Title
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I. INTRODUCTION

The large output of spark chamber events recorded on film and the subsequent labor involved in their analysis using manually operated digitizing machines has prompted the development of faster and more accurate data processing devices.

The problem of automatic digitization of spark chamber tracks is considerably simpler than in the analogous case of bubble chambers. The simplifications stem from the fact that the selection of spark chamber events is counter controlled and hence the desired track is accompanied by few, if any, accidental tracks. Furthermore since in many spark chamber applications the useful tracks fall on straight lines or arcs of a circle (if the chamber is in a magnetic field), the "Pattern Recognition" aspects of an automatic scanning device to be used for bubble chamber pictures reduce to the simpler case of a position digitizing device with provisions for rejecting obvious background, or random sparks. In the approach we follow here, this last task is left to the versatility of the computer which sorts out and compiles the digitized information.

The "on line" digitizing system we describe below consists of a Vidicon television camera tube with associated electronic circuits built into an electrostatically and magnetically shielded assembly that can operate in an environment of spark chamber and accelerator electrical noise. At present the system is capable of storing the locations of two sparks per gap per view of the chamber (this number does not include the often present spurious corner and edge sparking which can be gated out). The digitization is accomplished using existing LRL 20 Mc scalers which record the positions of the sparks relative to a system of fiducial slits located at the extremities of each chamber view. The digitized information is temporarily stored in a 6000 bit magnetic core buffer and then transferred on to magnetic tape for subsequent processing by the 7090 computer.

From the description given below it is clear that the same Vidicon camera can serve also as the digitizing device to analyze pictures of spark chambers which are taken with a suitable format of views and fiducials. It is also clear that the accuracy, speed and data handling capacity for which we are aiming at present is not the maximum attainable with existing electronic componenets and techniques; we recognize that it is also possible to achieve greater versatility, although at greater cost and with more complicatins, by designing the system to be "on line" to a computer.

The present system is, however, more than adequate for the needs of the immediate physics experimental program on which we intend to use it. The approach we are taking, is to place the greatest emphasis in the present design on the reliability of the operation as an experimental tool; the performance of the system can be upgraded and the more elaborate features added on as required by the exigencies of the physics experiments.

The object of this note, written while the work described here is still in progress, is to help clarify the ideas of the people involved in various aspects and to provide sufficient guide lines so that final assembly of the various units is done with a minimum of last minute improvisations. Most of the sub units described here have been tested successfully in prototype form. Some - such as the Alpha 63 data compiler have been in use many months for a Bevatron run and have demonstrated the usefulness and the reliability of their componenets.

II. NEUTRON POLARIZATION EXPERIMENT

The first experiment in which we will use the Vidicon system for recording the spark chamber data is to measure the polarization of the recoil neutron from a π^- charge exchange interaction with protons, as a function of the neutron angle of emission. This experiment is scheduled for December 1963 in the meson cave of the 184-inch cyclotron. The experimental layout is shown in Fig. 1. Charge exchange neutrons produced in the 4-ft. long LH_2 target are detected by recoil protons produced in the rectangular LH_2 target which serves as the analyzer. The spark chamber which measures the position and direction of the recoil protons is 40 x 4 x 14-in. and has 10 gaps with a gap width of 5/16-in.

A charge exchange event is identified by a coincidence $123\overline{45}$. A charge exchange neutron which has converted in the rectangular LH_2 target is identified by a coincidence $123\overline{45}\,N_i$ where any one of the four N_i counters detects the recoil proton. An appropriate time of flight coincidence between monitor counter 2 and the N_i counters, which gates the signal $123\overline{45}N_i$ will distinguish a neutron event from a γ ray converted in the LH_2 or its vicinity which then produces electron, or positron, tracks in the chamber.

This time gated signal is then used to trigger the spark chamber, the Vidicon camera, and a standby Flight Research photographic camera which also views the spark chamber.

The arrangement of mirrors and lenses which projects the spark chamber onto the viewing cameras provides a format in which the two views of the spark chamber appear next to each other and with the plates parallel. This allows a simple scan and digitization to be done by the Vidicon camera.

For a measure of the polarization, the output information required is the distribution in position and angle of the recoil proton tracks. From this, by splitting the distribution function of position into bins the angular distribution of the neutron is obtained, a further calculation as to the relative number of left and right scatters in each bin yields the polarization.

The output data of the Vidicon as stored in the digitized form in the magnetic tape consists of the coordinates of each spark identified by a gap number, view, and counter N_i which triggered the chamber. We propose to split the computer program into two; the first part will take the raw data from the magnetic tape and construct the track distribution function by performing straight line fits to the spark coordinates. The output of this section can then always be readily compared with the film information from the Flight Research camera. The remainder of the program will do the physics analysis to obtain the polarization distribution function.

III. SPARK DIGITIZING

Sparks are digitized by sweeping the Vidicon parallel to the spark chamber plates. If a spark is present a 20 mc scaler is turned on when the sweep passes over the spark and is turned off when the sweep passes over an illuminated graticule line at the end of the spark chamber, as seen in Fig. 2. As the total sweep time is 50 μsec the quantitizing error is one part in 10^3. At present, two scalers are available for this digitization and they may be used either to digitize two sparks per gap, or one spark per gap and the total gap length. To improve resolution, the digitizing is repeated four times in each gap and the average of these four sweeps is delivered to the buffer store. The scalers count in pure binary, thus it is convenient to obtain the average of any 2n sweeps by shifting the readout of the scalers n places. The format of spark chamber views, direction of scans and the arrangement of fiducial graticules are seen in Fig. 3.

