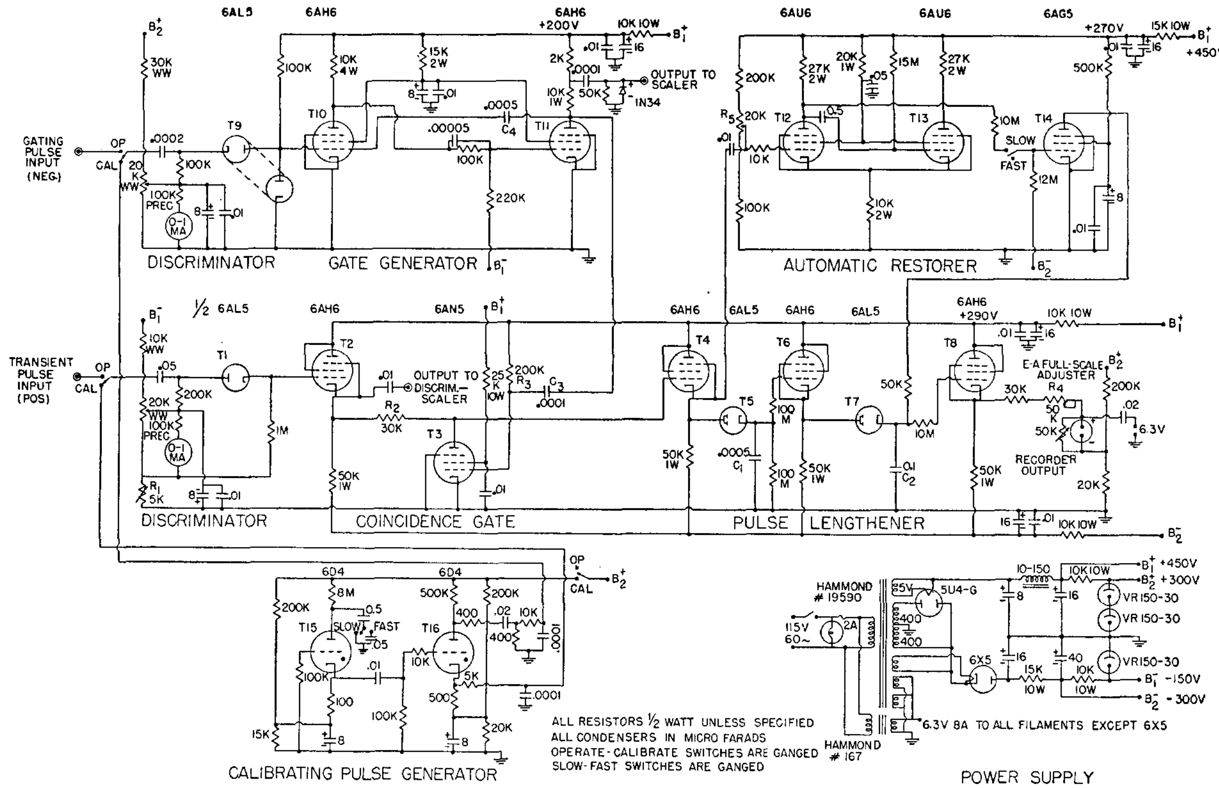

FIG. 2. Circuit diagram of the pulse amplitude recorder.

the pulse before it has appreciably decayed. The rectoring circuit allows the pen about one second to reach its maximum traverse and then returns it in a fraction of a second to its normal position in readiness for another pulse. The use of a restorer decreases the dead time by a large factor since, in its absence, the pen would follow a very slow exponential decay. The calibrating pulse generator provides standard pulses, simulating the transients in speed of rise, to facilitate the adjustment of the recorder and to check the linearity of the system. A complete diagram of the circuit is shown in Fig. 2 and a more detailed description follows.

Pulses with amplitudes sufficiently large to overcome the biased diode T_1 are fed into a coincidence gate circuit consisting of the cathode follower T_2 driving the load R_2 in series with the tube T_3. Normally T_3 has zero grid bias and draws a large screen current so that it has a plate to cathode resistance of about 500 ohms. Consequently only two percent of an input pulse reaches the grid of T_4 when the coincidence gate is closed. On the other hand, when a negative pulse from the gate generator drives the grid of T_3 beyond cut-off, this tube acts as a very large resistance shunted by its plate-cathode capacity, wiring capacity and the input capacity of T_4. Complete charging of these stray capacities through R_2 requires about 1 μsec.; hence if the input transient rises in a fraction of this time it must remain at maximum for a microsecond to ensure that no loss in pulse amplitude will occur in the coincidence gate. This necessitates that exponentially decaying input pulses have a total duration of about 40 μsec.

As it is difficult to predict accurately from the published data the performance of T_3 under such conditions, a number of different miniature tubes were investigated to determine their effective resistances at low plate voltages. The results are shown in Fig. 3. In each case the tube was tested at zero grid bias and sufficiently large screen voltage to produce maximum rated screen dissipation with no plate current flowing. It is evident from Fig. 3 that the 6AN5 is best suited for the application; it has a resistance of 500 ohms at plate voltages up to eight volts. Several other coincidence circuits were investigated but the one described was found to be the most satisfactory. It responds rapidly and has the advantage that small unavoidable delays in the gating pulse cause no loss in the size of coincident pulse reaching the lengthener provided that pulse remains at maximum for at least one microsecond after T_3 has been driven to cut-off.

