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A MULTIPLEX PULSE-HEIGHT RECORDER  
AND ANALYZER

BERKELEY, CALIFORNIA

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A MULTIPLEX PULSE-HEIGHT RECORDER AND ANALYZER

A. A. Wydler

May 26, 1961

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### ABSTRACT

A system intended for the analysis, processing, and storage of pulse-height and time data originating from chemically prepared samples is described. This system can record the pulse height and time of an event received from one to six detectors. Included is a device to assist in the reading and evaluation of the recorded data. The system is such that input signals are coded, mixed in a passive network, and fed to a common pulse analyzer of the height-to-time-converter type. The output of the pulse-height analyzer is arranged to provide immediate visual indication on a ten-by-ten register matrix, and permanent storage on a paper tape that has been previously identified by the originating input signal. Each entry on the paper tape includes the time of entry.

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### I. INTRODUCTION

In nuclear experiments, information from many sources must often be accepted within a limited amount of time. One convenient way of accomplishing this is to convert the information to digital form, identify it as to source, indicate the time of acceptance, and then store this composite as a permanent record for future evaluation. Whereas the volume of information stored may be great, usually the area of interest is small compared to the total. Therefore the system for storage need not be exceedingly fast; however, it must treat all information equally, regardless of source.

A system intended for the analysis, processing, and storage of pulse-height and time data originating from chemically prepared samples is described herein. This system can record the pulse height and time of an event received from one to six detectors. Included is a device to assist in the reading and evaluation of the recorded data. During November 1960 this system was relieved of its assigned duty, modified slightly, and used in the identification of the new element, lawrencium ( $\text{Lw}^{257}$ ).<sup>1</sup> Its performance was gratifying. The system is such that input signals are coded, mixed in a passive network, and fed to a common pulse analyzer of the height-to-time-converter type (Fig. 1). The output of the pulse-height analyzer is arranged to provide immediate visual indication on a ten-by-ten register matrix, and permanent storage on a paper tape that has been previously identified by the originating input signal. Each entry on the paper tape includes the time of entry.

Friden model MCP617 punches are used to make entries on the paper tape. These punches are capable of punching up to eight transversely spaced holes on 1-in. -wide oiled paper tape; this dictates the need for binary coding to store 100 channels of information. The punching rate, 20 lines per second, allows for the encoding and punching of 10 groups of pulse-height and time information per second. Since the punches are individually blocked upon receipt of data, several may be recording simultaneously. A companion to the punch—a model MR690 tape reader, used with its associated apparatus—decodes previously punched tape as to data or the time of entry of any part of the spectrum. Where applicable, the reader also indicates the time of decay of any part of the nuclear spectrum. These data are presented by means of a ten-by-ten register matrix or by the printer-and-plotter combination of an associated pulse-height analyzer.<sup>2</sup>

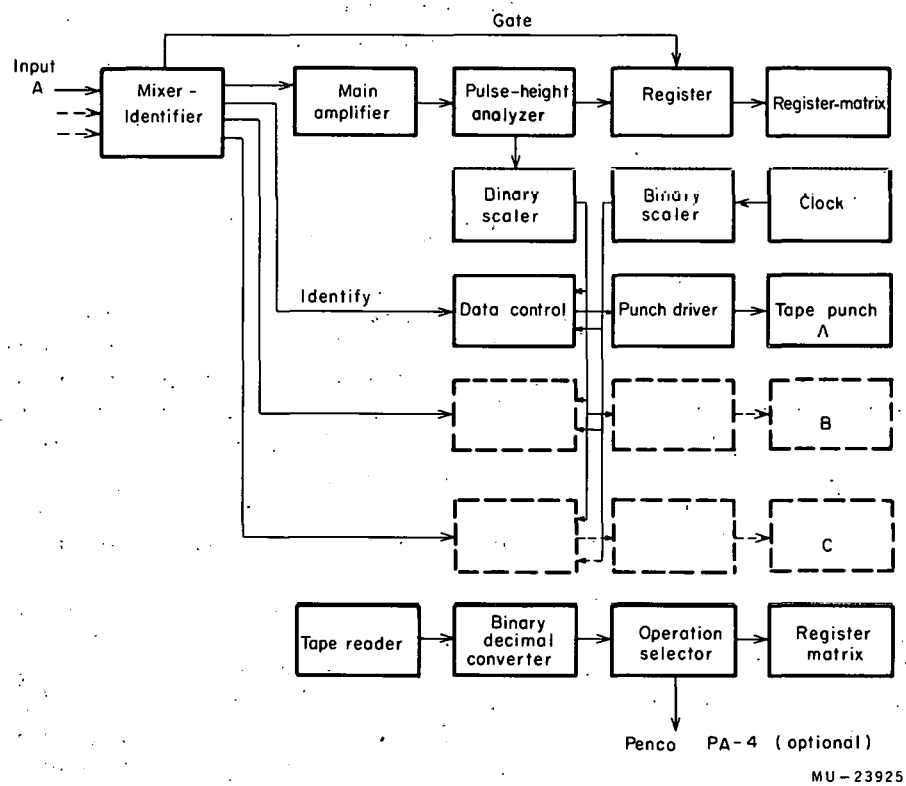


Fig. 1. System.