This arrangement of the views gives the maximum resolution along the gap as the resolution is a fixed percentage of the full length in the fast sweep direction. Since the aspect ratio of the spark chambers is rather large (about 6:1 in this experiment) this view arrangement gives an overall aspect ratio of about 3:1. Typical resolution of a 1-in. Vidicon is 600 lines, so with a 3:1 aspect ratio we have a 200 line resolution in the slow sweep direction, or about ten lines per gap. Of these ten lines the middle four are used for digitizing the spark. The digitized information is transferred to the buffer storage while the sweep is proceeding to the next gap; about 300 μsec is available for this transfer, of which only 20 μsec is needed. It would be possible to use an accelerated slow scan between gaps and thus reduce the overall scanning time by a factor of two, however for the present experiment there was little advantage in doing this, since the overall dead time is 60 ms from the Flight Research camera.

A 250 line scan is planned, this allows 200 lines for the gaps and 50 lines for margins. For a 50 μsec sweep and 10 μsec fly back, we have a 15 msec total scan time. Using an RCA 7263A Vidicon the video signal level will be down to about 30% at the end of the full scan.

Once an event has been digitized it is necess ry to completely erase (i.e. recharge the Vidicon target). To accomplish this the electron beam is defocused and the beam current increased. Three 5 msec sweeps of the Vidicon target are made immediately after an event has been digitized, and thereafter periodic recharging scans are done during the off gate time of the cyclotron beam. The slow sweep sequence of scan, erase, and recharge are shown in Fig. 4.

We plan to run at the 184-in. cyclotron. The 60 cps beam spill of this accelerator is quite convenient for we may synchronize the Vidicon recharge with the "beam-off" time of the accelerator.

The graticule arrangement consists of illuminated slits placed on both ends of the spark chamber views (Fig. 2). The left hand slits are stopped down such that the top of these slits mark the central region of the spark gap. As the sweep proceeds in the slow sweep direction the first video signal, from a left hand slit, sets the digitizing logic so that on the following fast sweep, digitization starts. The 20 mc scaler begins counting when a spark is picked up and stops counting when the sweep passes over the right hand slit. The delay of one fast sweep is necessary only when one scaler is digitizing the slit spacing.

In order to identify the video signal from the slits a coincidence is required between the video signal and an internal timing signal. These internal timing signals are slaved to the fast sweep circuits and may be adjusted in both position and width. These adjustments are made by "brightening up" the video signal displayed on a monitor scope that is also displaying the spark chamber image. Thus one can see on the monitor both the slits and the timing signals. In a similar manner one may "brighten up" the four fast sweep lines that are being digitized. This type of direct display should make initial set-up adjustments quite straightforward.

IV. DATA COMPILER

The data acquisition system known as α-63 is designed to accept, store, and transcribe onto magnetic tape digital information from an experiment. It accepts the information as events occur at a random rate, stores it temporarily in a core memory buffer and, when the buffer is filled, transfers the stored information onto magnetic tape. The format of the recorded information is suitable for direct entry into a computer such as the IBM 7094.

A. Block Diagram

A block diagram of α-63 as it will be used with the Vidicon Digitizer is shown in Fig. 5. It shows that information is collected from three sources: the Vidicon digitizer; the experimental electronics--counters, coincidence circuits, etc., that serve to identify and characterize each event; and the scalers and fixed register that provide cumulative information about a series of events (a run). The function of α-63 is to derandomize and correlate all this information into a decipherable form on the magnetic tape.

The operation of α-63 will be followed in terms of the several sequences it follows.

B. Event Sequence

The data combiner controls the sequence of occurrences during storage of events. When it is signalled by the "fast" counter electronics that an event has occurred, it first inhibits further collection of data and then transfers 24 bits of data from the current event into the core memory. This block contains the event serial number, identification of counter(s) detecting the event plus miscellaneous bits. This is transferred in two 12-bit words. Next, the data combiner signals the Vidicon digitizer to begin digitizing the addresses of sparks in the chamber, and simultaneously connects the output of the digitizer to the input of the buffer store. The digitizer then issues the 40 12-bit words containing the spark addresses and erases the Vidicon screen. When finished, the digitizer signals the data combiner. The data combiner then resets its data registers, advances the event serial number register by one, and removes the inhibit condition on the "fast" electronics. The "fast" electronics now searches for another event.

C. Data Record Sequence

When the buffer store has been filled to capacity by the data from 12 events, its contents are transferred in a block onto magnetic tape. The sequence of occurrences in this transfer is as follows. When the buffer store is filled to the point where it cannot accept another event, it issues a "Store Full" signal to the Master Control. The Master Control then starts the IBM 729 tape transport, and after an appropriate delay, begins requesting data from the buffer store at a 62,000 characters per second (7 bits per character) rate. When emptied, the buffer signals the Master Control with a "Last Character" pulse. Master Control then generates the longitudinal parity check character and stops the tape transport. During the 25 milliseconds required to transfer the data, the Data combiner inhibits further acquisition of data.

The format of the data on tape is similar to that shown in Fig. 6 except that the words are broken into characters of six data bits plus one odd parity bit each (see Fig. 7). The 12 events are recorded one after another without separation until the store is empty. Each record therefore consists of 12 events x 14-36-bit computer words x 6 characters = 1088 characters (computer word = six 6-bit characters). At a writing density of 800 characters per inch, each record occupies 1.25-inches of tape, plus the 3/4-in. record gap.

D. Identification Record Sequence

At the start and end of each run, an identification record is recorded on the magnetic tape. Its purpose is to establish and record the run serial number at the start of the run, and to record the accumulated contents of several monitor scalers at the end of the run.

