A DISC ORIENTED GRAPHICS DISPLAY SYSTEM*

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INTRODUCTION

Some 8 years ago, an EAI TR48 analog computer and a DEC PDP-8 digital computer with 4K of core were acquired in the Department of Electrical Engineering at McGill University. Since then, the Systems Group has built up a number of specialized computer facilities to support research in such areas as adaptive and digital control, image processing and pattern recognition, identification, and hybrid computation. The increasing need for a graphics facility to support this research has resulted in the construction of "McGraph", the disc-oriented graphics display system presented in this paper. In this design we have specially tailored the system to take into account the computer resources available in the department as well as the nature of the research projects being envisaged.

1. FEATURES

The graphics design is based on a hierarchy of computers each one dedicated to a specific task. Figure 1 shows a block diagram of the system. The main interactive software manipulations as well as numerical computations are performed in the DEC PDP 15/20 computer with 16K of core storage at the present time. Plans are underway to expand this unit to a model 40 which has background, and foreground mode capabilities. The PDP 15 is linked by a high speed data channel to the PDP-8 computer, with 4K of core. The PDP-8 has as its main task the servicing of peripherals and research equipment. These include the scanning system for microscope slides, the hybrid facility using the EAI TR-48 analog computer, a heat-exhanger, the peripherals namely IBM and DEC tape drives, an ASR-33 teletype with paper-tape punch, the joystick and light pen, the disc and finally a high speed data link to the IBM 360/75 at the computing center.

The IBM 360/75 computer link is not available for on-line interactions since it is serviced on a job queue basis. However, its great value lies in the available library programs on the IBM machine and its use for large scale computations which are not possible on the PDP-15. Both PDP computers are completely dedicated to on-line man-machine interactions. The main design features of the Graphics and TV interfaces will nowbe presented.

The disc is an integral part of the graphics system since it is used

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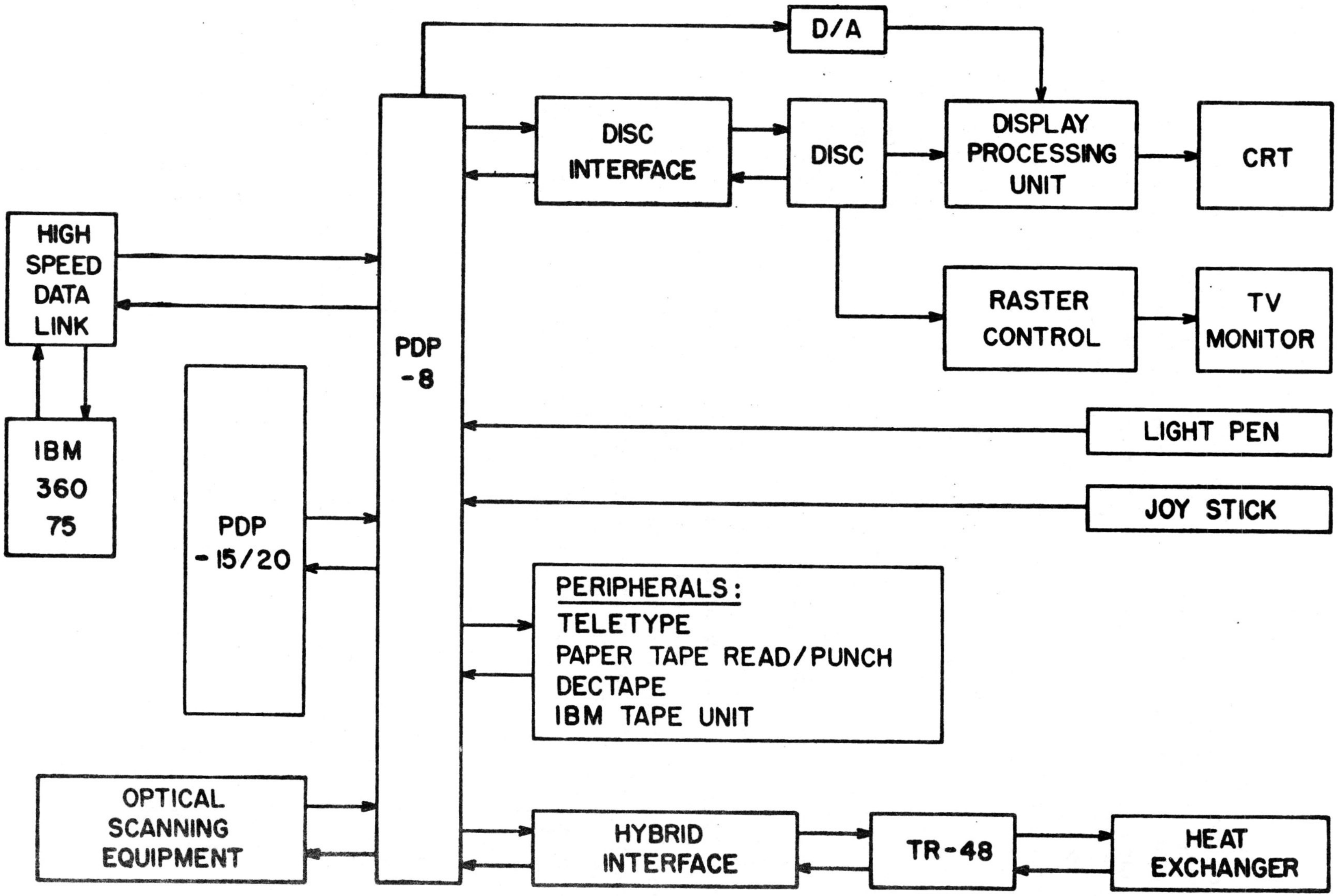