## DESCRIPTION

The mixer-identifier accepts positive pulses from one to six different sources (Fig. 2). These pulses may be up to 100 v in amplitude and either RC or delay-line clipped; any length greater than 1  $\mu$ sec is acceptable, but the rise time should be from 0.1 to 0.5  $\mu$ sec. The purpose of this circuit is to route any input to the main amplifier without cross talk and to remember which input received the pulse. This circuit accomplishes these functions by first combining all inputs in a passive network and feeding them to the height-to-time converter via the main amplifier. If a signal is acceptable, the analysis process begins, and an "Inspect" pulse is generated which opens a 1.2-msec univibrator gate. The input signal, having passed the discriminator, is delayed 5  $\mu$ sec and arrives at the gate in coincidence with the "Inspect" pulse, allowing the 1.2-msec univibrator to trigger. The gate then closes, preventing further triggering of this univibrator--thus the origin of input-pulse information is retained during analysis time. By means of a switch, any or all identified outputs may be selected and used to generate a gate of 25-msec duration, enabling storage of pulse information in the register bank. After the mixer, pulses are attenuated as necessary and then amplified about 50 times (Fig. 3). An adjustable threshold selects anywhere from 1% of the top to the complete pulse as desired. Another amplifier then increases the pulse height up to about 100 v. This combination must pass stringent stability requirements, because any drift is amplified by this "window" amplifier.

The principal feature of this system, a height-to-time converter, also performs most of the necessary timing functions. After being amplified, the input pulse is presented to a linear gate that passes it to an adjustable threshold for acceptance or rejection (Fig. 4). If not rejected, a Miller integrating circuit does the actual conversion of the input pulse, but a Schmidt trigger circuit produces the necessary low-impedance output whose pulse width is proportional to the height of the input pulse. The pulse from the trigger circuit opens a gate, allowing 500-kc timing pulses from a crystal oscillator to synchronously trigger a blocking oscillator operating at a 100-kc rate. These blocking-oscillator pulses, delayed 10  $\mu$ sec, are the count pulses. This delay is necessary to allow for resetting the scalars before receipt of count pulses. Another function of the Schmidt trigger is to provide a block to the linear gate so that no distortion is produced by following pulses after acceptance of one for analysis. This block is accomplished by the trigger gate, fast- and slow-block univibrator, mixer, and block cathode follower. The trigger gate allows only the rise of the Schmidt trigger to operate the fast- and slow-block univibrator; these are arranged so that the slow block is operating while the fast block that initiated the linear gate block is recovering. In this manner complete blocking is assured, regardless of count rate. Other triggers are taken from the fast-block univibrator, namely those for the reset and inspect univibrator, and also for a delay univibrator. This delay allows sufficient time for a count train to be generated before triggering the store univibrator. After being gated, the count train feeds both binary and decade scalars. As mentioned previously, the decade scaler is used solely to provide immediate visual indication; it consists of two decade-counter tubes, their associated gates, and drivers necessary to operate a bank of 100 mechanical registers.