E. Monitoring and Checking of Data

The magnetic tape unit has facilities for reading the tape immediately (within 4ms) after writing it. The Master Control has the necessary electronics for checking the parity of the information read from the tape, and for issuing an alarm if errors are discovered. Thus one can be assured that the data are being properly recorded on the tape. Parity errors can be caused by faults in the writing electronics or by bad spots on the tape.

The Visual Readout block is a device for monitoring data, either from the data combiner (one 36-bit word can be displayed) or from the characters read from tape (three 36-bit words can be displayed from a pre-chosen area of the record). The data is displayed on three banks of 36 incandescent lamps each. Using the visual readout, one can compare data as received from the fast electronics and after being read from tape.

F. Buffer Store

The buffer store is a magnetic core memory device having a storage capacity of 256 24-bit words. Its input circuitry can be arranged to accept data in either 12 or 24-bit words. Before storage a 25th parity bit is added. The parity is checked whenever a 24-bit word is read from memory.

The output circuitry is built to generate 6-bit characters from the 24-bit stored words, and a 7th odd parity bit is added.

VI. DISPLAY MONITORS

In a system such as this, with large numbers of components, it is absolutely necessary to have some form of continuous monitoring of the output data in order to ensure its correct peformance at all times.

In this case, this is accomplished by displaying in suitable form samples of the data which are being processed. Part of this display has been described briefly in Sec. II; whereby the four digitizing sweeps are brightened and displayed on a scope together with the spark chamber image to monitor the position and orientation of the T. V. raster relative to the image of the spark chamber.

A more elaborate monitor is the one described below which takes the output of the digitized information from the tape unit or from the buffer store and reconstructs the tracks viewed by the Vidicon in a display on a scope screen.

The display-unit (DU) receives information from the Master Control in the form of a series of 6-bit characters and a strobe-pulse. This is the direct source of information. One has a choice out of two indirect sources:

1 TAPE UNIT

2 BUFFER STORE See Fig. 8.

Several TV-EVENTS will be stored in one Record of 1008 characters. During the actual writing (and reading back) of the record on magnetic tape the display on an oscilloscope takes place. Only the selected TV-event (one out of 12) will be displayed. The selection is performed by a switch.

The display is a digitized reproduction of the original TV-picture. Gap and view correspond with Y-axis, spark distance from left side chamber (the "address") with X-axis.

Every point of the displayed picture is beamed on the phosphor-screen for 12 μs. The whole picture of max. 40 points is built up in 1333 μs.

Hook up: One 10 wire cable runs to one out of two possible connections of the Master Control. Three BNC's provide the connection to any oscilloscope.

ACKNOWLEDGEMENTS

We would like to thank all the members of the Nuclear Systems group for their work in building up the hardware we now have. We would also like to thank Quentin Kerns, Dick Mack, Lloyd Robinson and Fred Goulding for their advice and help on various aspects of this development. Don Zurlinden and Loren Meissner have advised us on computer problems and have developed the necessary computer programs.

The physics experiments described here, which we are using to test and develop this system, are part of the program of the Moyer/Helmholz group whom we thank for their encouragement and support of this project.

This work has been done under the auspices of the U. S. Atomic Energy Commission.