FIGURE 1: COMPUTER SYSTEM CONFIGURATION

to refresh the display images and thereby frees the CPU's from this major burden. Its choice was primarily due to the large storage requirements for the display of microscope images. A DATA DISC having sixteen tracks plus a clock track and giving approximately one million bits of storage is used. A special interface was constructed between the PDP-8 and this disc which permits six modes of storage and retrieval, namely, 8 bits serially in one track, 12 bits serially in one track, and 12 bits written in parallel on 12 tracks. This last mode is used to drive a conrac TV monitor in displaying the microscope images in a manner similar to the system described by A.M. Noll.* The 12 bit serial version is suitable for storage of programs or data for the PDP-8 which is a 12 bit machine. The 8 bit serial modes are used with the link to the IBM 360 computer as well as in driving the graphics system display on a 10 x 12 inch Dumont XY display. A P-31 phosphor was selected to allow a minimum of 30 per second refreshing rate from the Data Disc. Higher refresh rates can be obtained by repeating the files however this duplication results in a decrease of storage available per revolution. A 6 x 6 inch monitor is equipped with a Tektronix Polaroid camera for obtaining photographic hard copies of the displayed images. A Saunders light pen and Dec Joystick are available for man-machine interaction, in addition to the teletype. These are serviced by the PDP-8 since considerable manipulation of the graphics display files residing on the disc is envisaged.

Graphics files are written on the disc using the serial 8 bit word format and subsequently read sequentially by the Display Processing Unit (DPU) to refresh the CRT. One or two such words are used in specifying both DPU instructions and data. The file begins with a HEADER which permits specifying a file name to be used in identifying image parts with the light pen. One of the HEADER bits permits turning a complete file ON or OFF. A normal image is limited to a full disc revolution or one track length but this length may be assembled from sequenced files residing on different tracks since automatic switching to a new track is possible under disc program control using the BRANCH instruction. In addition, the track selection can be controlled by switches at the graphics console where we may manually select the track in which the display originates at each disc revolution. When a disc file is OFF, it is completely ignored so any BRANCH instructions contained in that file are inhibited. Displayed images will usually occupy less than the maximum track length so that the disc may contain many more pictures than are currently being displayed and much user interaction will simply involve switching disc files ON and OFF.

