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A SIMPLE DISPLAY UNIT FOR MINICOMPUTERS AND ITS APPLICATIONS

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ABSTRACT

This paper presents a result of implementation to improve the ability of a minicomputer by making use of a simple and extremely cheap interface and also its applications to such a field that is intended to increase the performance of data processing in the man-machine system. A 5-inch cathode-ray oscilloscope, the cheapest and most readily attainable one, is used for display and the displaying area can be divided into 256 by 256 bits, which are stored in 4 kilowords memory locations of core memory. This paper also describes the software system to support the hardware of the interface as well as the display system, which allows the users to apply this system to the field of education, one of the most adaptable fields of the computer applications.

1. Introduction

Minicomputers are widely used at present because of their low-cost, and a considerable amount of them are equipped in the laboratories as a tool for research and education uses. A basic system of minicomputer organizations can not necessarily be enlarged or improved as to the extent that most people will intend, partly because of the limitation of research expenses and partly because of the almost unexpandable characteristics of its structure. A display unit, though its usefulness is actually considered effective, is usually very expensive as a whole, especially, in case of a large-scale computer organization.

Considering from the fact, on the other hand, that minicomputers have a characteristic for the special-purpose use, and also have a role as a system element and, moreover, thinking about the feasibility of the man-machine communication system, then a display system, especially a simple and low-cost one, becomes indispensable for the machine to meet the various demands of computer users. Here

presents a simple, stable, and reliable display unit, designed and implemented by making use of the interface mechanism that is opened for the users to interconnect with the computer.

A HITAC-10 computer is used, where a simple characteristic technology is adopted so as to make an indefinite transfer of a part of the main memory area by using the direct memory access (DMA) mechanism and also reduces the loading of software in the central processing unit (CPU) during refreshing the data. Figures as well as characters or letters are all generated by software on the display in order to reduce the amount of hardware that will be used to support this system. The FORTRAN and BASIC languages are also used for this system.

2. Organization of the unit

2.1 System design

In the usual simple display system, two A/D converters are used for the X-and Y-axes, and in almost all cases a refreshing system is widely adopted, where the display file for the data of dot coordinates is read out by software. This technique has a limitation of 2,000 dots or so to ensure a suitable and comfortable display and, moreover, due to the fact that CPU is occupied during the refreshing time, dynamic or fast-changing displays can not be done very satisfactorily and, accordingly, the duty cycle of CPU will be reduced. On the other hand, when an exclusive memory unit is provided for the display, such drawbacks as stated above can be eliminated, but the devices will become larger and more expensive. Such a method that uses a storage-type cathode-ray tube is considered to be realized, where the difficulties also lie in the cost and uneasiness of using light-pen. In this system, however, a part of the main memory is used as a refresh memory, which, of course, is used as usual memory when the display is not under operation. Some problems may be raised upon such a system, since a part of the small capacity of main memory is lent for display. Nevertheless, from the fact that the information to be displayed and the related processing programs are stored together in the same memory, it is possible for the computer to make a tight combination between them, and thus to carry out an effective processing. Furthermore, the following are also provided:

(1) Dynamic internal state changes of any memory locations can be observed visually and dynamically on the display.

(2) Several switches (that will be described later) being provided for manual operation, a program pattern that is running within the memory can be seen by themselves instead of using machine instructions.

(3) Consequently, visual confirmation can be made directly of the dynamic allocation of memory, the memory area of current use, and so forth and thus be utilized for the analysis of programming.

The features of this unit are as follows:

(1) 2 (or 4) kilowords of the consecutive locations of main memory (of 20 kilowords) are used for a refresh memory.

(2) Implementation of a considerable amount of the control for display is left on the DMA transfer mechanism of CPU, so that a simple interface between CPU and the display is realized.

(3) As for display, the first (topmost) location is designated from the AC (accumulator) register, and only two instructions, Start and Stop, are required without any other software supports.

(4) Start and Stop mechanisms are provided by manual switches. Another one switch can alter any area of every 2 kilowords, which is operated independently of the instructions.

(5) Although the memory cycle is stolen once in eleven cycles, the remaining cycles are arbitrarily used, and thus it is possible for the users to execute the programs on the display and also to alter the pattern of them. In addition, the display can be presented even when CPU is stopped.

