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ABSTRACT

A system has been developed to make density measurements on particle tracks in nuclear emulsions. The output signal of a videcon viewing the track through a microscope is digitized to detect developed grains in the emulsion. This digitized information is transferred in real time to a computer which selects grains falling in the track and sums their volumes and computes parameters related to their spatial distribution. Analysis of tracks at arbitrary angles is accomplished by rotating the track image in the focal plane with a Pechan prism and by driving the focal plane through the emulsion while taking data.

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INTRODUCTION

When a charged particle traverses a nuclear emulsion plate it loses energy not only to the silver halide crystals threaded by its trajectory but also to secondary electrons that are capable of producing their own tracks. The latter may be seen radiating outward from the track of the primary particle. The resultant complex structure observed in the processed emulsion is highly sensitive to the nature and energy of the incident particle. Standard visual measurement techniques[1], however, are sufficiently tedious and subjective as to allow only a small fraction of the desired information to be extracted from a given track segment.

In an effort to improve the quality and speed of measurements on particle tracks a number of automatic instruments have been constructed. These include the photometric device used to measure the "mean track width" by von Friesen and Kristiansson[2,3], and a television scanning system that has been used to measure the linear grain density of tracks[4].

Most of the instruments previously devised assume a track image that lies in the plane of observation. The television scanning instrument to be described here scans a volume of emulsion and can thereby measure tracks of arbitrary inclination to the microscope focal plane. Since the system operates on line with an IBM 1800 computer, the precise parameters measured are under program control and several independent measurements may be made on a given track segments.

The system (Figure 1) we have developed accomplishes rotation, tilt, track location, and scaling entirely by electronic and optical means. The method used is; to view the emulsion through a Pechan prism mounted in the camera port of a Leitz Orthlux binocular microscope with a high resolution videcon TV camera, to digitize the image with a grey scale of two, to detect developed silver grains, to measure the beam traversal time of all grains lying in or near the track being analyzed on each scan across the track. Scanning of the track in depth is accomplished by taking several TV pictures as the focal plane is driven down through the emulsion by a motor driven fine focus mechanism.

HARDWARE

The TV camera chosen has a 1208 line interlaced scanning raster and a 20 MHz video amplifier response allowing a theoretical horizontal resolution of approximately 550 lines. In practice however, less than 400 lines has been achieved because of the spatial frequency response of the videcon tube. The field of view examined is approximately 67 by 91 microns in area.

The Pechan prism, an optical rotator which revolves an image projected along its axis by 2θ for every θ the prism is turned, is placed in the optical path to allow rotation of the track into a plane normal to the TV scan raster.

The black white digitizer (Figure 2) consists of a 710 threshold comparator and a reference voltage generator which is servoed to the video signal. The output function of this circuit is true when the instantaneous video level is less (blacker) than some predetermined percentage of the video amplitude and is false otherwise. Since the emulsion grains are opaque the signal falls toward the dark current of the videcon when a grain is viewed. The dark current and white current of the tube are sampled by FET/capacitor holding circuits and the threshold voltage is set at a value between these dynamic limits of signal swing. White current is sensed by holding the sampling FET "on" during the time the emulsion is being scanned and dark current is sampled by masking off a portion of the tube face and sampling the signal during the time this area is being scanned.

The electronics unit contains a 15 MHz clock, three registers to monitor and scale data, and computer interface buffers. The first counter sums horizontal sweep lines and is reset by the vertical sync pulse. It is used to create a vertical gate which allows the center 512 lines of each picture (each interlace being considered as a separate picture) to be analyzed.

The second counter counts clock pulses and is reset by the horizontal sync pulse. It monitors the horizontal displacement of the scanning spot and is used to generate a horizontal window within which a segment of each line is analyzed.

The third counter counts clock pulses only within the vertical and horizontal gates when the discriminator output is true, and is reset by horizontal sync. This counter measures the width of the signal blackness on each sweep. At horizontal sync time the contents of this counter are stored in a buffer register and a data transfer to the computer is initiated. During the first data transfer in the vertical gate a tag bit is sent to the computer to assure proper data sychronization.

A monitor is provided on the operators panel on which video from the camera as well as processed video from the digitizer may be displayed. It is used as an alternate to the microscope eyepieces when locating tracks and in setting a track segment within the processing fiducial marks when taking data.