The graphics system is also capable of operating in the graphics display mode and the TV monitor mode simultaneously, thus displaying two images at the same time. The Conrac TV monitor is refreshed by the disc using a specially designed interface which produces an analog video signal from data in 12 disc tracks. The four remaining tracks are available for simultaneous graphics displays. The desired original image matrix, containing sixteen grey levels at each point in the raster, must be written in suitable form on the disc to take into account such considerations as flyback time, raster size, and horizontal and vertical synchronization. An additional synch-

* Noll, A.M. "Scanned-Display Computer Graphics"
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ronization track on the disc is provided for the latter purpose. The disc data is read twelve bits in parallel and fed four bits at a time sequentially into a 30 MHz digital/ analog converter. The latter produces the video signal which is fed to the TV monitor.

INSTRUCTION FORMATS

We shall now discuss the DPU instruction formats which are used in generating graphics files. Figure 2 shows the formats of the three command instructions: HEADER, BRANCH and OPERATE. The INT bit allows the PDP-8 to be interrupted, the DISP bit determines whether or not processing is to wait for track origin before displaying is resumed. The graphics system is capable of displaying both points and vectors with variable intensity and using different scales for the X and Y axes. The HEADER and BRANCH commands have already been discussed. The OPERATE command specifies which of the 4 types of data instructions follow, namely, POINT, VECTOR, INTENSITY or SCALE.

Figure 3 presents the data word formats. The DISP bit distinguishes blanked moves which do not write on the screen from the illuminated ones. The TYPE bit specifies the short 1 word format or the long 2 word format. In the POINT mode, the one word format specifies an increment of three bits while the two word format can specify all of the ten bits in a register. In the VECTOR mode, the one word format specifies a three bit increment for a move along one axis while the two word format specifies three bit increments along each axis for a vector move in an arbitrary direction. The INTENSITY instruction can set 16 levels of intensity at each of 4 possible CRT channels. Alternately we may control 1 color and one black and white display. The SCALE feature is achieved by shifting the INCREMENTS up the register before processing them through the X and Y axis circuits. This permits magnification in powers of two up to 128X. Standard files may thus be repeated and simply scaled to the right size when needed such as in letterings. The INV bit effectively changes the sign of the increment and may be used in inverting an image. The OP bits of each data word select which of the four following are performed with the data:

1) CLEAR registrer and ADD increment
2) ADD increment
3) SUBSTRACT increment
4) Return to COMMAND mode

With these operations we may generate either absolute or incremental addresses.

THE DPU

A block diagram of the Display Processing Unit is shown in Figure 4. The principal input to the DPU is the disc. Disc data first enters a track selector where all 16 read/write heads are buffered. The BRANCH statement together with