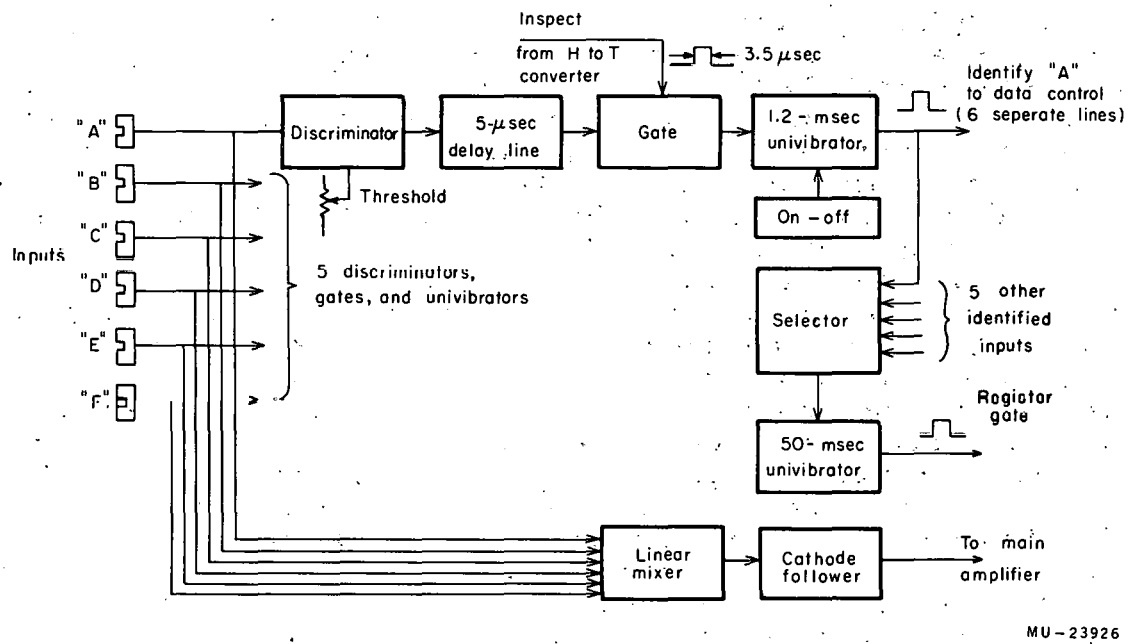
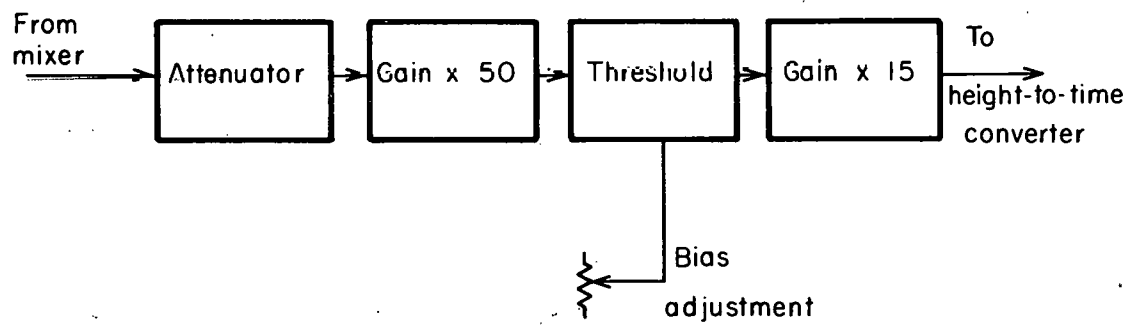
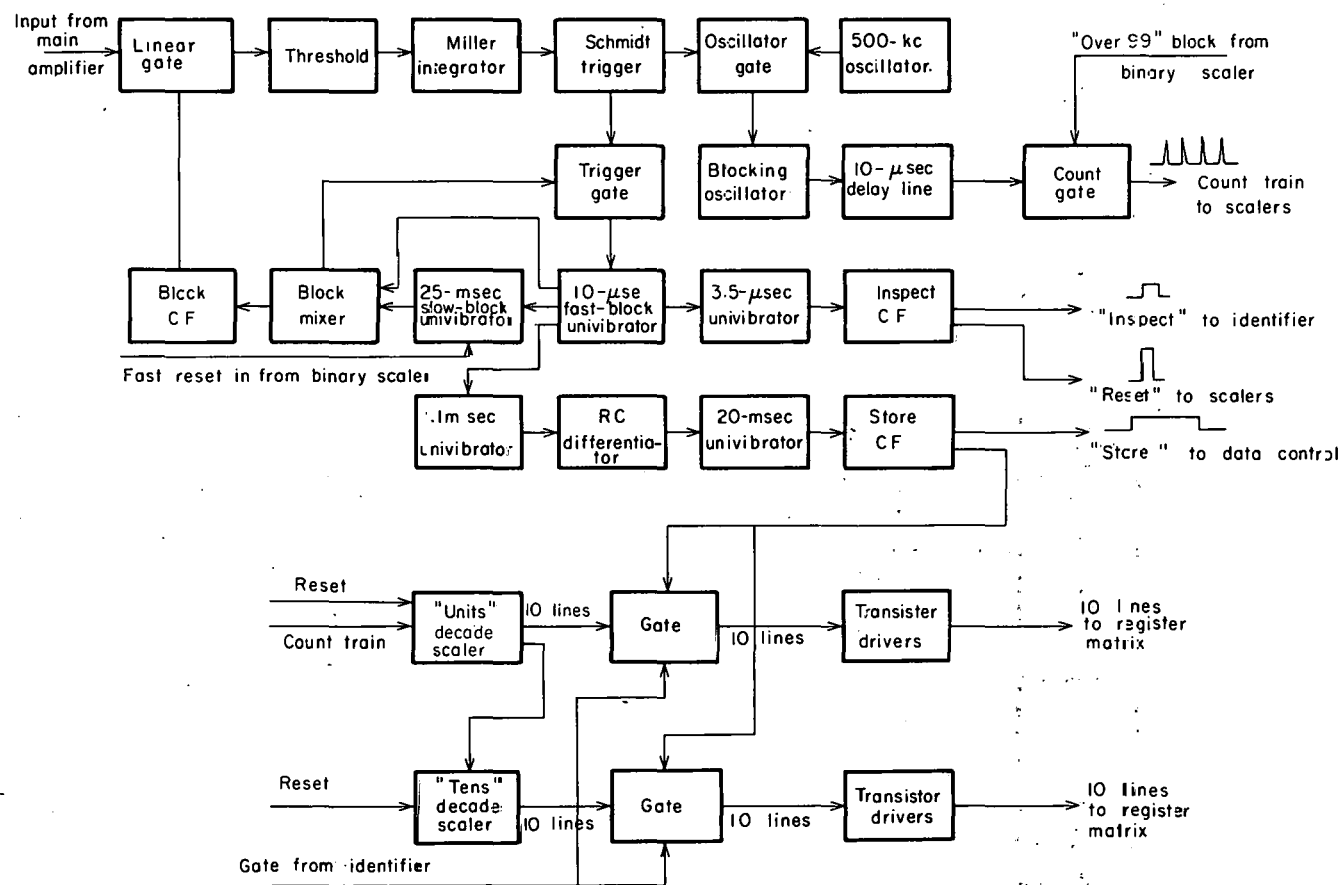