Two fiducials are provided. As was noted above only 512 lines of each 604 line frame are processed since several lines fall in the vertical retrace and the extreme lines in each frame have less resolution than those in the center. This is accomplished by decoding two states from the vertical line counter and using them to blank the processed video going to the monitor to generate two horizontal black lines. The first gate output is also used to send a tag bit to the computer to signal that a new picture has begun.

The second fiducial, a horizontal gate symmetric about the vertical centerline of the picture, is used to define the area within each frame occupied by the track. This gate, which is displayed as two vertical black lines on the operator's monitor is generated using the displacement counter.

This counter is reset by the horizontal sync pulse to a state such that its most significant bit switches from zero to one at the center of the scan. Using this bit, and the fact that in any binary counter states equidistant from the half modulus of the counter are complements, a simple logic scheme (Figure 3) is implemented using two digital comparators a latch and a thumb wheel switch to open the gate at some selected time before the center of the screen and close it an equal time afterward. The position of the thumb wheel switch is fed to an input of the computer data multiplexer for use in data analysis.

The electronics unit also contains a shaft encoder of the absolute, brush type which is coupled to the fine focus drive. The output of this device is decoded from Gray Code to BCD, is displayed on the operator panel on nixie tubes and is fed to one of the computer data multiplexer inputs. This encoder is used to monitor the depth in the emulsion at which the plane of focus is located.

Also applied to the data multiplexer via thumb wheel switches are ten decades of decimal information used to serialize data runs, and control certain functions of the analysis.

DATA PROCESSING

The hardware described above is operated on line with an IBM 1800 Process Control Computer. This machine, a 16 bit fixed wordlength, $2.2\mu s$ cycle time, binary processor, has powerful interrupt handling and data capabilities. It has twelve external interrupt levels with fixed hardware priority, each having 16 sublevels with software priority. One of these levels is devoted to the microscope system and is used to gain the computers attention to request performance of control or data handling tasks. It also has a data input/output multiplexer which can be accessed in either one word at a time or in burst transfer mode

Two sets of multiplexer input points and one set of output points are devoted to the microscope system. One set of inputs, accessed in the single word transfer mode, is used to read in horizontal gate width, I.D. Data, and shaft encoder position. The second set of points, accessed in the burst mode, is used to read in blackness counts during the data taking sequence.

The burst mode operates as follows:

1. The program in progress clears an input area and requests a specified number of input data words.

2. The word count and starting address of the data area are transferred to the burst data channel.

3. The channel signals the external device that it is ready to accept the first word of data.

4. The external device sets up the data and sends a transfer pulse which causes the ready signal to be removed until the word is transferred.

5. The channel steals a memory cycle from the CPU and stores the acquired data word at the starting storage address, increments the storage address, decrements the word count and restores the ready signal.

6. This swapping of ready, data, and transfer pulses continues until the required number of words has been transferred.

7. The channel causes an interrupt on its own level notifying the program that the transfer is completed.

Using the input multiplexer in this manner allows new data to be acquired while processing of previous data is in progress greatly increasing system efficiency.

The output points are utilized to light indicator lamps on the TV console to inform the operator which step of the analysis is to be performed next, to warn of any error conditions detected, and to select which input parameter is to be entered through the single word input points.

This external level of multiplexing is desirable to minimize the number of cables running between the computer and the TV system. It is not possible, however, to multiplex all the data through a single set of input points since it is often necessary to read through both the burst and the single word path simultaneously.

SOFTWARE

The 1800 installation is operated under an IBM supplied process control operating system (TSX) which allows time sharing under both interrupt driven and time scheduled conditions, as well as stack job processing of background jobs when no process control functions are running. It initiates operation of core image job modules on command from internal timers or external interrupts with provisions for interrupting work in progress if jobs of higher software or hardware assigned priority request service.

TSX operates in two modes: system director, and non-process monitor. System director is responsible for answering service requests, scheduling jobs, handling interrupts, and maintaining linkages between jobs. Non-process monitor runs as a job under system director and provides facilities for generating, debugging, and testing new programs, building job modules, and maintaining and modifying system director, as well as handling data processing tasks as a stack job monitor from the card reader.

