The Primary Pattern Generator
Part III–The Control System

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I. INTRODUCTION

The primary pattern generator (PPG) writing-control system has two main functions: (*i*) interpret the commands generated by the XYMASK PPG postprocessor, and generate from these commands a bit-by-bit image of a scan line and stepping-table control; and (*ii*) check the operation of the PPG system.

The interaction between the PPG and the writing-control system must take place in synchronism with the rotating mirror on the PPG. The writing beam moves continuously across the photographic plate; once a scan has begun, a complete line must be written. One task of the control system is to assemble completely the bit image of a line in a buffer before the start of that scan line. Each line consists of 26,000 bits which must be taken from the buffer in a serial fashion in synchronism with the writing-beam position. A line is scanned in approximately 12 ms; hence, the bit rate during the writing period is 2.2 Mb/s. We thus require real time interaction with a nonstop mechanical device operating at electronic speed.

A complete pattern requires exposure of 32,000 scan lines or approximately 10^9 bits. Accurate operation requires a high degree of system reliability and thorough checking of operations. One check uses parity data generated in the XYMASK PPG postprocessor and regenerated from the signal input to the optical modulator of the PPG. Other checks are on the interface between the control system and the PPG. These checks monitor the operation of the electronics; they proved valuable during fabrication of the system.

II. THE CODE-PLATE SYNCHRONIZING SIGNAL SYSTEM

A block diagram of the computer control system is shown in Fig. 1. The code-plate synchronizing signal is obtained from the photo-

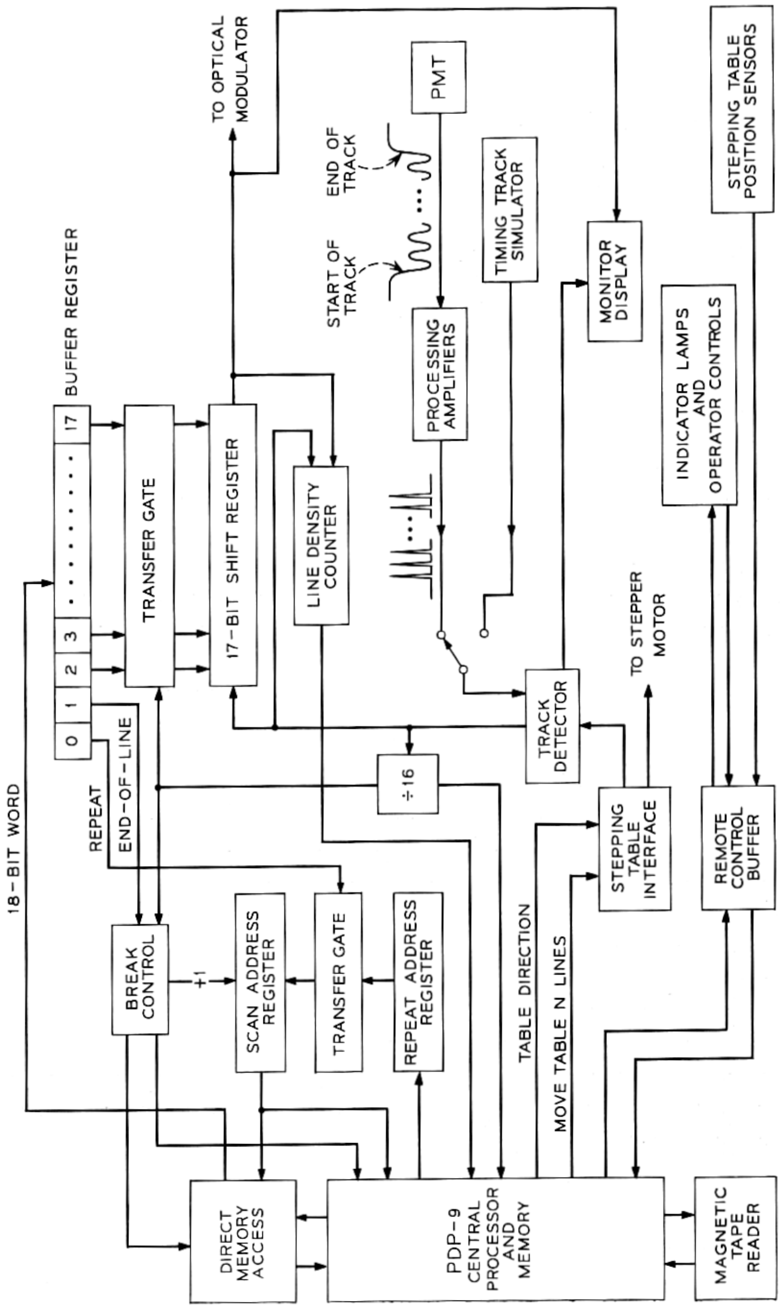

Fig. 1—Block diagram of electronics.

