The Type 339 Programmed Buffered Display is a precise and extremely powerful incremental cathode ray tube display option for PDP-9 general purpose computer systems.

Designed to operate from command files generated by the PDP-9 and stored in the memory shared by the PDP-9 and the display, the Type 339 can rapidly convert digital data into graphic or tabular form, draw vectors or characters, expand or contract its picture size, and respond to external commands to modify or change the information being displayed.

The Type 339 features multiple modes of operation, fast point and vector plotting, multiple scale and intensity levels, and automatic scissoring. It is provided with a light pen and a push-button function box as standard accessories, and its options includes a character generator, automatic search logic, zoom logic, and a slave mode that can accommodate up to six slave scopes.

THE PDP-9/339 SYSTEM

The Type 339 Programmed Buffered Display interfaces to the PDP-9 general purpose computer through the optional Direct Memory Access Channel Multiplexer Adapter, Type DM09A. The result is a true multi-processor system in which both the display processor and the computer's central processor operate out of the same core memory on a time-shared basis.

The direct memory access channel (DMA) interface allows the Type 339 to operate from the PDP-9 memory, obtaining its instructions on a true cycle-stealing basis while allowing the PDP-9 to process a completely separate program. The PDP-9 can quickly interrupt this program, when necessary, to service real-time interrupts generated by the operator, the display, or other external devices. The use of a common memory for the display and the PDP-9 allows the computer to quickly update the display files with a minimum of communication problems.
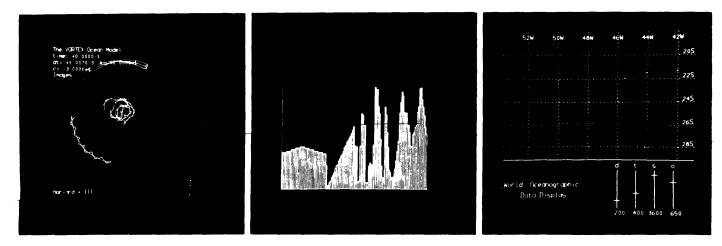
The PDP-9 can be used as a general purpose computer completely independent of the Type 339 display. The PDP-9 features a non-volatile, 8,192 word, 18-bit word length, random access core memory with a 1.0 microsecond cycle time and a 2.0 microsecond addition time. Standard input/output devices include a 300 character-per-second paper tape reader, a 50 character-per-second paper tape punch, a 10 character-per-second console teleprinter, and a real-time clock. Memory can be expanded in 8,192 word increments (to a total of 32,768 words), while central processor options in-

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clude high speed multiply/divide, a multi-level automatic priority interrupt system, memory protection, parity, and a power-fail option. PDP-9 peripherals include magnetic tape systems, drums, disks, card readers, line printers, analog-to-digital and digital-to-analog converters, communications equipment, and interfaces to other computers. The PDP-9 ADVANCED software system includes a FORTRAN IV compiler, a macro assembler, two complete monitor systems, an editor, a debugging system, and a peripheral interchange program. Comprehensive diagnostic routines are supplied for the PDP-9 and all standard peripherals and central processor options.

As a result, the PDP-9/339 system is equally at home as a powerful stand-alone display system or as an extremely versatile buffered display terminal, connected to a larger computer system via dataphone or direct channels. Its applications include automated design, information retrieval and processing, computer-aided instruction, and research into the problems of man/machine communication.

PDP/ 339 DISPLAY EXAMPLES

FEATURES

Precision -- The Type 339 magnetic deflection and focusing system insures precise data conversion and uniform spot repeatability. Spot location stability is ±0.05 inches over an eight-hour period within an ambient temperature range of ±3°F. Spot size is approximately 0.015 inches.

Fast Point Plotting -- The Type 339 display accepts digital data from the PDP-9 memory in the form of commands and scope face locations (there are 1024 x 1024 points on the 9-3/8-inch square display area). Discrete points can be plotted at the rate of one every 46 microseconds in point mode or every 40 microseconds in graph-plotting mode. If the sequence of points lies near one another, the plotting rate can be increased to about 20 microseconds per point (14 microseconds/point in graph-plot mode). In other modes, the plotting rate is 1.1 microseconds per intersified point. Non-intensified points can be plotted at a rate of 300 nanoseconds each.

Multiple Modes and Instructions -- The user has seven data state modes to use in plotting points, straights lines curves, and characters. These include an increment mode, vector mode, vector continue mode, short vector mode, point mode, graph-point mode, and character mode. The Type 339 also features eleven control state instructions.

