THE ELLIOTT 928 GRAPHICAL DISPLAY SYSTEM

GENERAL

The Elliott 928 Graphical Display System is a powerful but low cost graphical processing system based on a cathode ray tube display and light pen. It is connected to an Elliott 905 computer which provides the computation power necessary for graphic manipulation and the associated calculations. The Graphical Display System is designed primarily for use as a satellite display attached to another computer.

The Elliott 928 graphical display system includes a graphical console with a light pen, character and vector generators, a graphic control unit, an optional keyboard and an extensive graphical programming system to complement the hardware. The system may be extended by adding more graphical consoles or more keyboards.

This combination of hardware and software in the 928 graphical system now offers the user a powerful and easily programmed tool for tackling the many applications which are suitable for solution by graphical methods.

OPERATION

The 928 display functions by autonomously extracting data from any area of the core store (referred to as the display file) on a cycle stealing basis. The data is used to generate an image on the cathode ray tube and to control the display system, particularly with respect to the input devices such as the light pen and the function keys.

The display file is created and changed by programs obeyed by the Elliott 905 computer either in response to the graphical input devices or as the result of calculations performed. The operation of the 905 is concurrent with the operation of the display so that there is no loss of picture while the 905 is computing. The computation could, if required, be by a completely independent program.

THE GRAPHICAL CONSOLE

This is the operator's console which contains the cathode ray tube viewing unit and light pen, and has been carefully designed for ease of operation. The cathode ray tube is a 17-inch tube coated with a special long persistence orange phosphor, which enables the display to be refreshed at the low rate of 10 frames per second. This low rate enables a large flicker-free picture to be

generated before refreshing becomes necessary. This special phosphor has a sharp fall-off in light output after a period of 160 milliseconds, so that there is no smear on rapidly changing displays. The tube is retained by an amber tinted P.V.C. implosion shield to give good contrast and to reduce operator fatigue when using the display for periods of many hours.

The picture on the screen is built up by means of points, lines and characters positioned on a basic raster of 1024 by 1024 points occupying an area of 10 inches square. Two 10-bit binary numbers are required to specify a position on the screen. The picture is generated mainly by changing the contents of the horizontal and vertical position registers so that the electron beam traces out the required picture. This is known as "directed scan" as opposed to the "line scan" method used with television. Different parts of the picture can be displayed at different brightness levels under program control. This can be used to accentuate details by using the brightest level, or to fade background information using the lower level of brightness.

THE LIGHT PEN

This is contained in the graphic console and is a small hand-held device similar to a pen. It is connected by a flexible light guide to a light-sensitive circuit. This circuit is sensitive to a particular wavelength emitted by a small percentage of a very short persistence phosphor (less than one microsecond persistence) which is mixed with the long persistence phosphor. When the light pen is activated by a foot switch and pointed at a visible picture part, this part is detected by the pen the instant it is drawn so that the graphic processor can determine what feature is currently being drawn. It can then interrupt the processor to take the appropriate action. The pen is used in this mode as a pointer, but it can also be used to input new positions by means of a simple program which continuously tracks the position of the pen by using a small cross drawn on the screen.

THE CHARACTER AND VECTOR GENERATORS

Any picture could be made up entirely of individual spots positioned close together. This is, however, inefficient in both speed of generation and in the amount of core store necessary to define the picture. The Elliott 928 display is, therefore, equipped with special items of hardware to draw the most frequently used graphic features, characters and straight lines.

The character generator is located in the console. It generates an alphanumeric symbol at the current beam position and increments the horizontal

deflection register an appropriate amount ready for the next character. The characters are formed by short strokes on a basic 4 x 4 grid. The description of each character is held is a fixed diode store. This particular method produces characters of good legibility with the greatest reliability and freedom from the need for frequent adjustment. The character repertoire consists of 59 visible characters plus space and newline, and all of these are available in three sizes controlled by program. The visible character set is extensible to 88 characters. Special hardware ensures uniform brightness between characters of different sizes. The high speed deflection circuitry enables the basic size of character to be drawn in an average time of 11 to 21 microseconds including positioning, and this enables 8,192 characters to be displayed simultaneously.