multiplier (PMT) used as the code-beam detector. The PMT output consists of a periodic signal superimposed on a level change. When the code beam begins its scan across the code-plate grating, the output level of the PMT changes with a relaxation time of approximately 400 ns. Similarly, when the code beam finishes its scan and leaves the code-plate grating, the PMT output level returns to zero with the same time constant. The periodic signal superimposed on this average level change represents a modulation index of approximately $\frac{1}{3}$. However, as is seen in Fig. 2 the average amplitude of the PMT output changes quite significantly over the length of the scan. Since we are solely interested in the phase of the periodic component, a limiter with controlled AM to PM conversion is employed before phase detection. The limiter will necessarily drop out during the dead period of each scan. The resulting noise into the phase detector will be unacceptable and so a silencer must be employed. This is accomplished by a gate which is opened and closed by the level changes occurring at the start and end of the scan. The laser power can be changed by a factor of five without affecting the processed output.

Referring again to Fig. 1, the processed output from the code-plate

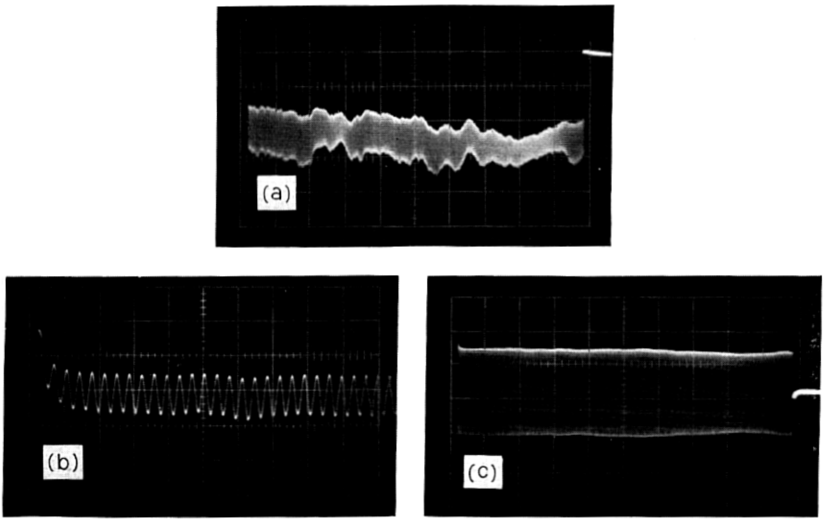

Fig. 2—Code-plate synchonizing signal. (a) Raw signal from the photomultiplier tube showing the entire scan, X sweep ≅ 1.2 ms/box. (b) An expanded view showing the start of the track, X sweep ≅ 2.2 μs/box. (c) Output of the limiter showing the entire scan, X sweep ≅ 1.2 ms/box.

synchronization system is fed to the interface between the PDP-9 control computer and the PPG. The functions of the blocks are best explained by following the sequence of steps that occur when one line is written. Before the line can be written, the bit-by-bit image of that line must be assembled in a core buffer in the PDP-9.

III. THE DATA INPUT SYSTEM AND CONTROL COMPUTER OPERATION

The data read by the PDP-9 control computer is a sequence of magnetic-tape records each of which is 1625 PDP-9 words in length. These records are of two types: one type contains a series of operation commands which define changes to be made to the current scan-line buffer in producing the succeeding scan line. Consecutive lines normally do not differ appreciably in their makeup. Therefore, only a few commands can update a scan line and thus the updates for many scan lines can be held in one record. The second type of input record is used for those instances in which a great number of update commands would be required to produce the succeding scan line. When this condition arises, a record is produced which contains all of the 26,000 bits for the new scan line rather than the update commands which would be required to produce that scan line.

Within the PDP-9 are four buffers of 1625 words each; one buffer holds the current scan-line data and another is the current-command buffer. The other two buffers allow for the overlapping of tape-reading operations with the updating and outputting of scan lines. Therefore, when a new scan-line buffer is requested or the current-command buffer is exhausted, outputting or processing of the next buffer can begin immediately. In the scan-line buffer, the rightmost 16 bits of each 18-bit PDP-9 word are used to designate whether the laser beam should be turned on or off at each of the 26,000 address locations. The magnetic-tape-handling operations were facilitated by making the update-command records the same length as the scan-line buffers.

The following is a brief description of the operation codes used to update the scan-line buffer.

(*i*) Change word N in the scan-line buffer in such a way that a specified, single transition from "beam on" to "beam off" or vice versa occurs. An index to the 32 possible single-transition words is used; this allows the word address and the index number to be packed into one PDP-9 word.

(*ii*) Change M consecutive words to all zeros.

(*iii*) Change M consecutive words to all ones.

(*iv*) Change word M to a specified bit-by-bit configuration. This covers changes entailing more than a single transition.
(*v*) Replace the current scan line with the line described in the next magnetic-tape record.
(*vi*) Write N scan lines identical to the last one.
(*vii*) Skip N scan lines. This allows the rapid coverage of blank areas of the pattern.
(*viii*) Write N consecutive lines of all ones.