The pulse lengthening is effected by a straightforward two-stage integrator comprising tubes T_4, T_5, T_6, and T_7.[2] Each stage consists of a cathode follower which charges a reservoir condenser through a sharp cut-off diode. The cathode follower will supply 50 ma without drawing grid current so that the first reservoir condenser

[2] W. C. Elmore and M. L. Sands, *Electronics: Experimental Techniques* (McGraw-Hill Book Company, Inc., New York, 1949), p. 196.

C_1 can be charged to 100 volts in a microsecond. It loses its charge in about 25 msec., while the second condenser C_2 is charged in half a millisecond and has a decay time constant of approximately five minutes. As the Esterline-Angus pen requires half a second to sweep fully across the chart, it cannot actually follow this millisecond rise but attains its full traverse before the pulse has perceptibly decayed in magnitude. The use of a "Glassmike"* condenser for C_2 is strongly recommended because of its extremely high leakage resistance. The lengthened pulse appearing across the final reservoir condenser is coupled to the Esterline-Angus recorder through the cathode follower T_8. The d.c. voltage at the cathode is balanced out by a voltage divider so that little current normally passes through the recorder. Accurate balance is not necessary because of the manual pen shift on the instrument. A variable resistor R_4 in series with the recorder is provided for adjusting the size of the pulses on the chart; usually it is arranged that 100 volt input pulses produce full scale deflection. For large pulses the recorder is critically damped by 15,000 ohms shunt resistance but small pulses appear slightly overdamped due to the friction of the pen on the chart. However a small 60-cycle voltage applied to the movement aids the pen in responding more quickly to small pulses. The oscillation caused by this a.c. voltage is barely perceptible, producing only a slight widening of the trace.

As already mentioned the function of the restoring circuit is to discharge rapidly the final reservoir condenser after the recording pen has had ample time to reach its maximum, i.e., after about one second. Otherwise the lengthener would not be ready for another pulse until condenser C_2 had completely discharged, which would require about fifteen minutes. The restoring circuit consists of the cathode-coupled trigger pair T_{12} and T_{13} and a discharge tube T_{14} which normally conducts and acts as a relatively low resistance across C_2. Positive pulses from T_4 fire the trigger pair producing negative pulses of about one second duration and of sufficient size to bias off T_{14} completely. For this interval of one second, condenser C_2 is allowed to retain the charge which it accumulates; at the end of the interval T_{14} conducts and discharges C_2 in a few milliseconds. As the coincidence gate is not 100 percent efficient, small non-coincident pulses of two volts or less can reach the lengthener. The purpose of R_5 is to ensure that these small pulses do not trigger the restorer and hence do not record on the chart. C_2 is actually charged by such pulses but loses its charge through T_{14} before the pen has had sufficient time to respond.

The gate generator was rather arbitrarily chosen to accept negative input pulses, up to 100 volts in magnitude. Pulses large enough to pass the biased diode T_9 fire the direct-coupled trigger pair T_{10} and T_{11} producing fast rising output pulses of 50 μsec. duration. The differentiating combination C_3R_3 transforms these to sharp triangular pulses causing T_3 to be biased off for a well-defined interval of time, which should be somewhat greater than the rise time of the transients under study. The load resistor of T_{11} is tapped to provide a small negative output to feed an external scaling unit. Positive pulses can be obtained equally well by reversing the 1N34 diode.

The internal calibrating pulse generator has been found extremely useful for checking the overall operation, adjusting the recorder to correct full scale deflection and testing the linearity of the transient channel. It consists of a 6D4 thyratron relaxation oscillator T_{15} providing positive pulses at two frequencies, either one every four seconds or two per second, to trigger the thyratron pulse generator T_{16}. The pulse shaping elements in the second stage may be altered at will to provide pulses with rise and decay times simulating those of the actual transients under study.

ADJUSTMENT AND CALIBRATION

The system is adjusted and checked as follows. With the internal pulse generator arranged to give pulses of the desired shape, C_3 and if necessary C_4 are adjusted so that the gate generator biases T_3 to cut-off for roughly twice the rise time of the transients under study, with a minimum of two microseconds. R_3 is then varied by screwdriver adjustment until the cathode of T_2 is at ground potential. With no input pulses to either channel and with the "Operate-Calibrate" switch on "Operate," the recorder pen is balanced to have minimum pressure on the chart consistent with proper tracing and is then brought to the proper baseline by the manual adjustment provided in the instrument. The switch is then turned to "Calibrate," which starts the internal generator operating and connects the standard pulses to the gate generator and transient channels. A discriminator-scaler, whose calibration is known to be accurate, is connected to the monitor output of T_2. With the calibrator frequency switch on "Fast" the magnitude of the pulses entering the discriminator-scaler is adjusted to be 100 volts, the frequency switch is thrown to

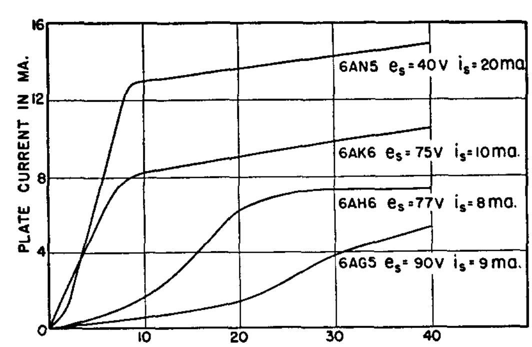

FIG. 3. Low voltage characteristics of several pentodes. Screen voltages are constant and screen currents indicated are those which obtain with zero plate current.