The vector generator is incorporated in the control unit. It draws straight lines automatically on the screen at any angle and of any length. The co-ordinates of the end point are simply specified by program relative to the starting point. The display code for a vector is therefore independent of its position on the screen, and this is very useful in the subpicture feature which is available. The lines are drawn by digitally incrementing or decrementing the contents of the horizontal and vertical deflection registers at a constant rate of 1.3 increments per microsecond. This gives accurate lines of constant brightness with complete stability. As with the character generator no periodic adjustments are necessary.

An extension of the vector generator hardware enables arcs or complete circles to be drawn using only four store words. The arcs are relatively specified, as are the vectors, and are produced digitally in a similar manner.

THE GRAPHIC CONTROL UNIT

This control unit functions by extracting the data from the display file held in the core store autonomously every 100 milliseconds. Once initiated by the Elliott 905 this refreshing is completely automatic. The data is in the form of single-address instructions with a format almost identical to that of the 905, with a 4-bit instruction field, a 13-bit address or operand and a modify bit which determines whether the operand is the 13-bit address or the contents of the location specified by it.

This direct addressing technique is relatively unknown with computer graphic displays and adds considerable power to the instruction code. It enables direct reference to a variable in a complex data structure to be made, without the need to change the display file when this variable is changed.

The range of instructions enables all the graphic features, such as co-ordinate positioning, vectors and characters, to be generated with relatively few words. For instance a single character instruction displays two alphanumeric symbols. As well as the graphic instructions, there are instructions specially designed to aid the program. These include 'jumps', which have provision for preserving the current address, so enabling subroutines to be used in the display code, and control instructions to vary parameters like character size and brightness levels, as well as the provisions for interrupting the 905 computer.

A further innovation is the introduction of an arithmetic instruction which can be used, for instance, to create conditional jumps by operating on the sequence control register, or to store the registers of the 928 in the core store.

There is an occasional need for the temporary interruption of picture generation to perform some function like informing the 905 computer of a "light pen see", or the pressing of a function key by the operator. This is accomplished in the 928 by storing the current instruction address and transferring control to an interrupt routine (still obeyed by the 928). The cause of the interrupt is determined by using the conditional jumps and then appropriate action is taken. Depending on the reason, the 928 may handle the interruption without using the 905 (for instance in regular tracking of the light pen) or it will interrupt the 905 to take action (as in the case of a 'light pen see').

Other features of the 928 control units include "picture scissoring" and the "naming" of items. The horizontal and vertical deflection registers are actually of 13-bit length, enabling points off the screen to be specified. By using this feature the display can be used as a window on a much larger area (up to 80 inches by 80 inches). If programmed using relative instructions, this window can be moved rapidly over the whole area by altering only the initial starting co-ordinates. Instructions are provided to enable sections of the display code called items, and also collections of these items such as subpictures, to be assigned an identifier or "name". This naming structure functions regardless

of the nested depth of the subpictures. By using the "naming" feature, rapid identification of picture parts can be made either by the program or from the operator via the light pen.

Construction of the 928 control unit is similar to that of the 905 central processor. High reliability integrated circuits are used and full engineers' facilities are provided.

By careful design many improvements in processing speed have been attained. Whenever possible the next instruction is extracted from the store while the present instruction is being obeyed, thus saving access time. In addition all non-graphic instructions can be completely overlapped with the settling of the electron beam during co-ordinate positioning.

SATELLITE OPERATION

The Elliott 928 Graphical Display System is eminently suitable for use as a satellite display to a larger central computer. When used in the satellite mode the Elliott 905 computer deals with the graphical operations such as pen-tracking, drawing or deleting lines, etc., while the central machine performs any lengthy calculations and administers the "data base".

The Elliott 905 may be attached to any large computer, either via a G.P.O. modem attached to a modem controller, via a British Standard Interface, or by a specially designed Interface Matching Unit.

PACKAGING

The display consists of three items, the viewing unit and character generator with their associated power supplies, the light pen and its power supplies, and the controller. The first two are housed in the display console which is connected to the controller by a single cable, normally 25 feet long. The controller occupies 19-inch racks and may be housed in a 900 Series cabinet.