Multiple Scale and Uniform Intensity Levels -- The Type 339 offers the user four scale factors (in all modes except point mode). Two flip-flops are provided to control the scale factors of X1, X2, X4, and X8. Intensity modulation is eliminated, and line intensity remains constant, regardless of the length of the line, because the Type 339 constructs lines from a series of discrete points rather than drawing them in an analog fashion. Three intensity flip-flops control the intensity of the picture and allow eight distinct intensity levels that can be used in all modes.

Data Acquisition by Cycle-Stealing -- The Type 339 display receives its data and control instructions from the PDP-9 memory through the direct memory access channel and its optional multiplexer adapter. This channel provides a high-speed (1.0 microsecond per word) direct access to memory that can relay information to the display processor while a separate computer program is being executed.

Automatic Scissoring -- The Type 339 can be programmed to construct drawings up to 75" by 75" in size, although only one section (9-3/8" by 9-3/8") can be displayed at any one time. The automatic scissoring feature of the Type 339 allows the user to quickly move to other portions of the larger picture and display them.

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Simplified Programming -- The all-new PDP-9 AD-VANCED software system greatly simplifies the programming task for many applications. The FORTRAN IV compiler and MACRO-9 assembler provide two powerful, convenient, and extremely versatile programming languages. Utility programs such as the editor, debugging system (DDT-9), and peripheral interchange program (PIP-9) simplify the programmer's housekeeping and debugging tasks, while the two monitor systems (the I/O Monitor and the more powerful Keyboard Monitor) free the user from the problems of I/O programming and allow him to run the same programs on basic PDP-9's or expanded systems which include bulk storage devices.

Easy Man/Machine Interaction -- The Type 339 standard input features--the light pen and push-button control box--provide the user with versatile means of communicating with the display system. The light pen allows the operator to "point" to a particular portion of the display and indicate that a change is desired. With tracking subroutines, the light pen can be used to "draw" lines and figures.

The push-button control box also provides a simple means of communication with the system. It features twelve push-buttons, in two banks of six buttons each, a manual reset button for each bank, and a manual interrupt button that can be used to cause a PDP-9 program interrupt.

Depressing a button complements an associated flip-flop. These flip-flops can be sensed by the display processor, using control state skip instructions, and by the computer, which can read the status of the push-buttons into the accumulator. The computer can also clear and load these flip-flops from its accumulator.

Other I/O devices, such as special keyboards and Rand Tablets, may also be interfaced to the PDP-9.

PROGRAMMING THE TYPE 339

The Type 339 display executes instructions contained in lists (groups of consecutive locations) in the PDP-9's memory. These instructions, which are usually created by PDP-9 programs, occupy twelve bits of an 18-bit PDP-9 word and are right-justified within the word. (The programmer is free to use the left-hand six bits of PDP-9/339 instructions as tags and indicators.)

Once a list of Type 339 instructions is created by the PDP-9 or loaded into memory from an external source, the PDP-9 supplies the starting address of the list to the display address counter, and commands the display to begin. At this point the PDP-9 is free to execute a completely separate program, pausing only to service interrupts caused by the display, light pen, push-button control box, or an external source.

Display programs may consist of continuous loops of instructions or chains comprising several widely-scattered lists. In both cases, the displays are kept running continuously by the use of "jump" or "jump to subroutine" instructions which can be used to direct the display processor to proceed to the next list or return to the beginning of the current list. "Skip" instructions, which cause the display processor to sense conditions and branch to different programs if the conditions are met, are used by the Type 339 to increase its power and versatility.

Display States -- Type 339 display instructions are fetched, in one cycle, from the PDP-9 memory and presented to the display processor for execution. When the processor finishes a Type 339 instruction, it returns to the PDP-9 memory for the next instruction (or, in the case of "jump" instructions, to the address indicated by the "jump".) The Type 339 display processor operates in two states: control state and data state.

In control state, the 12-bit display words are interpreted as instructions to the display logic. These control instructions can be used to set parameters and modes, or they can cause the display processor to jump to another instruction list location, jump to a subroutine, or skip on a processor flag.

Data state instructions are used to position and move the deflection amplifiers controlling the position and movement of the CRT "spot". Data state instructions can also increment the x or y positions of the beam, draw vectors, plot graphs, or (optionally) draw characters. Each data state instruction also contains an "escape" bit which, when set, causes the processor to return to control state and interpret the next instruction accordingly.

Control State Instructions -- Control state instructions include SET PARAMETER, SET MODE, JUMP, POP, CONDITIONAL SKIP, SKIP ON FLAG, and COUNT. "Jump" instructions occupy two consecutive 12-bit words, allowing three bits for the operations code (JUMP), six for special indicators, and fifteen to describe the address to which the display processor should "jump". The 15-bit address permits a jump to any location in a 32,768-word PDP-9 memory.