CHARGE EXCHANGE EXPERIMENTAL LAYOUT

$$\pi^- + P \longrightarrow \pi^0 + N$$

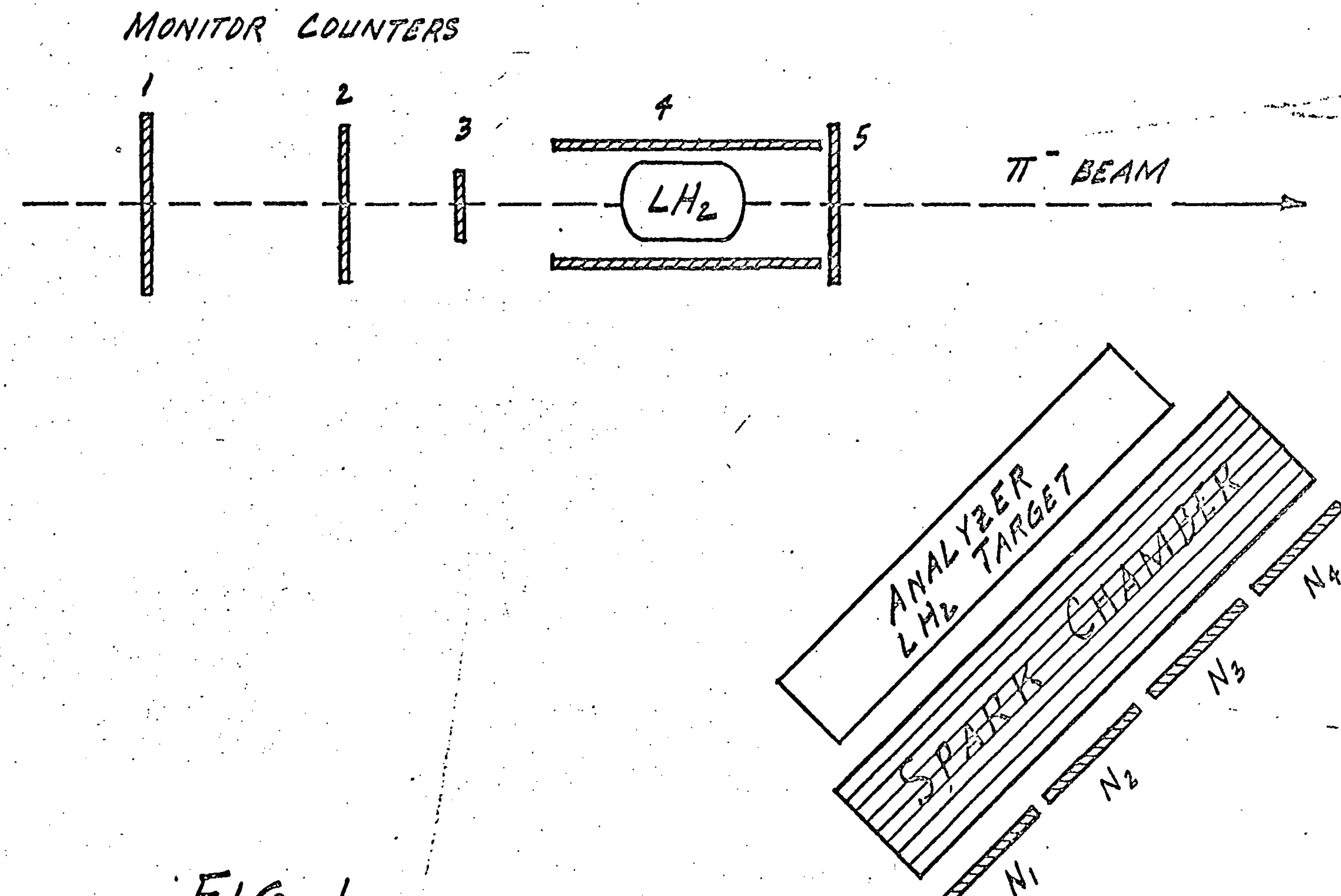
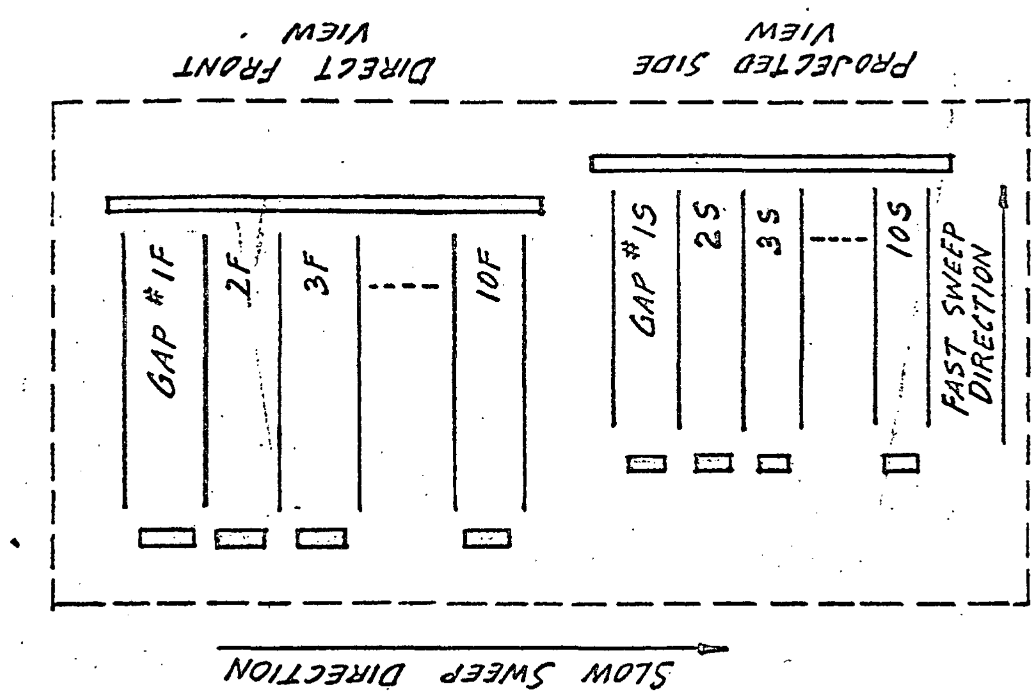
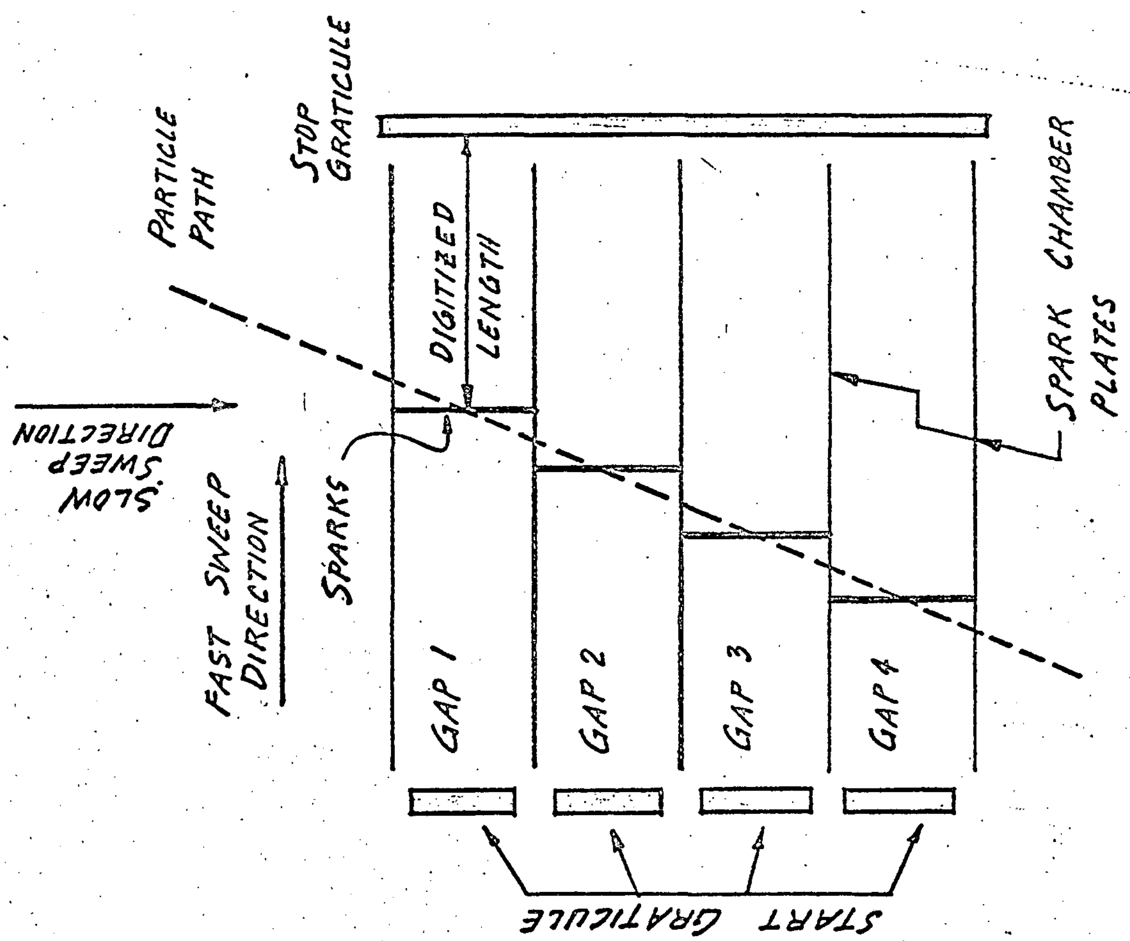