THE ELLIOTT 928 GRAPHICAL DISPLAY SOFTWARE

In the design of the flexible order code of the Elliott 928 Graphical Display, programming requirements have received as much consideration as graphics. Although it is anticipated that most users will use one of the programming systems available, the display is nevertheless easily programmed directly by the user. One of the main features of the available programs is that the user does not need to have a detailed knowledge of the 928 hardware; a broad outline of its operation and features is sufficient to enable full use to be made of the system. The communication with, and the control of, the 928 is handled entirely by these graphic programs. The nucleus of all these program systems is the Elliott 905 program DISMAN 900, the Display Manipulation System. This is supplemented by ALGOL and FORTRAN routines.

SOFTWARE SYSTEM

Figure A shows the normal structure of the software systems for the Elliott 928 display when it is used in a 'satellite' configuration.

When the Elliott 928 display is used as a satellite to a central computer the data structure and the analytical routines for operating on the data structure are usually held in the central computer. The display file together with the Display Manipulation System, DISMAN 900, and the users graphical routines reside in the core store of the satellite Elliott 905 computer. It may also be necessary to hold certain parts of the data structure (for example those parts which are being viewed) in the satellite computer.

For certain applications an Elliott 928 configuration with at least 16,384 words of store can be used on its own when the main computer is temporarily not available. Special data structure program aids are available which provide for the automatic linking of items and correct storage allocation.

DISMAN 900, the Display Manipulation package for use with programs written in SIR (Symbolic Input Routines) code, can be used on a 928 system with 8,192 words of core store. A system with 16,384 or more words of store allows use to be made of the powerful ALGOL and FORTRAN programming systems provided with the Elliott 928.

Other graphics programs include diagnostic routines, and programs to produce hard copy of the displayed picture on an on-line digital plotter.

DISMAN 900

DISMAN 900 is a comprehensive device routine package which acts as an interface between the users' SIR (Symbolic Input Routine) program and the 928 graphical display. It enables the programmer to utilise fully the capabilities of the display without having a detailed knowledge of the hardware or the complex "housekeeping" software.

DISMAN is written in Symbolic Input Code and as such can be used directly by another SIR program. The advantages of programming in this language are mainly in respect of efficiency in speed and use of core store. It is ideal for many real-time applications where speed is important. DISMAN consists of a modular group of routines; its main functions are the control of the 928 hardware and the maintenance of the display file.

The picture is built up as a series of display commands held in the main store. These commands, known collectively as the "display file", are accessed autonomously by the display controller, which in turn sends signals to the viewing unit to draw a picture on the face of the cathode ray tube.

The picture can be altered by modifying the display file as necessary, and the user is freed from any of the routine problems of storage allocation associated with a dynamic display file.

The facilities provided by DISMAN form three main groups:-

(i) Basic housekeeping routines to start the display and allocate areas in which to construct the display file.

(ii) Code generation routines to generate display commands for items such as points, lines, arcs and text.

(iii) An interrupt routine to react to the interrupts produced by the display and activate the appropriate users' routines.

DISMAN contains a number of display code generation routines which can be used to generate code for an "item" in a buffer. The item can consist of any mixture of points, lines and alphanumeric characters as well as control functions. This item is then inserted into the display file where required and at the same time it is given an identifying name by the user. This name can be used later to reference the item if, for instance, it is required to delete it, or the name may be handed to the user's program as a reference if this item is seen by the light pen. Using DISMAN the user is able to insert items into or delete items from the display file, and items, once in the display file, can be replaced, renamed or modified at will by the user. Facilities

exist for defining a collection of items as a subpicture, which can then be named and called up using that name within a subsequent item or items. This subpicture facility can be nested to any depth.

Besides the above-mentioned routines there are control routines mainly associated with the input hardware like the light pen and the function keys. These routines are set up by the user to cause entry to his own routines when an input occurs, making available all the information associated with it. Pen tracking can be initiated by the user at any time. The pen will be tracked automatically and continuously by a small cross on the screen, without further action on the part of the users' program. By this method the co-ordinates of the pen position are always available. Communication between the users' program and DISMAN is basically via a number of global identifiers and labels.