Process control tasks may be programmed to be resident core at all times, to be called in by interrupts, or to be called by other tasks. They may be programmed to run promptly, or to be entered in a job queue with software assigned priority to be run as time is available.

The set of programs which services the microscope system is written as a skeleton routine, resident in core at all times, which performs minor data taking functions and places into the job queue the names of other modules which are called from disk to perform the main tasks of data acquisition and analysis.

OPERATIONS

The system operates (Figure 4) by scanning through the entire depth of a field of view being examined and measuring the total width of all developed silver grains in each line of the scan. In order to consider in the analysis only those grains lying in or near the track being measured, a solid window is defined within the field of view. The width (ΔX) of the window is assigned by the operator when she sets the electronic horizontal gate. The height (ΔZ) of the window is calculated by the computer based on the gate width and angle of the track, so that a rectangular parallelopiped centered about the track is fully analyzed. The inclination of this parallelopiped within the emulsion is determined by locating the end-points (Z_1 and Z_2) of the track as it enters and leaves the field of view. The data for calculating the window is entered into the system by an operator by the following means. She locates the track, to be analyzed, under the microscope using the monitor, a set of dial indicators on the stage, and a table of locations of tracks, which is generated by other workers. Having located the track, she centers it in the field of view and rotates the Pechan prism until it is parallel to the horizontal window lines. She then adjusts the "Z" axis drive until the in focus portion is located at the lower edge of the TV screen. She then presses a button which causes the computer to read the track identification number from the ID switch, the horizontal gate width from the thumb wheel switch and the setting of the shaft encoder, and to enter these readings into a common area in memory. She then focuses until the point of best focus along the track is at the top of the TV screen and causes the computer to read the shaft encoder at this point. Both of these operations require only very simple service routines and must be performed with short response times, therefore the routines are resident in core at all times.

At this point all the information required to set up a data run is stored in common and the computer waits for the operator to proceed. The program controlling the data run is long and complex and is called in to core memory from disk storage only when required.

The operator then focuses up a small distance since the spacial window includes some volume above the track. She next commands the data sequence to begin, causing the name of the data program to be entered into the job queue with high priority. When the job becomes active, it will turn on a motor to drive the fine focus mechanism to scan through the emulsion, it will then cause data to be taken only in those lines of the TV which pass through the window. It must therefore calculate which lines in each picture it will need to consider. It does this by computing the angle of the track from Z_1, Z_2 and the known height of the field of view, and from that angle and ΔX two constants: the first a projected window width determining how many lines from each picture to consider; the second a displacement determining how far to move the analysis area between successive pictures. After calculating these two constants, it starts the motor and reads the shaft encoder continuously until it finds the elevation ($Z_1 + \Delta Z/2$) of the first picture (P_1) to be analyzed. It then begins a burst data transfer and reads information from all lines of that picture. As soon as the read in is completed it begins to sum data into an area, located in common, five hundred and twelve words long, in which one word is assigned to each line of the TV picture. Only those lines from each picture which fall in the window are summed, each one into the word assigned to its line number. As this is being done, the burst data channel is accepting data from the next picture. This process continues until the last pictures (P_n) has been read in and its contribution summed, it then returns the fine focus mechanism to its initial position and exits to an analysis program.

The area in common now contains a linear profile of the track expressed as the measured area of the 512 slices in depth through the track produced by the corresponding line in each TV picture. This information forms the basis for all analysis to be done late.

The analysis program in its simplest form prints out only summary data about each track segment. This data includes the slope of the track and the total volume of developed silver in the track as well as the volume of each of a number of segments along the track. In its present form it also produces a histogram, on the line printer, of track widths at each point and maintains statistics on successive fields of view in a common area in core. These summary statistics are printed out on the console typewriter at the end of each analysis. This printout is called by changing the track number entered in the ID switches.

The present analysis program also sums the total blackness volume of a track segment, measures the mean "blob" (blackness) and "gap" (whiteness) lengths along the track, and examines the distribution of blackness along the track by calculating moments of that distribution. This information is also accumulated from over many track segments.

On completion of these printouts, the analysis program exits through the skeleton routine, which notifies the operator of completion and leaves the computer free to service other jobs until it is again required.