FIG. 1



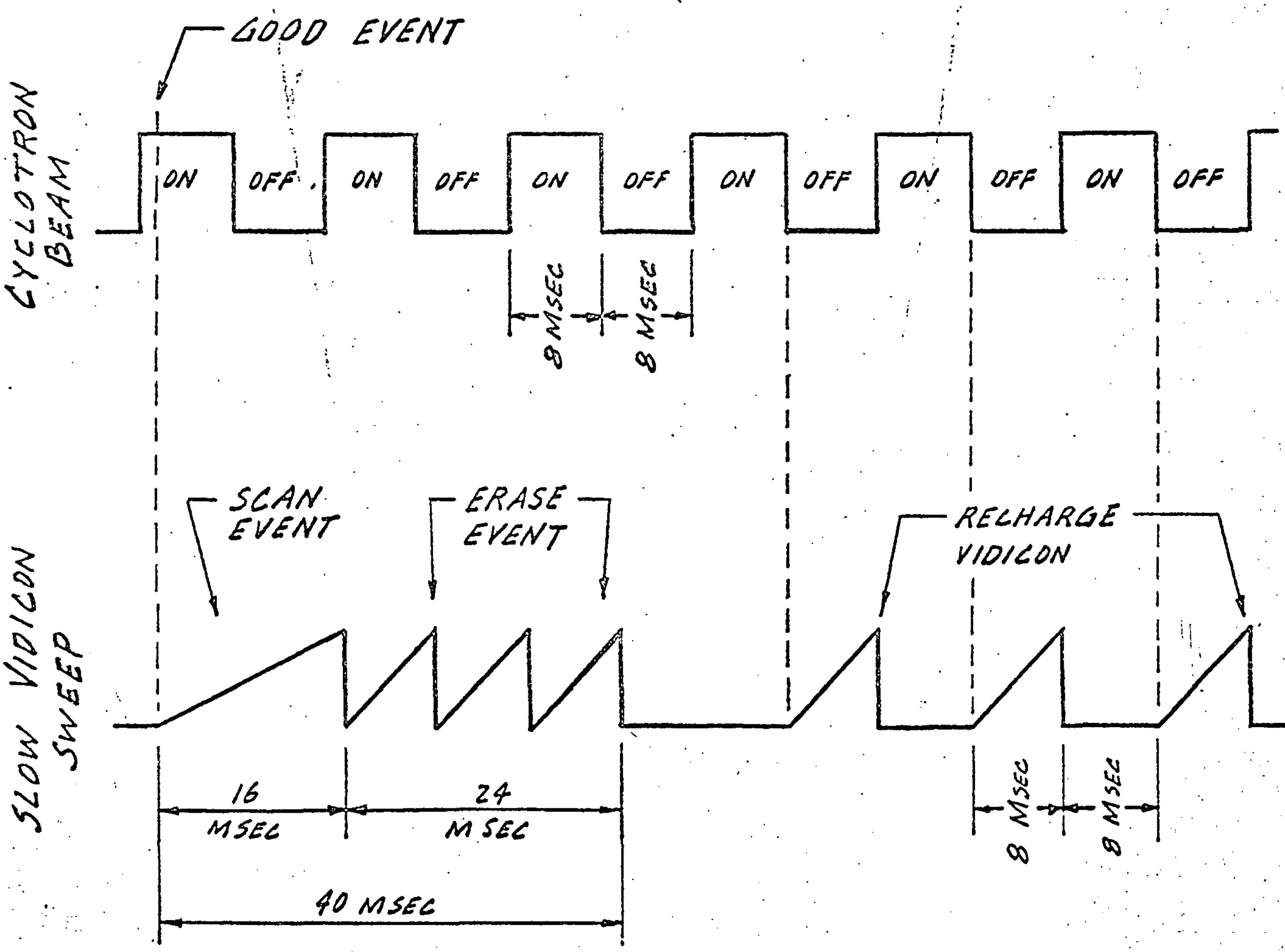
DIRECT FRONT VIEW
PROJECTED SIDE VIEW
GAP #1F
2F
3F
10F
GAP #1S
2S
3S
10S
FAST SWEEP DIRECTION
SLOW SWEEP DIRECTION