Objects on the screen may be at one of two brightness levels, thus certain features of the picture may be visually emphasised relative to the rest of the picture. Characters may be displayed in two sizes - small or normal. Lines may be plain or dotted, either at 16 or 32 increments frequency. Objects on the screen may be made to blink on and off to attract attention to any given part of the picture, and may be made visible or invisible to the light pen.

EDGAR 900 AND FRED 900

All the facilities of DISMAN are available to the ALGOL user via a procedure package known as EDGAR 900 and to the FORTRAN user via a subroutine package known as FRED 900. These packages of procedures enable the ALGOL or FORTRAN programmer to use the Elliott 928 Graphical Display System for input and output of graphical information, including conversational operations using the light pen and console keys, and autonomous pen tracking. Procedures are provided for creating and modifying a file of display commands in the store, detecting when a picture part is indicated with the pen, interrogating the console keys in various modes, and tracking the pen.

Examples of the instructions for EDGAR 900 are

```
NEWBUF (A);                 Start a new buffer: array A.
POINT (X, Y);               Generate display code for point (X, Y).
VECTOR (DX, DY, B);         Generate a vector with DX and DY as
                            relative components.
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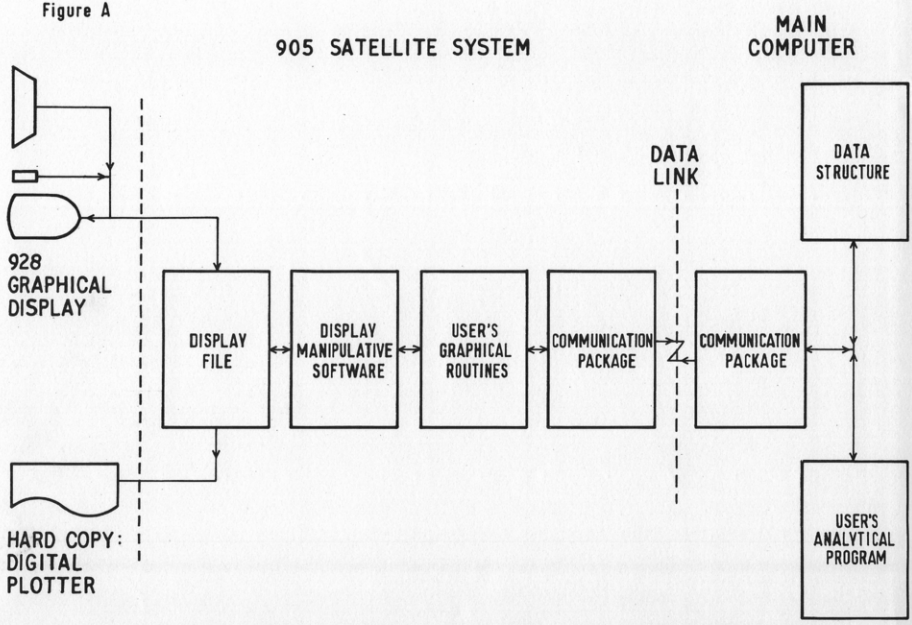
ARC (X1, Y1, X2, Y2, WAY);	Generate an arc from X1, Y1, to X2, Y2.
DELETE (N);	Delete item N from display file.
SUBPIC (N);	Enter Subroutine N.
PENTRAK (X, Y);	Sets X and Y to the current position of the tracking cross.

Similar instructions are available to the FORTRAN user via FRED 900.

The provision of graphical features in ALGOL and FORTRAN gives the user a very powerful high level programming system which has the advantages of ease of writing and ease of understanding by other users and establishments. Using EDGAR 900 and FRED 900 the Graphical Display can be programmed with almost the same ease as any other input or output peripheral, while maintaining the unique interactive capabilities that make the display such a flexible and powerful device.

Figure A



SOFTWARE SYSTEM FOR SATELLITE CONFIGURATION