* Oil-filled plastic film capacitors supplied by Condenser Products Company, Chicago, Illinois.

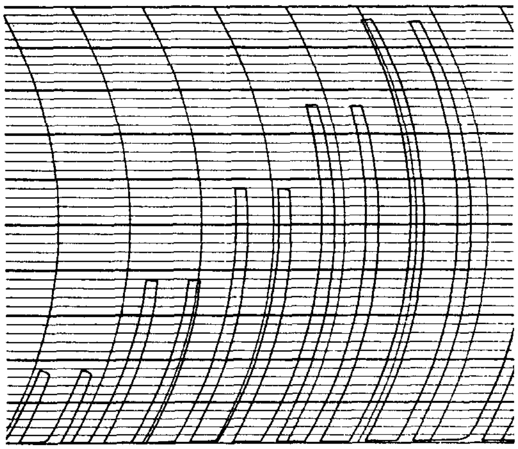

FIG. 4. Response of the recorder to test pulses of one microsecond rise time. The width of each pulse on the chart is approximately two seconds.

"Slow" and the height of the pulses recorded on the Esterline-Angus is adjusted to be full scale by means of the variable resistor R_4. The linearity of the system, as well as the satisfactory operation of the recorder, is then checked by reducing the size of the calibrating pulses in a number of steps, each time noting the pulse amplitude entering the discriminator-scaler at "Fast" frequency and the amplitude on the pen recorder at "Slow" frequency. The "Fast" frequency is provided merely to facilitate finding the cut-off point with the discriminator; this would be a very tedious process at a pulse frequency of one in four seconds. The frequency change is not sufficiently great to cause any change in pulse amplitude. Finally with 100-volt pulses at the monitor output of T_2, but with no gate pulses fed to T_3, R_5 is adjusted until no small pulses are recorded on the chart. The adjustment and checking are then completed and the "Operate-Calibrate" switch is moved to "Operate." Figure 4 shows the response of the Esterline-Angus recorder to test pulses of varying amplitudes, the rise time of the test pulses being approximately one microsecond and the decay 50 μsec.

DISCUSSION

In connection with the use of the pulse recorder one or two points are worthy of note. It is evident from the operation of the coincidence gate that the resolving time of the system for chance coincidences cannot be less than the duration of the input transients and for reasons previously given this is a minimum of 40 μsec. for an exponentially decaying pulse. A resolving time of perhaps 50 to 100 μsec. is not excessive in many experiments. If a spectrum of pulses is recorded in which a fraction of the pulses is due to chance coincidences a correction can be made by triggering the gate generator from an independent source, e.g. an external pulse generator, and subtracting the resulting spectrum of random coincidences from that previously obtained, after normalizing the two to identical counting rates.

When it is desired to achieve the minimum possible resolving time with fast-rising pulses these pulses should be preshaped into flat-topped rectangles of the same amplitudes and of about 3 μsec. duration. As the coincidence gate must remain open for at least 2 μsec. the shortest resolving time attainable is approximately 5 μsec. (If still shorter resolving times are required, coincidences must first be formed with a conventional mixer circuit whose output is then used to trigger the gate generator.) Pretreatment of the pulses may be effected by a simple one-stage integrator with restorer, very similar in nature to the circuits already described. It sometimes happens[1] that gate generating pulses, although nominally coincident with pulses to be recorded, have unavoidable delays of perhaps several microseconds. In such cases preshaping of the transient pulses is necessary because exponentially decaying pulses, unless exceedingly long, would suffer losses in amplitude in the coincidence gate by amounts depending on the delays involved. Preshaping is also necessary when one wishes to record pulses less than a microsecond or so in duration as these pulses are too short to pass through the coincidence gate properly.

If it is desired merely to record the amplitudes of all pulses entering the transient channel, the coincidence feature of the circuit can be eliminated by removing T_3 from its socket. In this case bypassing R_2 and decreasing C_1 will improve the response to pulses rising in less than a microsecond.

Indications are that the pulse recorder described in this paper will find many uses in cosmic-ray research where low counting rates are quite common. In this laboratory it has been used to record the number of counters in a tray of paralleled Geiger tubes which are fired simultaneously by the passage of a cosmic-ray particle, and is currently being used, in conjunction with a proportional counter, to study the specific ionization of mesons of selected ranges. However, it is believed that the circuit is sufficiently versatile to find application in other fields requiring peak voltmeters or pulse recorders.