Fig. 2. Mixer identifier.



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Fig. 3. Main amplifier.



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Fig. 4. Height-to-time converter.

For coding the data hole punchings, a straightforward binary-type scaler of seven bits capacity is used (Fig. 5). This scaler is limited in capacity to a total numerical storage of 100 in order to reduce dead time because pulse height greater than 100 channels is considered to be surplus and is accumulated in one channel designated "over 99."

Time information is provided by a binary scaler (Fig. 6) that is also limited to a capacity of 100 units, but since time information may be repetitive, the start of each cycle is indicated on the storage tape--this is called "0" time. A univibrator, held off by "store," is provided to delay any "0"-time indication that may be coincidence with input data. The time base itself may be provided externally or by the self-contained counter synchronous with 60-cycle power. By incorporation of a scale of 36 followed by suitably switched binary and decade counters, a time base of 0.01 to 40 min per step is available.

Upon receipt of either "0"-time or identify-store signals, the data univibrator in the data-control circuit receives a trigger through a coincidence mixer and gate circuit (Fig. 7). The gate circuit is closed by an operating punch, preventing the acceptance of additional data until it has completed a previously initiated cycle. The data univibrator generates a pulse which activates the punch clutch and samples the information at the data gate. It also punches an additional "code hole" that indicates the line containing the data. The absence of "code hole" indicates time. Two sequential code holes are punched for "0" time. A delayed output from the data univibrator is used to produce a trigger for the time univibrator which operates in a similar manner. See Fig. 8, typical tape format.

As mentioned previously, a reader is provided to enable punched tapes to be read as often as necessary during their useful life. To date, tapes have been read more than one hundred complete cycles with little observable wear. Because of the design of the reader, tapes must frequently be read several times in order to extract all useful information (i. e., once for time, once for pulse height, and possibly again to compute half life).

Briefly, the reader consists of a binary-to-decimal converter with the necessary timing and logic circuits needed to present that part of the data deemed most useful. Upon insertion of a punched tape into the reader, a rate generator and associated driver can be placed into operation so as to advance the tape at a rate of up to 20 characters per second (Fig. 9). To do this, a pulse is applied to a magnetic clutch contained in the model MR-690 tape reader. Each pulse allows one shaft revolution, causing the following sequence of events: A series of plungers, one per transversely punched hole, operates contacts that apply a small dc voltage to their associated binaries. Eleven msec later, an auxiliary pair of contacts close, initiating a Schmidt trigger that resets all binaries not having the dc set voltage applied to them. The plungers then retract and the auxiliary contacts open, terminating the Schmidt trigger pulse and initiating the electronic read cycle. The clutch then disengages, stopping shaft rotation, and the reader awaits the next advance command. Upon termination of the Schmidt trigger, an oscillator gate is opened for 1.1 msec by a univibrator to enable timing pulses to trigger a blocking oscillator at a 100 kc-rate. These pulses are propagated through a seven-bit