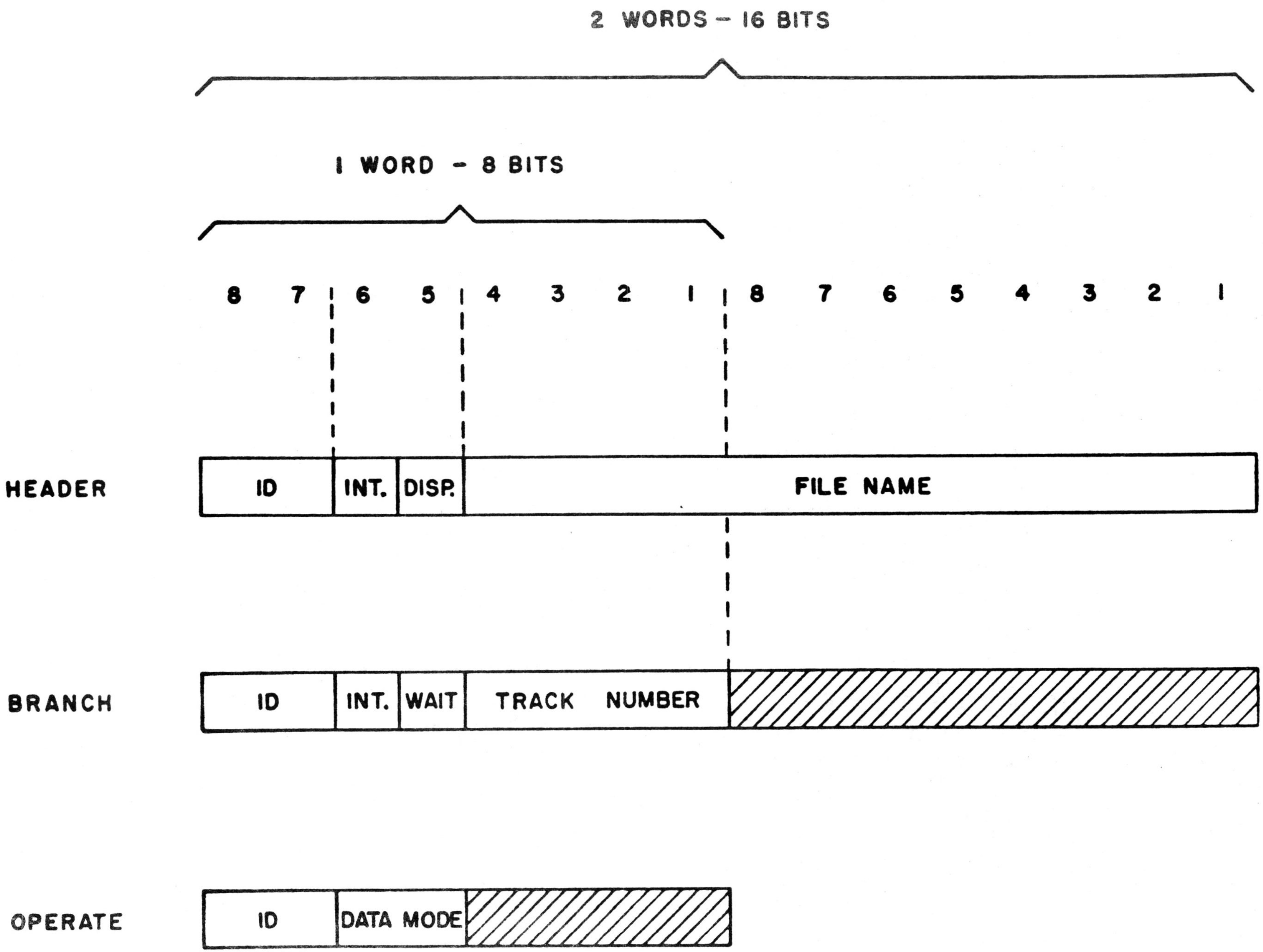

FIGURE 2 : COMMAND WORD FORMATS

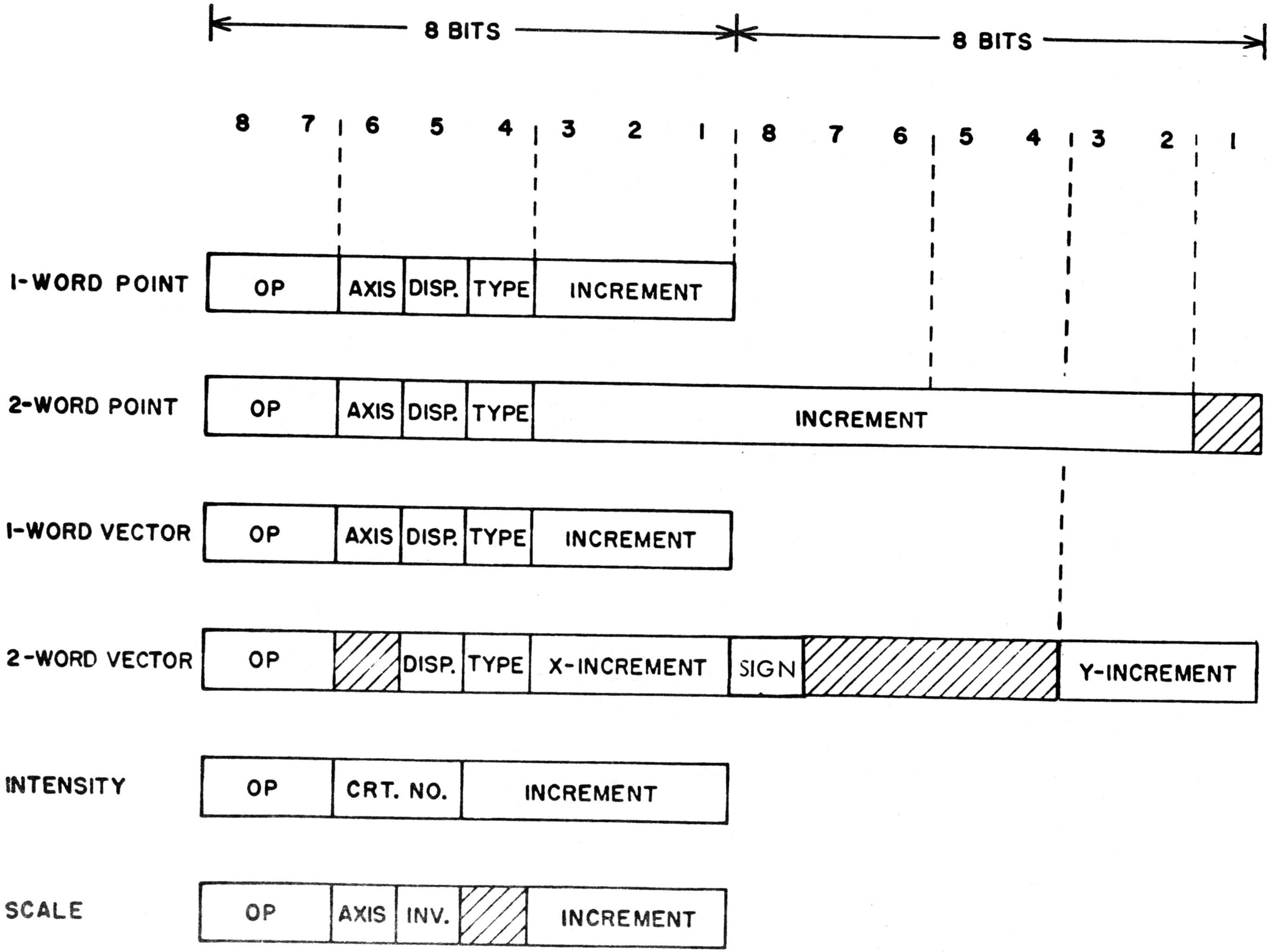

FIGURE 3 : DATA WORD FORMATS

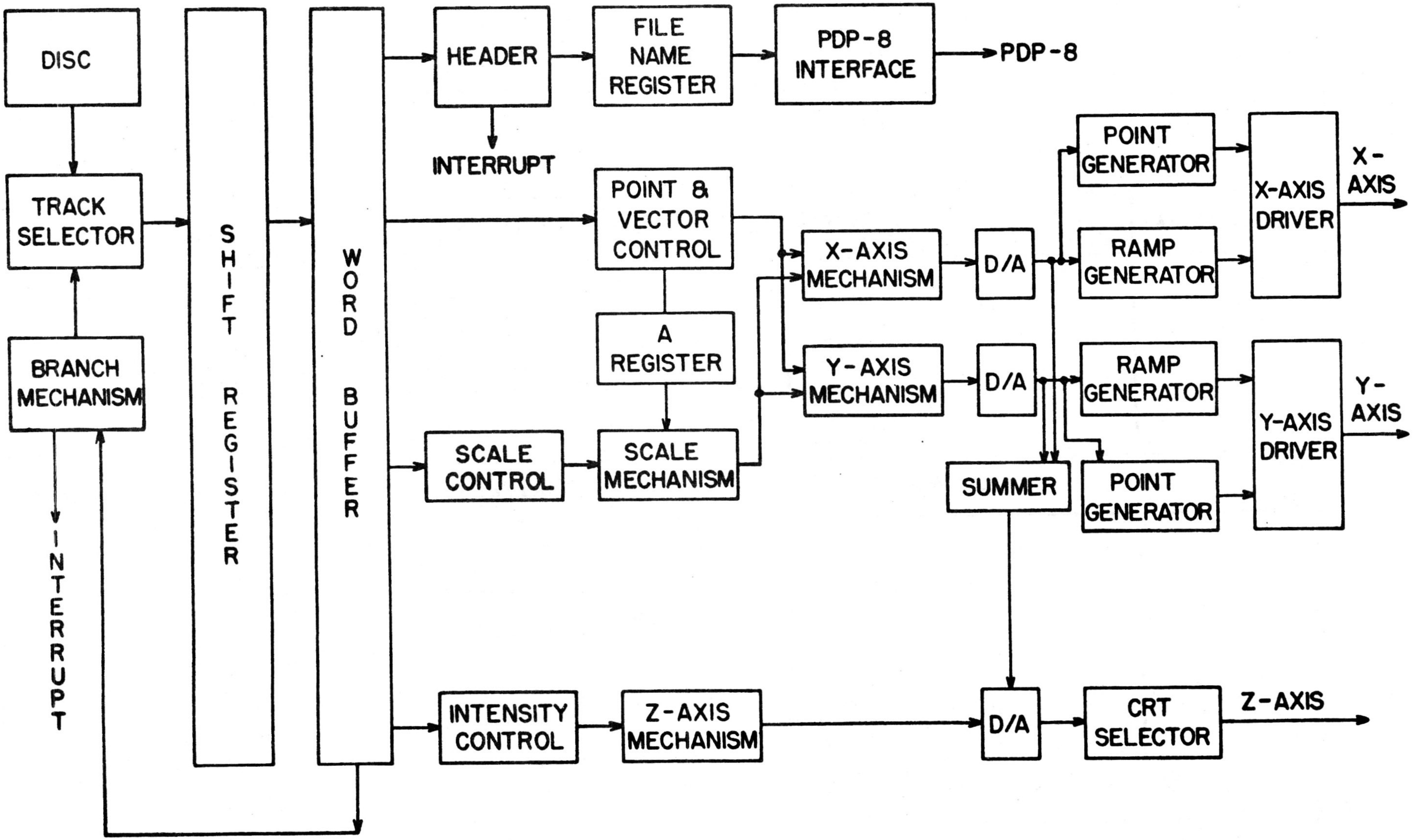

FIGURE 4 : DISPLAY PROCESSING UNIT

the track selector switch gate information from the proper track to the shift register. After 8 bits have been entered, the contents of the shift register are buffered and held for 2.4 microseconds forming the instructions to the system. According to the type of instruction, this information is gated to one of five main arteries seen in Figure 4.

1) a HEADER circuit.
2) POINT and VECTOR move mechanisms.
3) a SCALE unit.
4) an INTENSITY unit.
5) a BRANCH circuit.

Control of picture illumination is achieved as follows. First an INTENSITY instruction sets the desired level of overall brightness for various parts of an image. With this mechanism alone, the various vectors would vary in brightness according to their length, since a fixed drawing time of 2.1 microseconds is used for vectors causing short ones to be plotted at a lower linear rate and thus increasing their brightness. In order to compensate for this, analog signals corresponding to the X and Y components of the vector are summed and the result is used to modulate the Z axis D/A converter. Of course the above sum of components is only an approximation to the length of the vector - but laboratory experiments indicate that this compensation is very satisfactory. An INTENSITY instruction gates its bits to Z axis arithmetic unit being selected. The CRT selector gates the appropriate register through the D/A converter and drives the beam intensity of the appropriate CRT.