2.2 Organization and function

The cathode-ray oscilloscope used for the display is one of the cheapest which is partly used for maintenance, so that it has a small picture screen, and the number of dots is selected as 256 by 128 (or 256, if desired). 2 kilowords (1 word consists of 16 bits) can be switched by manual selector for display. Every bit of the 2 kilowords is so arranged as shown in Fig. 1 that 16 words (namely, 256 bits) are contained in every horizontal line, and 128 (or 256) lines are vertically arranged to form a rectangular (or square) area on the screen. The spot on the CRT screen corresponds physically one to one to the bit position in the 2-kiloword refresh memory. Accordingly, the spot will appear when the bit is one and it will disappear when zero. Namely, the brightness of the cathode-ray spot is controlled so that the spot may either appear or disappear according to one or zero of the bit, respectively.

The block diagram of the unit is depicted in Fig. 2. The Horizontal (X-axis)

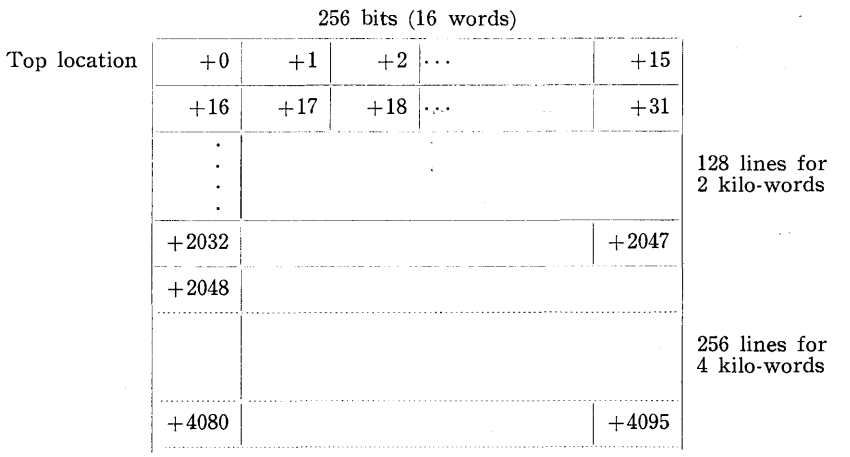

Fig. 1. Word allocation on the displayed surface.

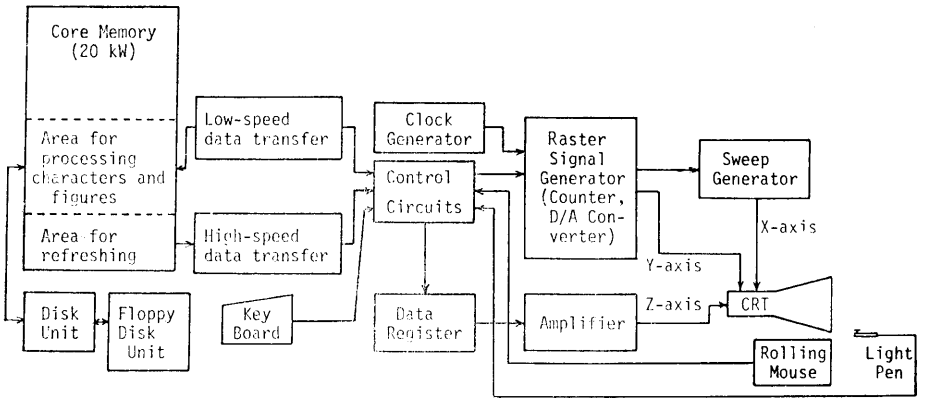

Fig. 2. Block diagram of the display unit.

and Vertical (Y-axis) Counters are serially advanced by one through the clocking signal of 1 MHz. The latter counter output is transferred to the corresponding D/A Converter to generate a series of raster control signals. Synchronizing with them, the contents of the predetermined locations of the refresh memory can be read out through the DMA transfer mechanism to be converted to generate the brightness (Z-axis) modulating signals.