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To enter and exit display subroutines, nested to any level, "push-jump" and "pop" instructions are provided. "Push-jump" (a variation of the "jump" instruction) causes the current state of the display--light pen enable, mode, scale, and intensity level--to be stored, along with the return address of the subroutine, in two consecutive locations in a push-down list in the lowest 4K of PDP-9 memory. The next locations to be used for storage by a "push-jump" instruction are determined by a hardware pointer in the Type 339 logic; this pointer is set initially by a PDP-9 IOT instruction.

To exit from a subroutine, a "pop" instruction is executed. A "pop" instruction contains no address; its execution causes the most recent word-pair to be fetched from the push-down list and the display to be returned to the state described by it. The hardware pointer is incremented by two for each "push-jump" instruction executed and decremented a like amount for each "pop".

The "set parameter" instruction can be used to change the scale, light pen, and intensity registers. It can be microprogrammed to provide any or all of these functions in a single instruction. The "set mode" instruction has six distinct functions: to stop the display, clear the push-button flags, set the mode register, clear the sector bits, clear coordinates bits, or enter the data state.

"Conditional skip", "skip on flags", and "arithmetic compare" instructions provide several methods of testing the states of the control box push-buttons. "Count" instructions allow the scale and intensity registers to be incremented or decremented.

Data State Instructions -- Data state instructions are of the "incrementing" variety; they cause the beam to move by incrementing or decrementing the x and y position registers. This counting is done at a rate of 1.1 microseconds per intensified point and 0.3 microseconds per non-intensified point.

Increment mode is used to draw curves, alphanumeric characters, and small symbols. One 12-bit word can contain two increment mode instructions; each instruction can step the beam position one, two, or three counts in any one of eight directions.

Vector mode is used to draw straight-line segments. A two-word instruction (24 bits) causes the beam to be moved from its current position $(x, y,)$ to a new position $(x \pm \Delta x, y \pm \Delta y)$. The instruction contains Δx and Δy as signed 10-bit numbers.

Vector continue mode is used to draw a straight line to the edge of the screen. It is similar to vector mode except that it causes the vector to be extended until an "edge" condition is encountered. An "edge" condition or "edge" violation is defined as the overflow or underflow of either the x or y position registers. As initial conditions, these registers may be specified to be 10, 11, 12, or 13 bits in length.

Short vector mode is similar to vector mode except that it occupies one word (12 bits) and operates on 4-bit increments.

Point mode is used for random point plotting. A two-word (24-bit) instruction, it causes new x and/or y coordinates to be set into the x and y position registers. The x and y coordinates it provides are 10-bit numbers.

Graph-plot mode is used to draw curves of mathematical functions. It utilizes a one-word (12-bit) instruction to change either the x or y coordinate at the same time that it advances the other coordinate by a count of one, two, four, or eight (depending upon the current scale factor).

Character mode is associated with the optional character generator, Type VC38. It uses a single 12-bit instruction to plot two characters.

OTHER FEATURES

Automatic Scissoring -- The x and y registers of the Type 339 display are 13 bits each, representing a 75" by 75" surface. The low-order ten bits of each register are used to determine the beam position on the 9-3/8" by 9-3/8" square matrix that defines the viewing area (1024 by 1024 points). The high-order three bits of each register are called "sector bits", and beam intensification can occur only when these sector bits are set to zero. Both the x and y registers are wrap-around, i.e. $(2^{13} - 1) + 1 = 0$.

By using more bits than are necessary to cover the viewing area, the user may construct much larger drawings. Although only a small segment (1/64th) of the total possible picture area can be viewed at any one time, a simple method exists for "shifting" the drawing horizontally and/or vertically to allow viewing of any desired section.

This method, called automatic scissoring, operates as follows:

- The picture is constructed using modes other than point mode and graph-plot mode. (Although this restriction may be ignored in some special cases, it is generally necessary if scissoring is to be used.) This creates the entire picture in "relative space" without tying it to one specific set of coordinates.

- The picture must be drawn as a "closed figure", i.e., an invisible vector is drawn from the end point to the starting point of the drawing.

At the end of the display file, before a "jump" back to the start of the display file can be executed, the instructions to effect the horizontal and/or vertical shifting of the picture should be inserted. These should be separated from the main body of the display file by push-button "skip" instructions which can determine, from the states of the push-buttons, if the shifting instructions should be executed.