FIG. 3



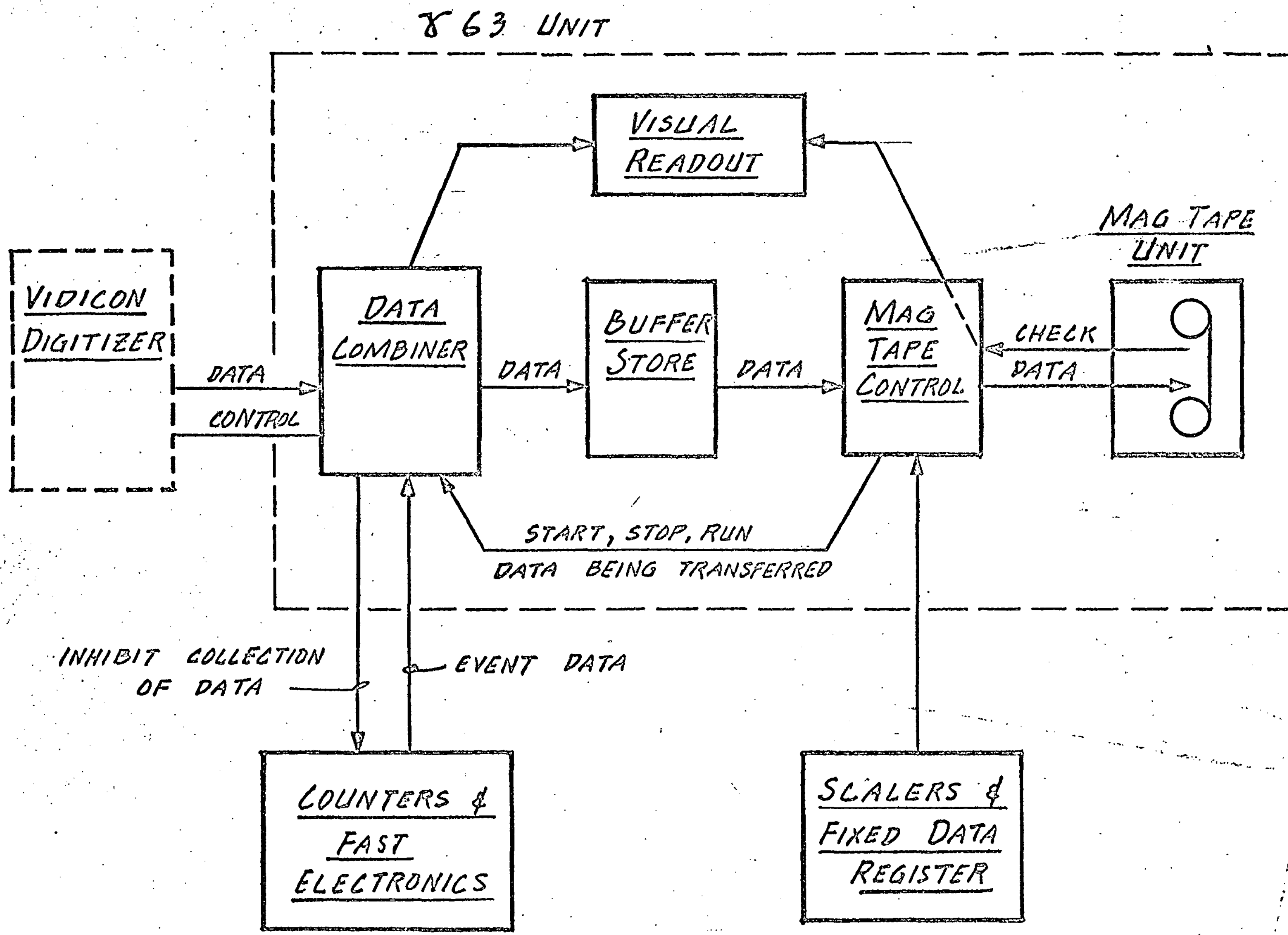
PARTICLE PATH
STOP GRATICULE
DIGITIZED LENGTH
SPARK CHAMBER PLATES
SLOW SWEEP DIRECTION
FAST SWEEP DIRECTION
SPARKS
GAP 1
GAP 2
GAP 3
GAP 4
START GRATICULE