A light pen, exclusively attached a key-board, and a rolling mouse (which generates the deflection voltages of X- and Y-axes by two variable resistors) are provided. Additionally, a mini-disk unit (some 35 kilowords), two floppy disk units are installed by means of the home-made interfaces to back up the less capacity of main memory.

Fig. 3 shows the construction of the main part of the display unit. Two instructions of Start (STRD) and Stop (STPD) are provided for the display. The former allows the topmost location number in the AC Register to set into the Top Address Register and to set the DISP.FF (Display Flip-Flop) on, through the output of which the gate for clock signals is opened, followed by the initiation of counting up the Horizontal and Vertical Position Counters, and then the raster control signals are generated. On the other hand, the contents of the Top Address Register are transferred to the Address Counter to carry out the fetch of words in the main memory through DMA mode. When the transfer of 2 (or 4) kilowords is completed, a carry signal is produced from the Vertical Position Counter and sets the contents of the Top Address Register to the Address Counter in order to repeat further the process indefinitely until the DISP.FF is set off by the Stop instruction. This indicates that the memory cycle is stolen once in 11 cycles, and the execution rate of instructions is reduced 8 per cent or so. Even when the computer is halted, however, the display is presented. The carry signals of the Vertical Position Counter can be picked up from the 7th or 8th bit position of it, by using the changeover switch, with which either 2- or 4-kiloword transfer is selected, respectively.

Moreover, three kinds of switches are provided: STR, STP, and CHN, as shown in Fig. 3. The STR switch sets the DISP.FF on, while the STP or GRES switch can reset it. (The GRES switch has been installed on the front panel of

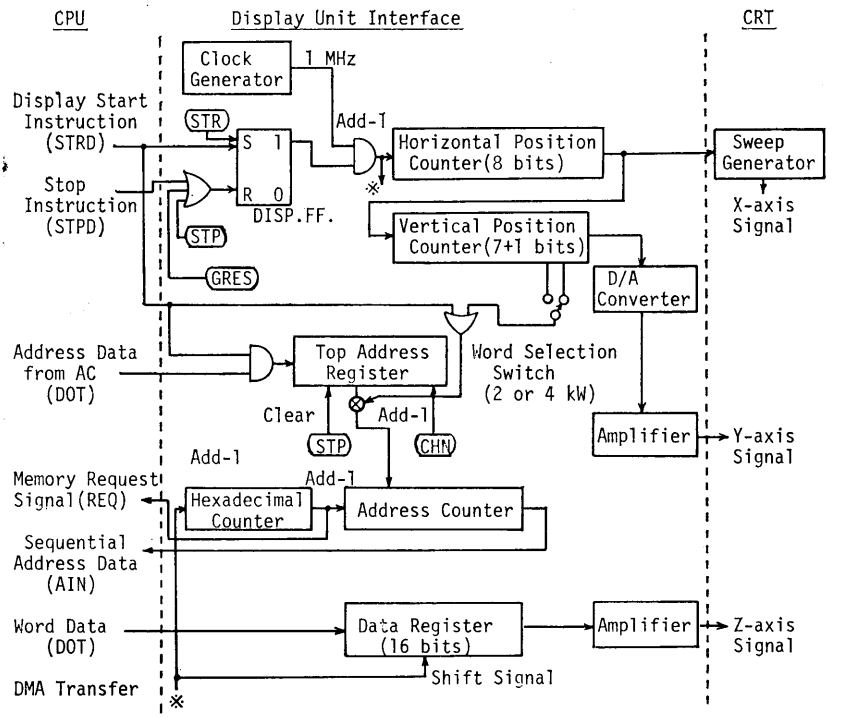

Fig. 3. Block diagram of the display unit interface.

Note: STR: Start Switch, STP: Stop Switch, CHN: Change Switch, and GRES: General Reset Switch on CPU Console.

the computer console.) Consequently, start and stop of presentation on the display unit can be manually operated without executing any instructions at any time. The STP switch, when depressed, also clears the contents of the Top Address Register, so that the contents commencing from the location 0 can be displayed when the STR switch is depressed. On the other hand, since the GRES switch, when depressed, does not clear the contents of the Top Address Register, the switch is used when the contents of the location previously designated in the Top Address Register are desired again to display. The CHN switch, when depressed, can add one to the contents of the Top Address Register at its 12th bit position; accordingly, the area to be displayed can be advanced every 2 kilowords. With the manual operation of such switches as stated above, another usage of display unit can be found in addition to the usual ones.