In addition to the scan-updating commands, the input tape contains control commands which direct the operation of the PDP-9 control program. These control commands cover such information as: (*i*) the file number of the pattern information on the tape reel; (*ii*) the total number of scan lines in the pattern; (*iii*) addresses for locating the repeat sections of a scan line; (*iv*) end of update commands for the scan line; (*v*) the number of horizontal repeats in a scan line; and (*vi*) identification of the last line of a pattern.

IV. THE INTERFACE BETWEEN THE CODE-PLATE SYNCHRONIZING SYSTEM AND THE CONTROL COMPUTER

When the computer has finished assembling a scan line, it loads the starting address of the scan-line buffer into both the Repeat Address Register (RAR) and the Scan Address Register (SAR) (Refer to Fig. 1). It also sends signals to the break control and track detector telling them that a line may be written. The break control causes a word having address specified by the SAR to be fetched from memory and placed in the buffer register. The SAR is incremented by one so that it now points to the next word in the scan-line buffer. When the track detector finds the start of the timing track, it opens a gate and allows timing pulses to pass to the 17-bit shift register and the divide-by-sixteen counter. Each timing pulse causes the bits in the shift register to be shifted right one place. The output of the last stage of the shift register is used to control the laser writing beam, turning it on if it is a "one" and off if a "zero." The divide-by-sixteen counter produces an output pulse at each 16th timing-track pulse. This pulse causes the contents of the buffer register to be transferred to the shift register. This pulse also causes the break control to fetch another word from memory and deposit it in the buffer register. The line density counter counts the number of "ONES" that are shifted out of the shift register. This count is used in error checking.

The process of transferring words from memory continues until a word which contains a "ONE" in either bit position 0 or 1 is loaded into the buffer register. A "ONE" in bit 0 signals that the portion of the line being written is to be repeated. Therefore, the contents of the RAR are transferred to the SAR and the next word fetched by the break control will come from the location in the scan-line buffer specified by the RAR. A "ONE" in bit 1 signals that this is the last word in the scan-line buffer for this scan line. The break control logic is disabled and ignores any further pulses from the divide-by-sixteen counter. In addition, the control program is notified that the end of line has been reached; the track detector notifies the program that the end-of-track has been reached when that event occurs.

Anytime after the end-of-line is reached, the control program can command the carriage to be moved. This is done by transferring a word to the carriage control logic that specifies how many steps the carriage is to be moved. If the carriage is to be moved one line, the carriage control logic will cause the stepper motor driver to deliver the sequence of steps required to cause the carriage to move and be stopped within the 7 ms allowable time. Thus, if the next line is assembled in the core buffer of the PDP-9, the line will be written by the succeeding mirror facet. If the carriage is to be moved more than one line, then the number of lines less one to be moved must be all blank, and so carriage motion can be carried out asynchronously at high speed. After the last line is stepped, synchronism is regained by the operation of the track detector. The last line is always output by the carriage control logic as if only one line were to be moved. This effectively stops the carriage 7 ms after the last line command is issued.

The remote control buffer is used to provide communication between the operator and the computer. It consists of a flip-flop register and lamp drivers for signaling the operator, and gates to allow the computer to sense the pushbuttons the operator uses to signal it.

V. ERROR DETECTION

There are a number of safeguards in the control program which check on both hardware and software types of errors. Error detections are transmitted to the operator via teletype and light signals. Most errors are fatal and necessitate the restarting of the pattern. When this type of error is encountered, the current run is aborted and the photographic plate is unloaded from the machine. Some errors occur before the pattern is begun and, in these cases, the operator is advised but no unloading takes place.

Most hardware errors are detected in two major ways. One is a count of the number of pulses the code plate synchronizing signal system send to the track detector. If this deviates by more than ±1 pulse, then a fatal error is detected. Another track check is the occurrence of end of track before the end-of-line word has been written. The second way that hardware errors are checked is by the line density counter. If some malfunction occurred, then the number of ONES in the line written will not agree with the control command specifying the number of ONES in that line. This line-density count checks not only the functioning of the interface hardware, but also the PDP-9 assembly of the line image in the scan-line buffer. Other hardware errors are checked by comparing the SAR value at the end of a scan line with the value the SAR should have after the line is output. The carriage control is checked by comparing the reading of a shaft encoder on the stepper motor with the required reading after the pattern is completed. This shaft encoder gives an indication of its position only once in 500 lines, so continuous monitoring is not feasible. However, if the reading at the end of the pattern is not correct, then indication of a carriage error is given to the operator.

Software and magnetic-tape errors are detected by program routines in the PDP-9. Illegal update commands, magnetic-tape reading errors and other magnetic-tape controller errors are the main errors detected by these routines.