A SCALE instruction updates the X or Y magnitude registers which specify the number of times data from the A register is shifted upward.

The POINT and VECTOR control unit directs data bits corresponding to such instructions into the A-register. The contents of this register pass through the SCALE unit and are fed to the X and Y arithmetic units. The results are then converted to analog signals which are fed to their respective point and ramp generators. These signals are also added by a summing circuit which provides a modulating signal for the beam intensity D/A converter. The point and ramp generators are then fed to X- and Y-axis drivers to supply the proper signals to the CRT. Gating is done using FET analog switches.

SOFTWARE

The development of software support for this disc-oriented graphics system is in progress at this time. Some programs have already been developed for specific applications but the overall software system is not completed and hence will not be discussed here. Instead, we shall briefly comment on the applications being envisaged.

APPLICATIONS

The application of methods of image processing and pattern recognition to problems in bio-medicine is being investigated. The specific projects are:

1) The computer determination of the internal surface area of the human lung,
2) Computerized cyto-screening,
3) Computer analysis of EEG artifacts using hierarchial associative learning techniques,
4) Computer analysis of electron micrographs in cell biology
5) Interactive pattern analysis and synthesis

Several other applications of the graphics system are under development by the Systems Group in the Department of Electrical Engineering at McGill University. These relate to interactive modelling of industrial processes, computer-aided network design, and computer-aided logic design using the Pseudo-Boolean Analyzer. The emphasis in each of these cases is on applications-oriented software rather than general purpose graphics languages. The objective is to develop specific engineering systems which incorporate interactive computer graphics and so hopefully improve their utility.

BIBLIOGRAPHY

1) Williams, R., A Survey of Data Structures for Computer Graphics Systems. Computing Surveys, Vol. 3, No. 1, March 1971

2) Smith, L.B., A Survey of Interactive Graphical Systems for Mathematics Computing Surveys, Vol. 2, No. 4, Dec. 1970

3) Ophir, D., Rankowitz, S., Sheperd, B.J., Spinrad, R.J.
BRAD: The Brookhaven raster display
Comm. ACM II, 6, (June 1968), 415-16

4) Burger, P., Nemeth, L., Rillings, J.H.
A Simple Graphical Display Unit for a Small Digital Computer Installation
Information Display Vol. 7, No.4, April 1970 pp. 39-43

5) Lewin, M.H.,
An Introduction to Computer Graphic Terminals
Proceedings of the IEEE, 55, 9, 1967, 1544-1552

6) Joyce, J.D. and Cianciolo, M.J.
Reactive Displays: Improving man-machine graphical communication
Proc. AFIPS 1967 Fall Joint Computer Conference. pp. 713-721

7) Terlet, R.H., The CRT display subsystem of the IBM 1500 instructional system.
Proc. IFIPS 1967, Fall Joint Computer Conference, Vol. 31, pp.169-176

8) Myer, T.H., and Sutherland, I.E.,
On the Design of Display Processors
Comm. of the ACM, Vol. II, No. 6, June 1968

9) Pulfer, J.K., Digital Display Hardware for Man-Machine Communications Studies. NRC 10552.

10) Prince, M.D., Man Computer Graphics for Computer Aided Design Proc. of the IEEE, Vol. 54, No. 12, Dec. 66.

11) Christensen, C., and Pinson, E.N.
Multifunction Graphics for a large Computer System.
Proc. AFIPS, Fall Joint Computer Conference 1967 pp. 696, Sec. B.

12) Sutherland, I.E., Sketchpad: A man-machine graphical communication System
Proc. AFIPS, Spring Joint Computer Conference Vol. 23, pp. 329-346, 1963.

13) Ninke, W.H., Graphic I : A Remote graphical display console System
Proc. AFIPS Fall Joint Computer Conference
Vol. 27, pp. 839-846, 1965