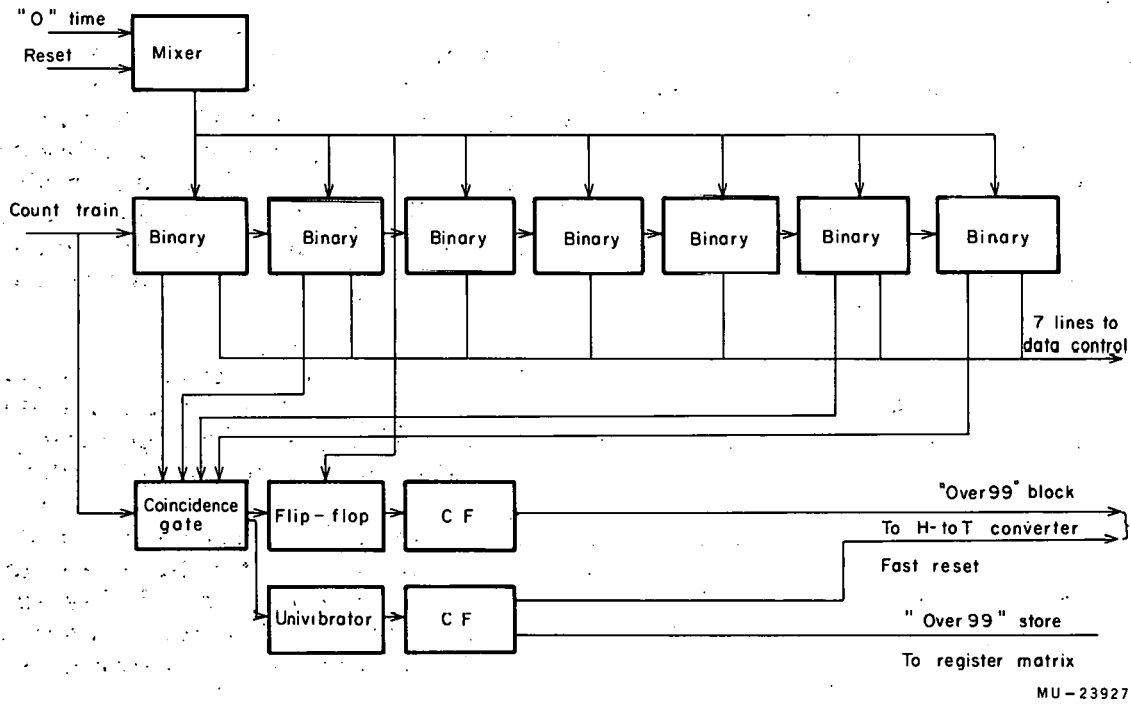


Fig. 5. Binary scaler.