The actual shifting instructions are invisible (non-intensified) short vectors in the direction that the picture should be shifted relative to the viewing area (or in the opposite direction to that in which the viewing area should be moved). Vector instructions in more than one direction may be included, and several "skips" may be used to test both direction and amount of shifting desired

Finally, after all the push-button "skip" instructions and invisible vector instructions, a "jump" back to the start of the display file should be executed.

Since the total picture to be drawn is plotted in "relative space", and drawn as a closed figure, the execution of any vectors or short vectors after the figure has been closed will move the picture relative to the viewing area and allow other portions to be shown. Continual execution of the "shifting" vectors will cause the picture to rotate past the viewing area, so that push-buttons should be turned off when the picture reaches the desired position.

In this technique, all "shifting" instructions are part of the display file, but they are executed only when the proper push-buttons are "on". This provides an "automatic" method of shifting which has many advantages over subroutines designed to accomplish the same effect. When coupled with the Zoom Option (see figure below), this provides the user with the ability to view the overall picture, expand it, and move to any point on the 75" by 75" drawing.
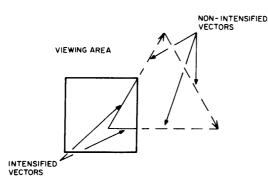

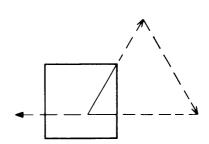
FIGURE 1a : ORIGINAL PICTURE WITH PUSHBUTTON OFF

FIGURE 1b : ORIGINAL PICTURE WITH PUSHBUTTON ON, BEFORE PICTURE SHIFTS
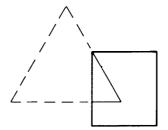

FIGURE 1c : SHIFTED PICTURE

Character Generation -- The basic Type 339 display can use subroutines to draw characters, with a series of increment mode, short vector mode, or vector mode instructions required for each character. With the optional Character Generator, Type VC38, the task of drawing characters can be speeded up and greatly simplified. The Type VC38, when installed, uses character mode to draw alphanumeric characters on a 5 by 7 dot matrix. Special characters may extend outside this matrix.

Characters are contained in character mode instruction words and used to locate the appropriate word in a dispatch table in memory. The words in the dispatch table control the operation of the character generator. Two modes are possible: in 6-bit mode, two characters are packed in one 12-bit character mode instruction, while in 7-bit mode, one character is stored per word. The 7-bit mode allows 128-character sets to be used. Because the characters are stored in memory, any charac-

ter set may be designed and executed, or mixed character sets may be employed. No restrictions exist as to types of characters, fonts or sizes employed, or the frequency of change of the character set.

A typical alphanumeric character can be drawn in 40-50 microseconds, depending upon the complexity of the character and the ratio of intensified to non-intensified increments needed to describe it (intensified steps take 1.1 microseconds each, while non-intensified steps are 0.3 microseconds). Control characters take 8-10 microseconds; a carriage return (set x register = 0) takes approximately 40 microseconds.

Slave Mode (Optional) -- The Slave Mode, Type VS38, allows up to seven display surfaces to be used with one Type 339 display processor. All surfaces can receive the same information, all may receive different information, or any combination may receive the same information. Slave Scopes, Type 343, are used as the additional display surfaces, and the routing of information to the proper slave scopes is done by control mode display file instructions. Each slave scope may have its own light pen, but only one push-button box can be provided with a Type 339 display system.

Search Logic (Optional) -- The Search Logic Option, Type VF38, can be used to search display files for increment mode and/or vector mode instructions. This option is useful when such instructions must be found quickly so they can be modified.

The operator requests search mode by having the PDP-9 issue an IOT instruction to the display. The state of PDP-9 accumulator bits 0 and 1 determines which instructions are sought (AC0: increment mode, AC1: vector, short vector, and vector continue modes). The display will halt and request a program interrupt when a display file word in the selected mode is read into the display input register. A "pop" instruction will also cause the display to halt, but "push-jump" instructions are ignored by search mode.

PDP-9 "skip" instructions can be used to determine whether an instruction of the desired mode or a "pop" instruction has been encountered. A "resume" instruction will cause the display file to proceed with its execution until the next item of interest is encountered.

Zoom Mode (Optional) -- The Zoom Option, Type VZ-38, allows the operator, by manual switch operation, to view the entire 75" by 75" drawing compressed to fit on the 9-3/8" by 9-3/8" display surface.

In nominal mode, the low-order ten bits of the 13-bit position registers control beam position; in zoom mode, the uppermost ten bits control beam position.

Other Options -- Type 339 display systems may also include any standard PDP-9 option. Complete lists of these options may be found in PDP-9 Price Lists and in the PDP-9 User Handbook (F-95).

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