FIG. 2



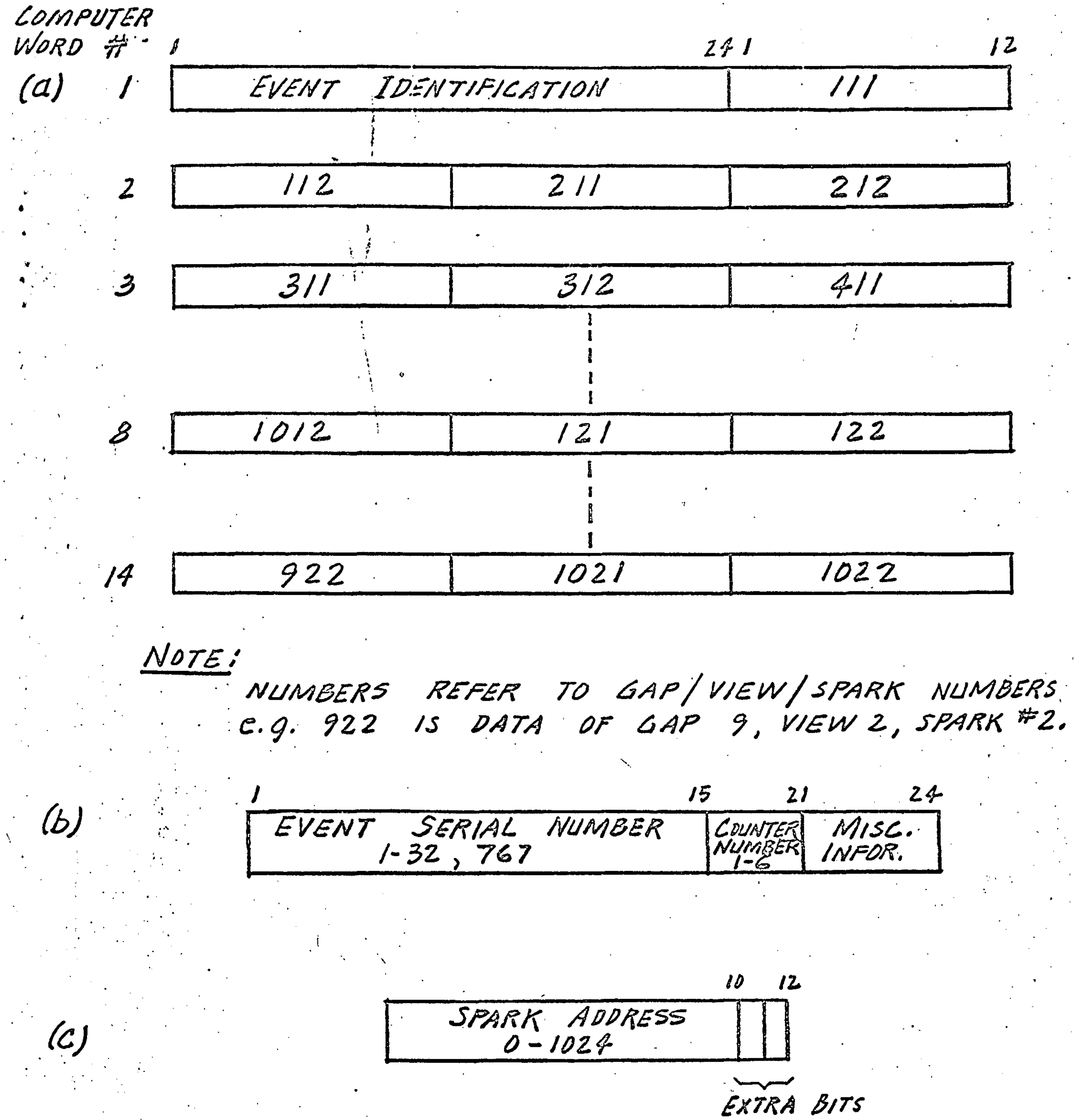
SLOW SWEEP SEQUENCE

FIG. 4



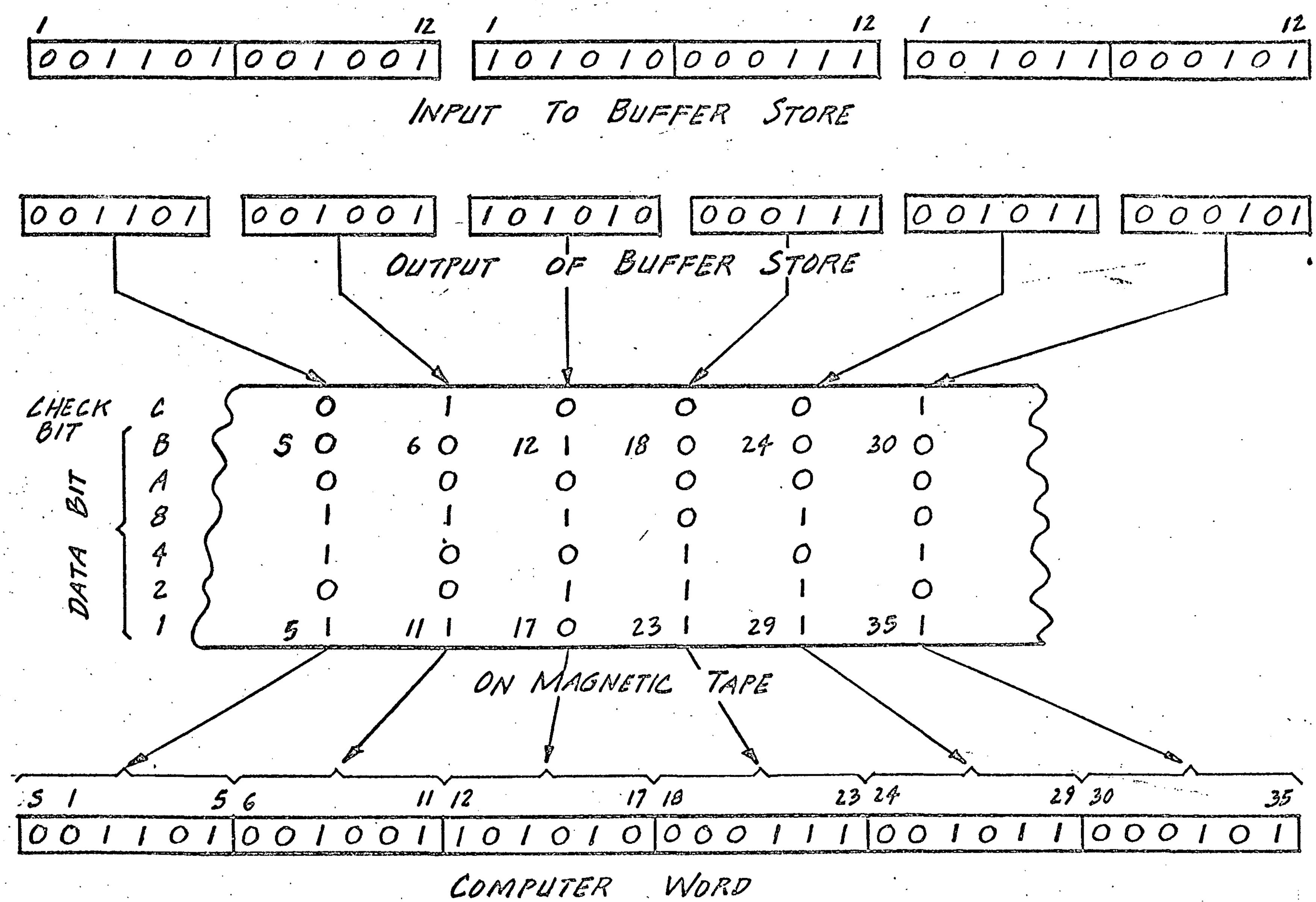
γ63 UNIT
VISUAL READOUT
VIDICON DIGITIZER
DATA
CONTROL
DATA COMBINER
DATA
BUFFER STORE
DATA
MAG TAPE CONTROL
MAG TAPE UNIT
CHECK
DATA
START, STOP, RUN
DATA BEING TRANSFERRED
INHIBIT COLLECTION OF DATA
EVENT DATA
COUNTERS & FAST ELECTRONICS
SCALERS & FIXED DATA REGISTER