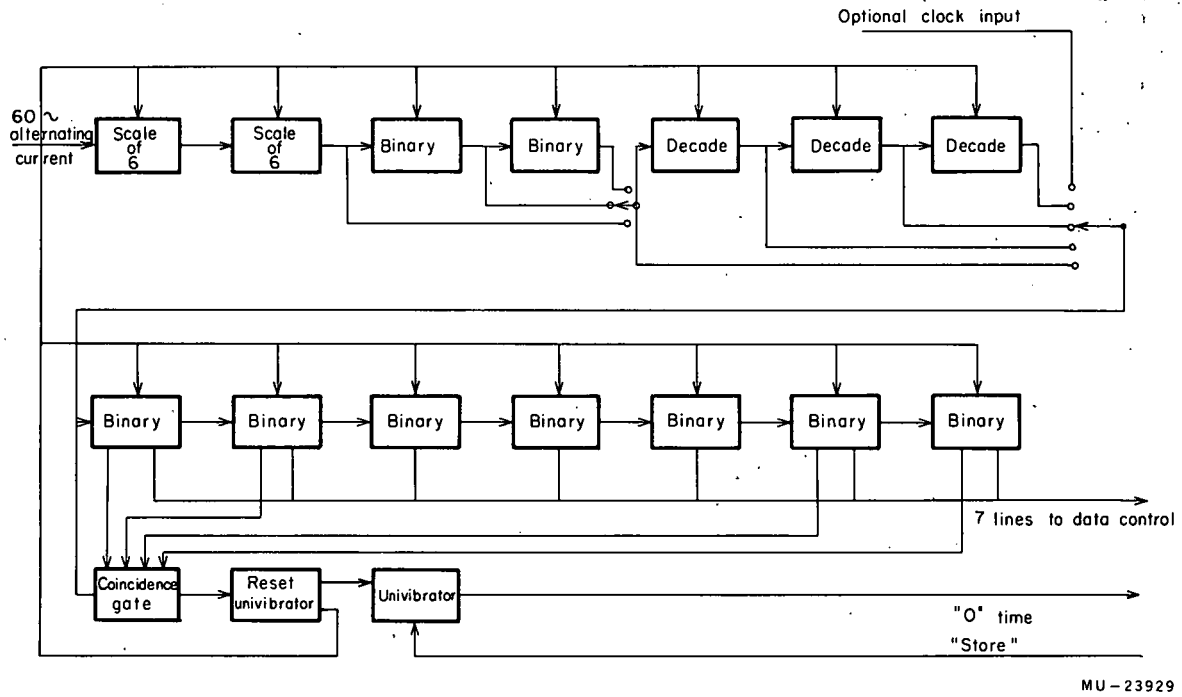
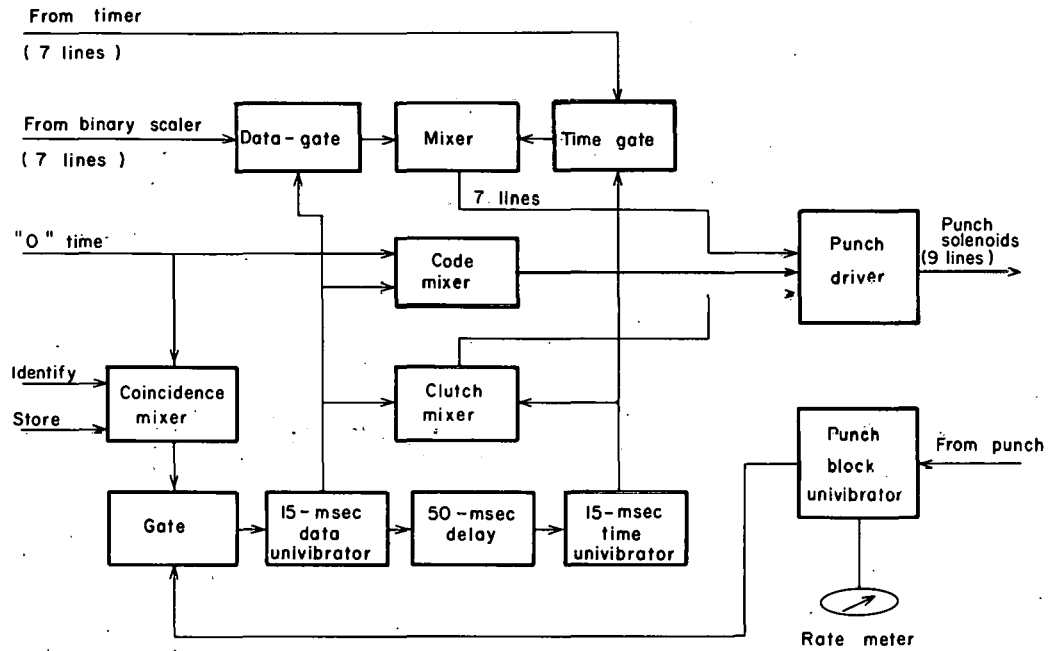
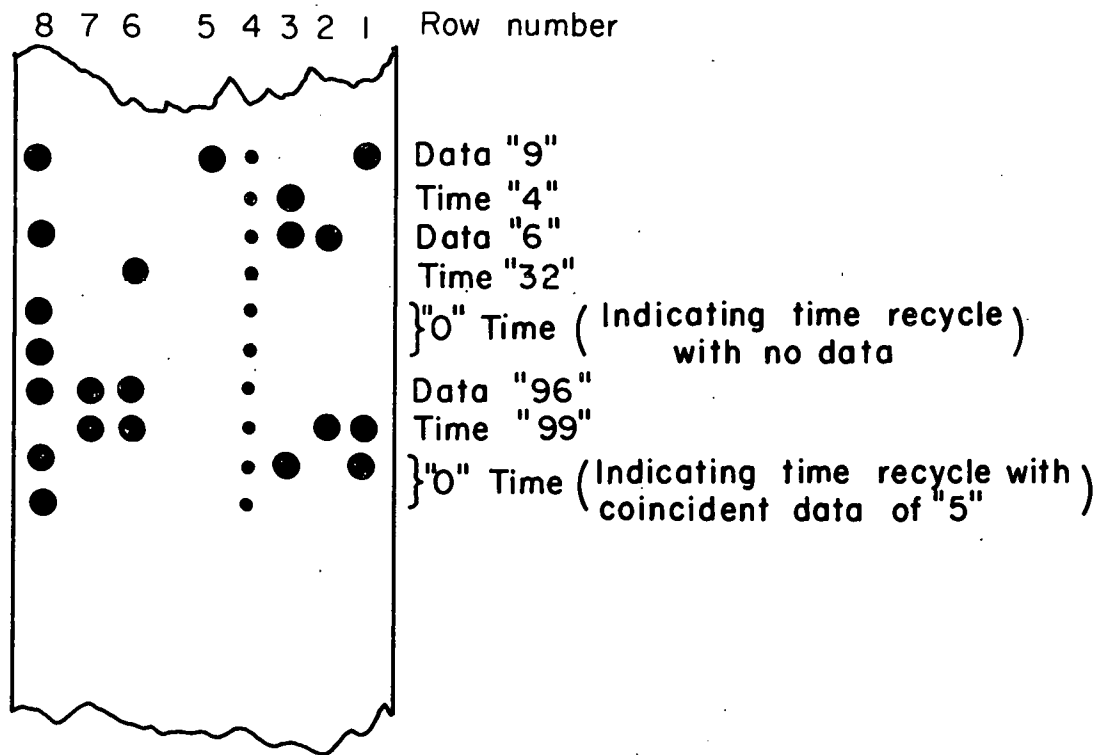


Fig. 6. Timer.