RESULTS

This equipment has been in operation for a period of several months, during which time we have been primarily engaged in making improvements to the TV camera and digitizer to bring their stability to an acceptable level. This has been accomplished by accurately controlling the illumination to the emulsion and being servoing the digitizer as described above. A stability on the order of two percent in track width has been achieved over a period of several weeks.

We are presently attacking a problem involving non linear responses to tracks of increasing width. We have found that the frequency response of the videcon tube is not adequate to follow the sharp edges of developed grains, causing narrowing of every fine track. The apparent solution to this problem is to decrease the rate at which the videcon is scanned until an acceptable spacial response is achieved.

The measurements to date, however, are sufficiently repeatable to allow the instrument to be used for production analysis, if the non linearities in response are properly taken into account. It is presently being used to conduct studies on plates exposed during the flight of Gemini XI.

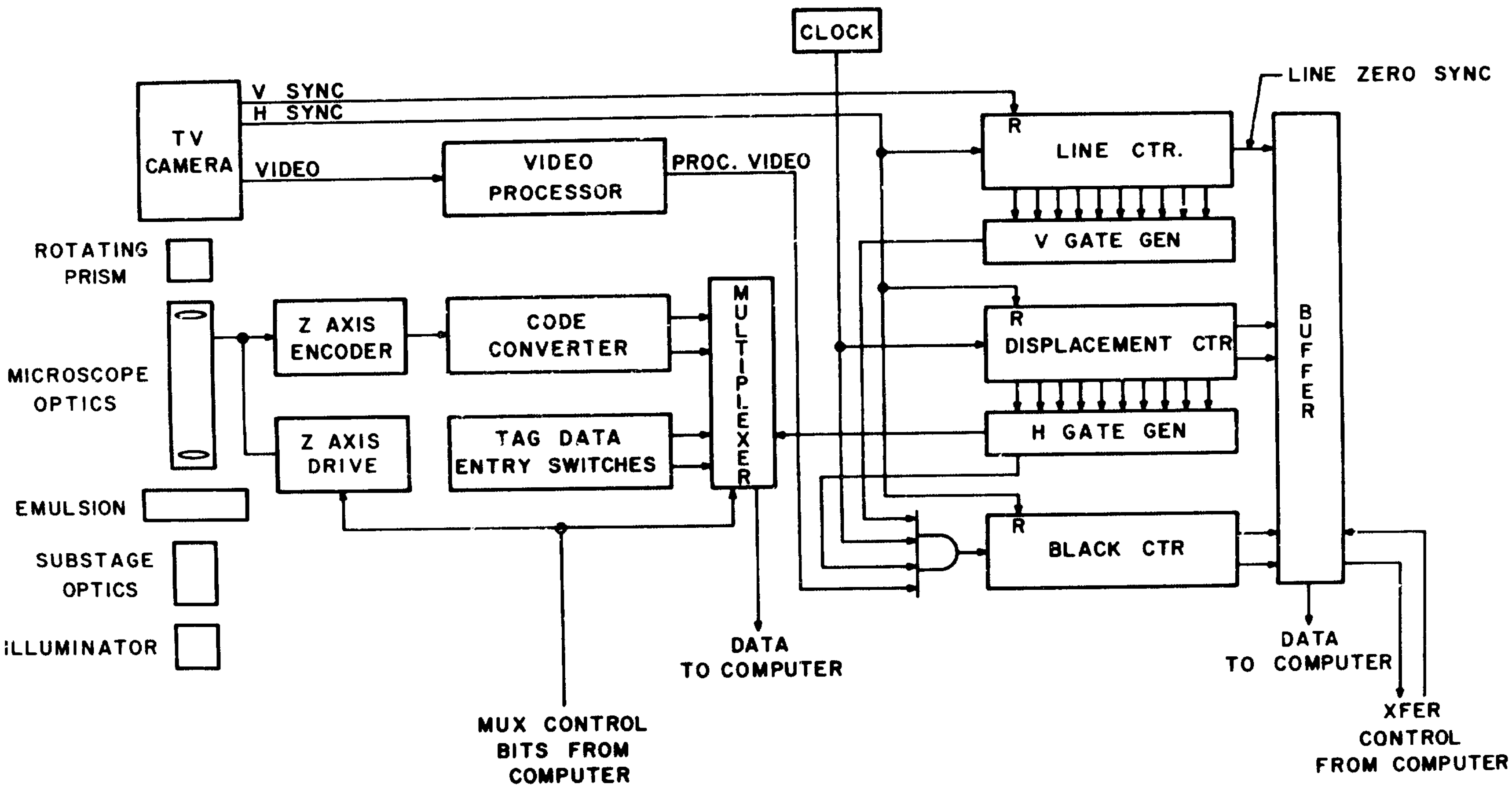
REFERENCES

1. Barkas, Walter H., Nuclear Research Emulsions (Academic Press, New York, 1963).

2. von Friesen, S. and K. Kristiansson, Arkin Fysik 4,505 (1952).