Next, with regard to the light pen device, five kinds of instructions are provided, as shown in Table 1. A buffer register of one word is prepared also for the light pen to fetch the X- and Y-position data of the raster control signals (that is, the contents of the Horizontal and Vertical Position Counters, respectively) at the moment when light is detected on the pen. These coordinate data are read into the AC Register by the RLP instruction, and then the control sequence is transferred to the software. The reason why this system has been adopted here

Table 1. Instructions and their functions concerning the light pen.

Instructions	Functions
SLP	The LP. FF (Light pen flip-flop) is set on.
KLP	Sense the FLAG and, if it is 1, skip the next instruction.
RLP	Transfer the content of the Buffer Register to the AC Register, and clear the FLAG.
RLPS	After executing RLP, carry out SLP instruction.
CLP	Clear the FLAG.

Note: When the light pen detects the light, the LP. FF is set off, and the FLAG is set one that causes an interruption to the computer. Then the contents of both the Horizontal and Vertical Counters at the moment are transferred to the Buffer Register after packing in one word.

is due to the fact that if the coordinate data are all to be fetched by the program only, spot scanning should be done; accordingly, the efficiency of the data processing will be extremely be reduced.

The key-board unit exclusively attached to the unit has the same key codes as the data typewriter already being used, except having additional 10 or more control keys, and also has four kinds of instructions prepared similarly for the typewriter.

Three groups of instructions described above have the same device number, and it should be considered that the system may be implemented with less hardware to result in the reduction of cost when a program has been prepared for the fully investigated software of high efficiency in order to support the units.

3. Software system

As described in the previous section, the hardware of the display unit has only a function of presenting the dot patterns of the contents in the specified memory area, so that the characters and/or figure patterns that are desired to display are generated only by the software. It actually includes various kinds of fundamental subroutines, utility routines for many different usages, and standardized displaying package programs (DSP) used for the application of this system to such languages as Assembly, FORTRAN, and so forth. These are all under the supervision of a DOS of disk or floppy disk base with a feasible consideration to use them.

3.1 Fundamental subroutines

Two kinds of subroutines are prepared for the character presentation and 13 subroutines for the figure, as shown in Table 2, together with some explanations of their functions.

Table 2. Fundamental subroutines.

Name	Number of words	Functions
For figure use		
CLEA	14	Clear all of the refresh area.
RVRS	16	Invert zeros and ones in the refresh area.
SPOT	39	Set the designated coordinate (X, Y) to one.
ERAS	41	Set the designated coordinate (X, Y) to zero.
SRCH	26	Test if the designated coordinate is one or zero.
GRAF	165	Connect between two points with either solid or dotted line. The starting point should first be specified.
FRAM	36	Designate two coordinates for each one of the X-and Y-axes and clear the inside area of the frame formed out of two X-axis and two Y-axis lines.
AXIS	84	Write the X-, Y-axes, and scales.
SCRN	63	Keep the memory capacity for three times the displaying area in the disk unit as the original area, and execute Load and Store instructions.
MARK	40	Write a mark (such as +) at the designated coordinate.
RVLU	193	Rotate the figure by the designated angle at the center of the specified coordinate.
SCAL	149	Carry out an enlargement or contraction at the center of the specified coordinate.
SLID	84	Make parallel translation to both X and Y directions.
For character use		
LETR	266	Write the specified characters by the given parameters of three kinds: position, number of characters, and character codes.
DISP	129	Display the designated number of characters in a line from the leftmost end of the displaying area and feed a line. If the displaying area is in full of characters, the system will once be halted.

Note: Some subroutines are used in combination with others, although the combinations will here be omitted. The number of words described in the second column does not contain the number of words associated with it. The RVLU subroutine is required beforehand to build in the FAP (Floating-point arithmetic package) before using it.