FIG. 5



FORMAT OF (a) AN EVENT PARTIAL RECORD; (b) EVENT IDENTIFICATION WORD (c) A SPARK ADDRESS WORD.

FIG. 6



RELATIONS AMONG THE DATA FORMAT

FIG. 7

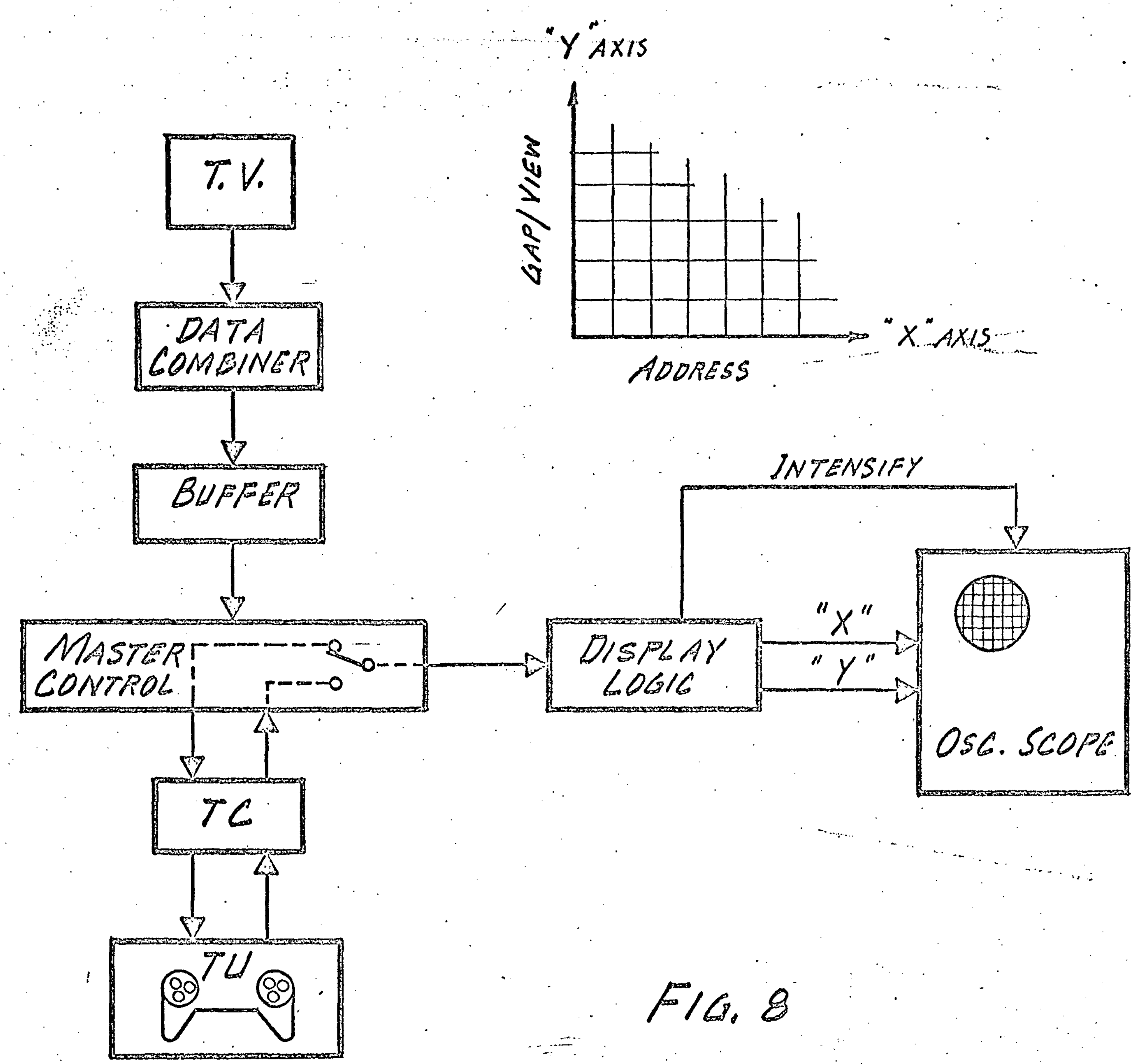

"Y" AXIS
GAP/VIEW
ADDRESS
"X" AXIS
T.V.
DATA COMBINER
BUFFER
MASTER CONTROL
TC
TU
INTENSIFY
DISPLAY LOGIC
"X"
"Y"
OSC. SCOPE

FIG. 8