3. Kristiansson, K., A. Ladd, and L. Malmqvist, Arkin Fysik 34, 139 (1967).

4. Heckman, H. H., Lawrence Radiation Laboratory, Berkeley, California, private communication.



T.V. MICROSCOPE BLOCK DIAGRAM

FIG. I

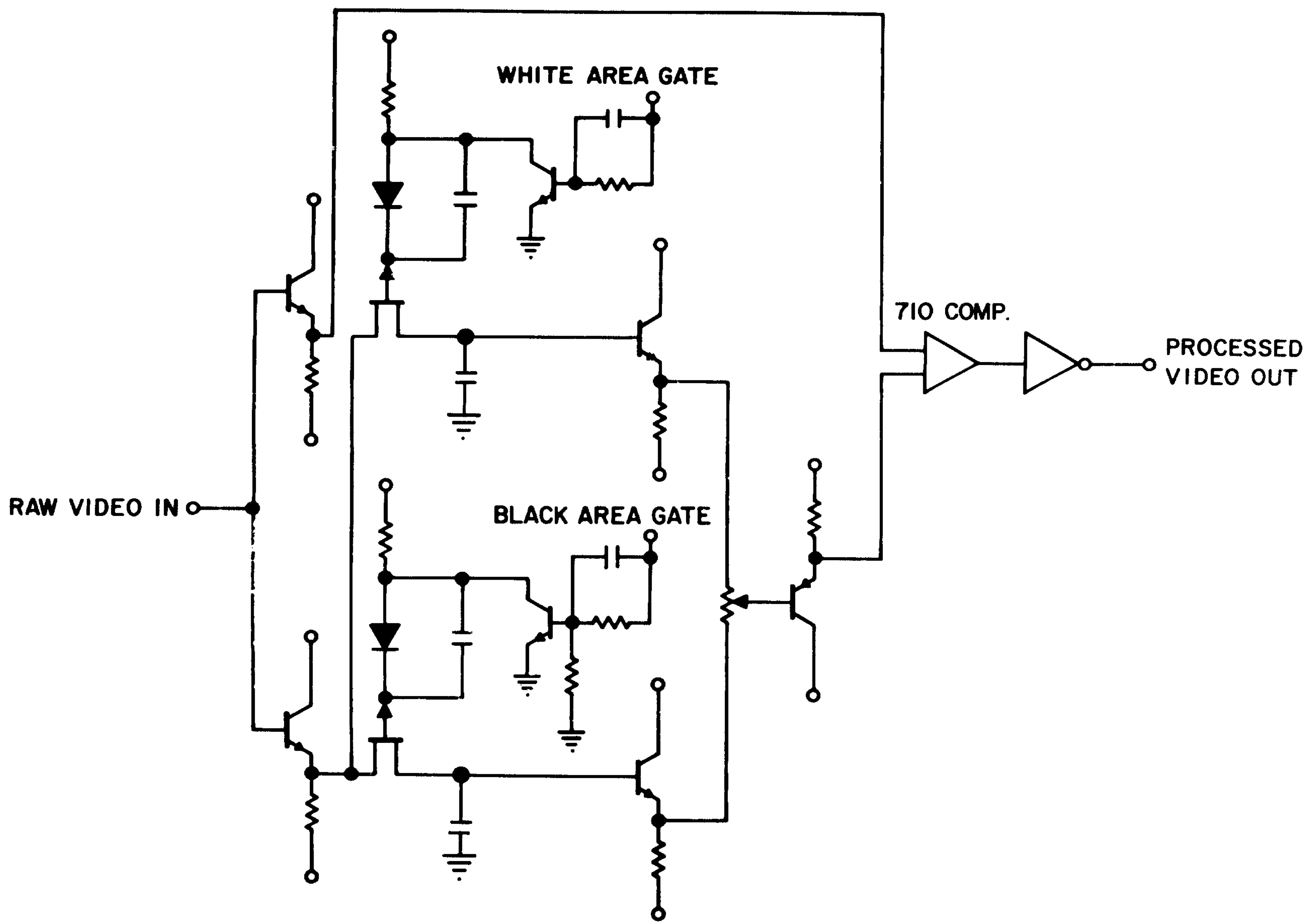
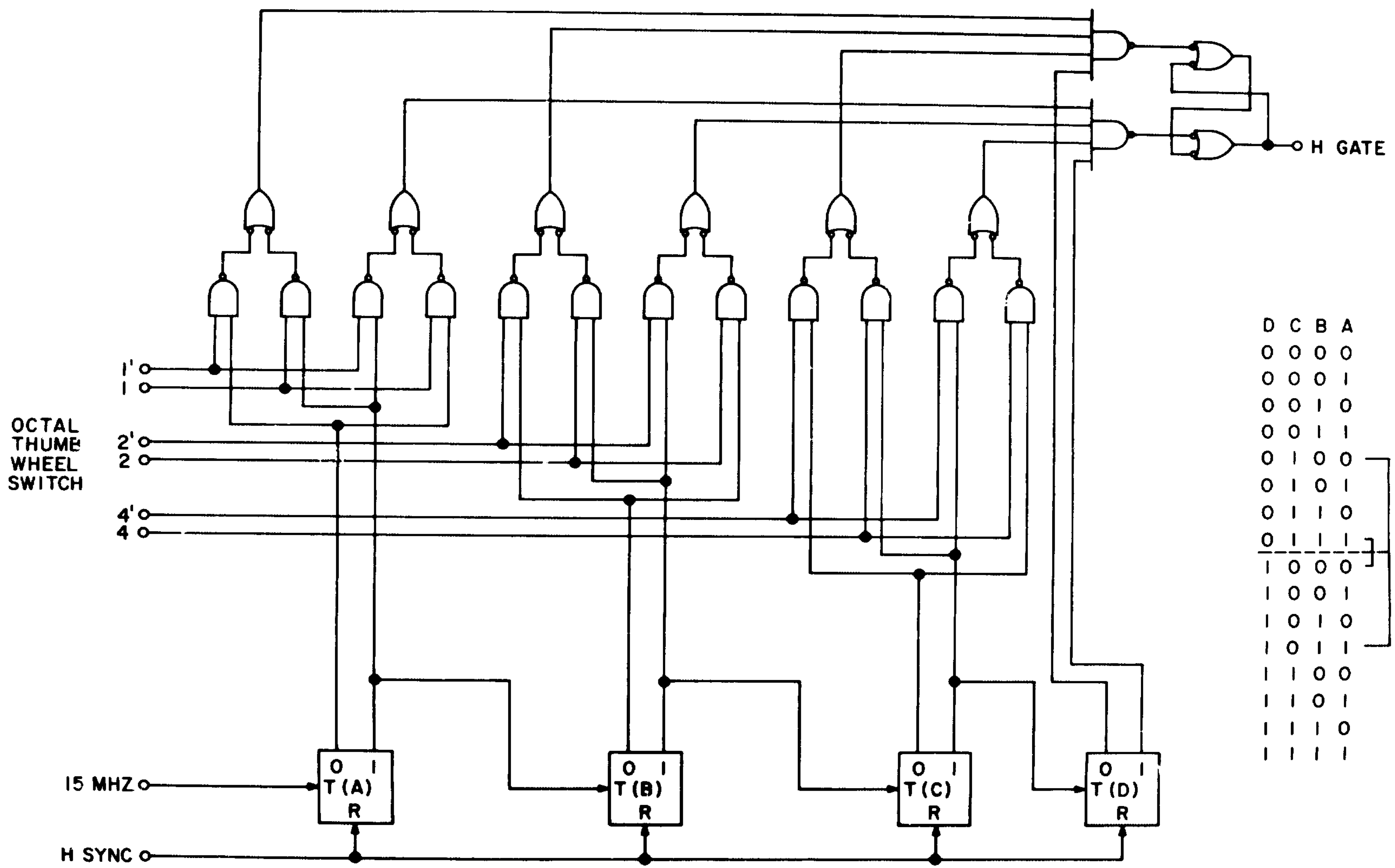