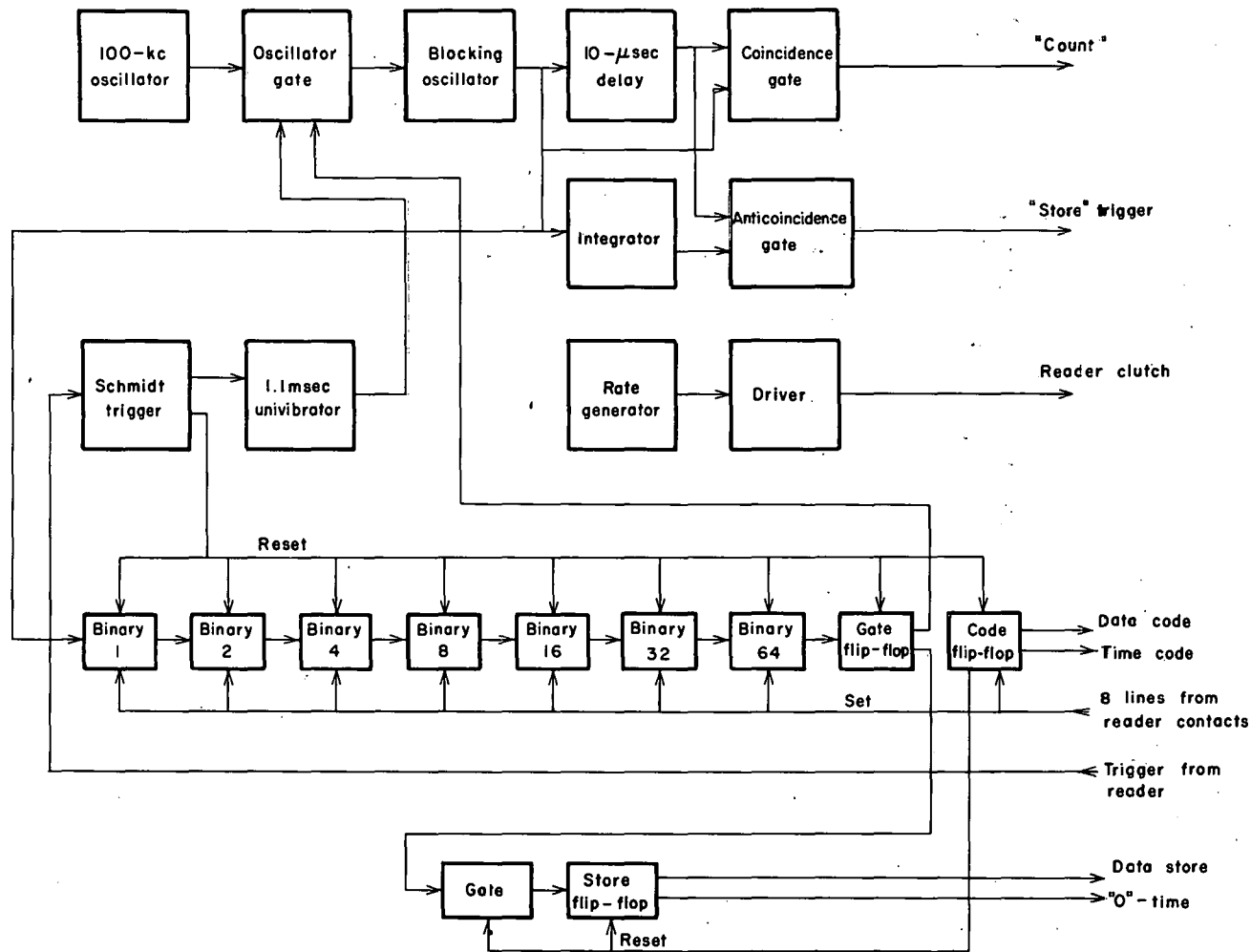
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Fig. 7. Data control.



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Fig. 8. Tape Format



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Fig. 9. - Reader and binary scaler.

binary scaler, finally arriving at the gate flip-flop that closes the oscillator gate and terminates the blocking-oscillator pulses. The number of pulses required to close this gate will always be one greater than the digital numeral set into the binaries by the dc voltage from the reader. As it is desirable to count these pulses in a decimal scaler to facilitate read out, this constant "one" must be subtracted from the pulse train. To accomplish this, one need only delay the pulse train by its own period, whereupon selection of the delayed and undelayed pulses that are in time coincidence produces a pulse train of one less than the original. A similar technique, integrating the undelayed pulse train and placing it in anticoincidence with the delayed pulses, produces a single pulse occurring 10  $\mu$ sec after the oscillator gate closes. This is the store trigger pulse.

The code flip-flop is operated by the eighth-row reader contacts and determines whether a particular row of holes contains pulse-height or time information. The function of store flip-flop and its associated gate is to count the number of successive code holes in order to extract "0"-time information from the tape. A pulse, similar to that which closes the oscillator gate but of opposite polarity, is used to operate the store flip-flop in a binary fashion when allowed by the presence of a code hole. To ensure proper operation, this flip-flop is reset by each pulse-height and time group.