3.2 Utility routine

(1) Editor routine (EDIT): The characters on the display unit are put in the computer by the cursor control, and the compiling functions of 13 kinds are provided with the function keys on the key-board. It is feasible to take in a program of up to 512 lines, to erase a part of it, and to insert characters in it, where successive every 13 lines of a program are displayed. This system adopts a method that carries out the alteration of the input programs through visual confirmation, while shifting the displayed lines of information. The system also provides the facilities of (1) registration or read-out of file to or from the disk, respectively, (2) read-in

or print-out of progams from or to the paper tape, and (3) linkage with the Assembler or FORTRAN Compiler in order to translate directly the filed programs. As soon as the translation is completed, it can be executed automatically. Up to two files of programs in the disk unit can selectively be executed with key operations. After execution of a program, the alteration, modification, translation, and execution can be repeated of the programs in the file that are preserved on the disk, if necessary to make an access to the Editor. This filed program can also be registered to the floppy disk unit through the CATALOG function which will be described later. Further, this Editor can also be used even while executing the CATALOGed program. This Editor routine allows the handling amount of paper tape to decrease and the utility efficiency of computers to increase, especially in case of the FORTRAN language.

(2) Memory dump routine: This is classified into two kinds and used for representing the memory locations and their contents in either hexadecimal or instruction format on the display unit, in order to facilitate the program debugging.

(3) Tracer routine: Two kinds of tracers are prepared. The first is such that the typewriter-oriented output is converted to the one for display unit, where the traced results are presented as a pattern composed of seven instructions on a displaying area. Using four kinds of commands, the tracing area and trace instructions can be specified and an address stop function is also provided. When the displaying area is full of information, the Tracer is once halted, and if the start key is depressed, the displayed information is eliminated in order to continue to display the information commencing from the next instruction. The other one is prepared for beginners' use, where the instruction, the effective address, and the contents of various registers are presented pictorially, and, further, has the function of displaying them in the hexadecimal, decimal integral, or decimal fractional format at the same time, for the individual instructions.

(4) Output routine: This is prepared for the character use by the subroutine, DISP, and provides the display of character data moved leftmost in the same way as the case of printing paper on a typewriter. When the displaying area is full of information, the routine is once halted. When the start key is depressed, the displayed information is eliminated in order to continue to display it again from the first line. This routine facilitates the confirmation of solutions and the observation of the program states after considerable steps of them have passed.

The above (2), (3), and (4) are all used in case when a hard copy is not required, thus complementing the low-speed of typewriters.

3.3 Display package

(1) Display package for Assembler (DSP): This is a packaging of the fundamental subroutines stated in Section 3.1. When this usage is specified in DOS, it will automatically be read out from the system file. The names of subroutines being registered in the Assembler as macro-instructions, it can be used in the same way as in the floating-point arithmetic package (FAP). Further such a function as mutual logic operations between two or more displaying areas is also provided. This package has a size of 1 kilowords as a whole and is stored in the locations from the address $(1800)_{16}$. (See Fig. 4.)

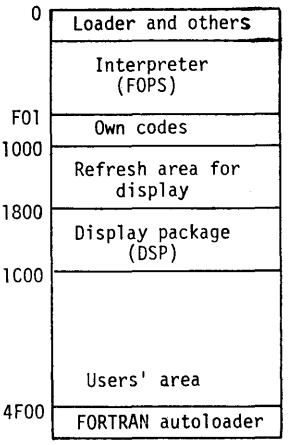

Fig. 4. Memory map of FORTRAN in execution.

(2) Display package for FORTRAN: When a display unit is prepared for the FORTRAN language to be used, it allows the users to reduce the burden on programming, and thus makes an efficient use of computers. In the HITAC-10, where a FORTRAN compiler is given which can be executed in the interpreter type of Level JIS3000, such a function that links it with the closed subroutines of the Assembly language has been prepared (that is, own-code function).