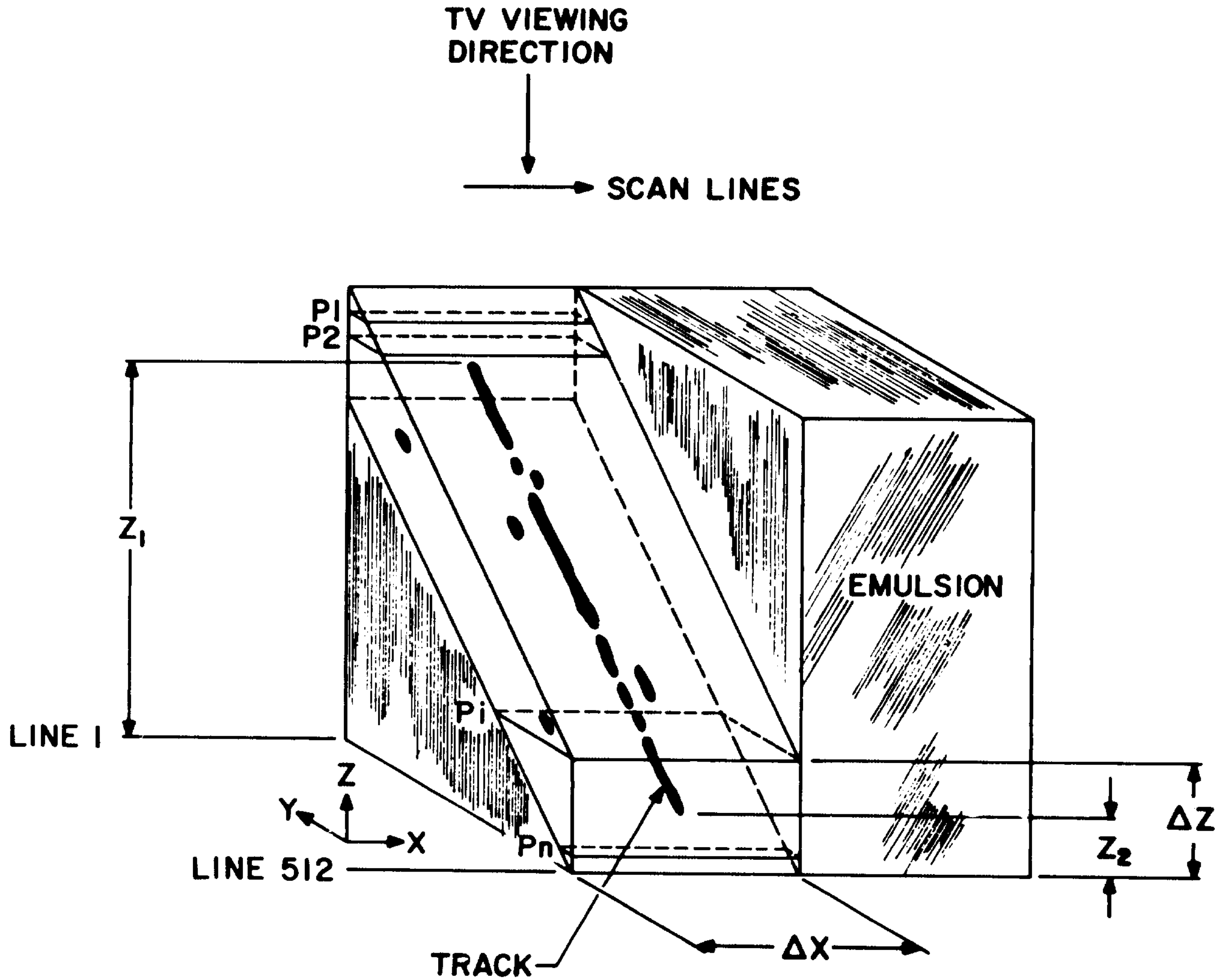


FIG. 2
VIDEO PROCESSOR



HORIZONTAL GATE GENERATOR

FIG. 3



DATA GATHERING SCHEMATIC

FIG. 4