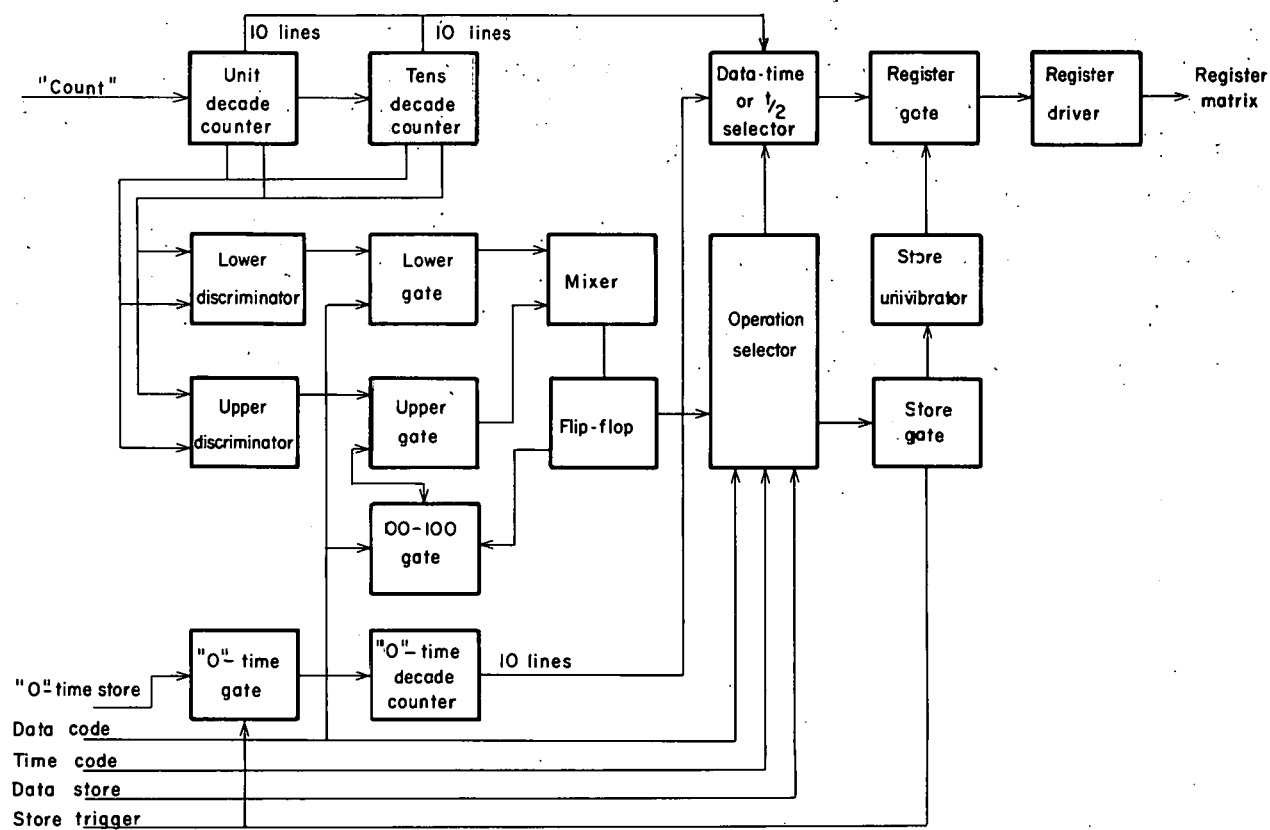
With reference to Fig. 10, "0"-time pulses, opening a gate, allow the store trigger to advance a glow transfer tube that is operated as a decade counter. In similar manner, count pulses operate two other glow transfer tubes. All ten outputs from each of these tubes are provided so that 100 channels of either pulse-height or time information may be presented to a register bank. When the "0"-time decade counter is used as a base for pulse-height data, a 100-point half-life curve will be displayed upon the register matrix. Because the same decade counters are used for both pulse-height and time data, selection is necessary. The operation selector, by channeling either time or data code to the store gate, allows a store univibrator to be triggered, thereby providing a drive pulse when the proper data appear at the register gate. The absence of data-store pulse is used to inhibit any operation when unpunched leader tape is being run or when "0" time is indicated.

To assist in further evaluating the pulse-height data, a time distribution of any portion of the data spectra may be displayed; this is done by disabling the operation selector when in time or half-life mode. All pulse-height data, corresponding to channel numbers lower or higher than those selected by two discriminators, operate a flip-flop that actually disables the operation selector.

When only two decades are used for a scale of 100, there is no discernable difference between the numerals 00 and 100 except for the time of occurrence; therefore an auxiliary gate is used with the upper gate to prevent the flip-flop from being operated ambiguously by the lower number. Similarly, a lower and upper gate allow operation only on pulse-height data.

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Fig. 1G. Reader, decimal scaler, and logics.

# FOOTNOTES

1. A. Ghiorso, T. Sikkeland, A. E. Larsh, and R. M. Latimer, Phys. Rev. Letters 6, 473 (1961).
2. Penco Model PA-4 made by Pacific Electro Nuclear Corp., Culver City, California.

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