When the name of subroutines, program areas, and the number of parameters are defined by the DEFINE statement at the top of the FORTRAN programs, they can be read out with a LINK statement. This corresponds to the same fuction that can read out the subroutine's subprogram by a CALL statement. By making use of this, own-coding is performed (which is a sort of reserving an area for the locations to assign the FORTRAN variables at the top of the subroutines) by adding a little program to the DSP that is described in (1). This FORTRAN compiler requires three kinds of system loads that comprise two kinds of translation processing (FTR1 and FTR2) and an interpreter processing (FOPS) in case of execution, so that an autoloader (FORT) has been generated to carry out the processing continuously by making use of the disk. Here the list of the DEFINE statements for display unit, as shown below, is registered in the compiler FTR1, and the above own-codes and the DSP as well as the interpreter FOPS are read out at the same time, so the display unit can be arranged to use without any special manipulations. The users can compose their programs only by assigning the name of subroutines and the actual parameters to the LINK statements. The following are the list of the DEFINE statements being used:

```
DEFINE LETR (X"0F76", X"0002", X"1C00")
DEFINE DBGN (X"0F0C", X"0000", X"0F10")
DEFINE DEND (X"0F10", X"0000", X"0F13")
DEFINE CLEA (X"0F13", X"0000", X"0F16")
DEFINE RVRS (X"0F16", X"0000", X"0F19")
```

```
DEFINE SPOT (X"0F19", X"0002", X"0F20")
DEFINE ERAS (X"0F20", X"0002", X"0F27")
DEFINE GRAF (X"0F27", X"0003", X"0F32")
DEFINE MARK (X"0F32", X"0002", X"0F39")
DEFINE SRCH (X"0F39", X"0003", X"0F47")
DEFINE FRAM (X"0F5A", X"0004", X"0F6D")
DEFINE AXIS (X"0F47", X"0004", X"0F5A")
DEFINE SCRN (X"0F6D", X"0002", X"0F76")
```

Two coordinate data are required to be given as the parameters of the above subroutines such as SPOT, ERAS, MARK, and LETR, and as to the GRAF the data for the starting point, solid line, and dotted line are also necessary to add to the above coordinate data. Four data of the origin coordinate and the corresponding unit-scale separation (width) should be given to the AXIS, while the data of the number of picture areas and either read-out or write-in, to the SCRN. To the LETR, only the starting coordinate of the letter is given. Letters themselves are given by the list of the WRITE statements of device number 5 and the corresponding FORMAT statements, which differ from the WRITE statements of device number 3 only in that the letter outputs are displayed at the leftmost position of the picture area. The function of the FORMAT statement is available in both cases of device numbers 3 and 5; accordingly, the output of numeric values and characters can readily be specified, where the page control function is replaced with the function of clearing the picture area.

The memory map at the execution time is depicted in Fig. 4, which shows that 3,300 words or so including the refresh area of the main memory are occupied for the display.

As described above, the function of this display package is designed so as to take into account the standardization and easy usage, while it is possible to add the corresponding subroutines after own-coding to the package, when such a function as rotation, enlargement, reduction, or translation of figures, or the usage of light pen is required to use.

3.4 Organization of the Disk Operating System

Fig. 5 gives the organization of the programs under the supervision of the Disk Operating System (DOS). As seen from the figure, 8 kinds of commands can facilitate to fetch the corresponding programs from the system file to the main memory, which are then either automatically executed or stayed in the state of waiting for the next command. When combining the command inputs, such a state corresponding to the specified application can be built in on the main memory.

The feature of this system is as follows: Considering from the role of minicomputers to be used by multiple users with different objects, only the control program is located in the disk unit which has an unexchangeable storage, and the others including the system program are all stored in the two sheets of media (diskette) of the respective floppy disk units, the contents of which this system depends on. Namely, when a medium is exchanged, the system organization will be altered through the medium.

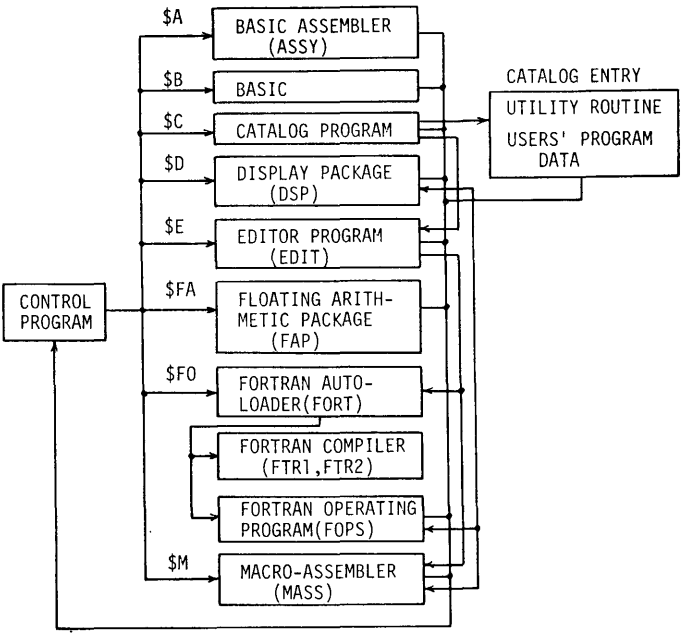

Fig. 5. Organization of the program under the supervision of DOS.

Usually two media are prepared for the standard usage, where 26 tracks (2 kW/track, 74 tracks/medium) are allocated to the system programs, and 18 tracks to the utility programs. The disk unit is also used for working area, and thus the system is organized as shown in Fig. 5. When some users want to use the system or utility programs in a different state from the standard one, if the programs are altered on occasion and are registered in their own media, they can be operated as their own system of exclusive use. When, in this case, the CATALOG program is used to register the user's program and the required utility routines for use by the name of 4 characters, those CATALOGed programs can be used on occasion through read-out from the media. Moreover, in this case, if the system program area is copied by the standard one itself on the user's own medium, the remaining 48 tracks are left to use freely. Further if the other medium can be used, 122 tracks are to be left for the users.

Registration by the CATALOG program is carried out in such a way that a name of 4 characters is labeled to the contents of the paper tape, the specified area of the main memory, or the disk which have been filed by the above mentioned Editor. At this time the form of the file should be registered to be able to read out it distinguished according to its from. Therefore, its form might be any one of the binary, standard loader, and character formats.

This system adopts a way of depending on the media, as described above, so that the processing speed is considered to be reduced in this case compared with the one when the DOS is throughly based on the disk unit only. It should be noted, however, that while processing a job, it will be controlled only a few times

by the DOS itself, and the processing efficiency will be improved when the disk unit of fairly higher speed is released for the working area during the program execution.

4. Application of the display unit

It has been recognized from the previous description that the function of the display unit aimed at as one of the output units of computers has been first accomplished. Whereas, the following subroutines of fundamental functions are prepared for the light pen and rolling mouse to put in the figures; that is, the ones for the designation of coodinate by spot-scanning, picking up the coordinate by means of matrix-like fixed-points or a light button, and so forth. But because of the narrower picture area and the smaller number of dots within it, the use of the light pen is restricted to such simple cases as composing character patterns, designating the selection of parameters and/or programs, putting in free-handed figures or letters, or gaming. In other words, it should be noted that such a small device as this is considered suitable to be used mainly for the output unit.

As for the application of this system, it will be carried out by means of the utility routines already stated, whereas here presents the general discussion on the application of it from the overall performance point of view of minicomputers. Although this display unit, having a small size of picture area, is limited to be observed by two or three persons at a time, some facilities are provided to connect several similar oscilloscopes in parallel in case of many persons with simply sharing the loads. Additionally, it is possible to enlarge the small-size of the displayed picture through ITV camera in order to get an improved image on a large-scale monitor TV. Furthermore, if necessary, the picture on the display can be recorded in VTR to reproduce it, whenever desired to make an access to it. This presents a possibility of useful applications, one of which, for instance, provides a method of utilizing the display unit to various kinds of educations in the classrooms fully installed with monitor TVs by the aid of VTR. This system will become more effective, if more different kinds of tape libraries are prepared for through backing up of computers.

One useful application of this system is to use it as a temporary output of the computer when a hard copy is not required for the moment. Namely, if the displayed output is recorded first on a video-tape through ITV camera to reproduce it afterwards by the slow reproducing mechanism of VTR, the biggest drawback of a minicomputer having low-speed outputs, say, typewriter, can be completely complemented and further the savings of noise and printing paper are effectively attained. The producing speed of letters is, say 160 characters per second when programmed by the FORTRAN language.

Presently, this system is widely used for the subjects such as character recognition or spoken voice recognition, or the similar and the education of programming. Especially in the latter case, this system is expanded and modified to meet the usage in a classroom installed with monitor TVs, in a remote mode from the computer located some 300 meters apart from it, and is used for teaching the As-

sembly programming and its practice which has resulted in a great effect on understanding how to make programs. For the moment the system is arranged such that only a teacher can control the usage of it and the others see the identical displayed picture on the monitor TVs. Now a modification is carrying out to be able to use it in parallel by multiple persons, so that every routine within the system is being rewritten to be a re-entrant or serial re-usable type.

5. Conclusions

The display unit has recently been high-graded as an intelligent terminal with various kinds of functions, whereas it should be noted that a low-cost display unit that can readily be used is also keenly desired by most minicomputer users.

The interface part of the display unit implemented here costs only a few tens of thousands yen, where, if combined with a simple oscilloscope, it becomes possible to generate any characters or figures with support of software. If the interface cards specially prepared could be installed inside the main part of the minicomputer, no other signal cables are required for the signals to connect the display unit to the computer. It is rather desired to make such minicomputers that the terminals

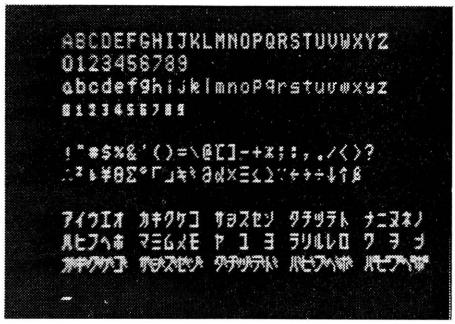

Fig. 6. Input characters by cursor control.

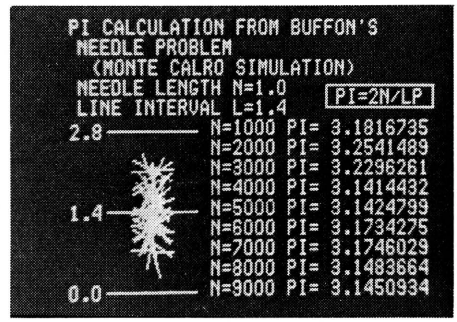

Fig. 7. Output example (FORTRAN program).

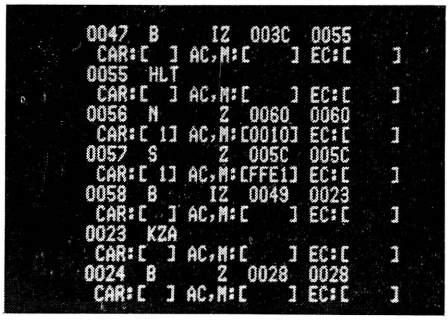

Fig. 8. Output example (Tracer routine).

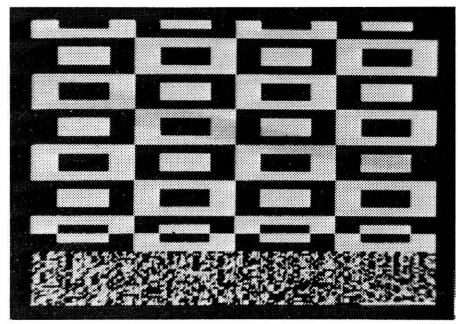

Fig. 9. Core memory pattern under checking by the worst pattern test program.

for the Y- and Z-axes and for synchronization as well as the manual switches are provided for the display. The FORTRAN language can be used even in a minicomputer having a capacity of 8 kilowords as its main memory. If the memory capacity is increased by adding disk or drum units, the range of applications will widely be expanded.

The display unit has its adaptability to the usage for education as well as for investigation in universities, whereas its practical use is not necessarily accomplished partly because of its fairly high cost. Considering a merit of the visual feature of the display, this simple and low-cost system is believed to have given a necessary and useful tool to the users of minicomputers when harmonized between their functions. Some examples of the displayed characters and figures are shown in Figs. 6 through 9.

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