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A HIGH PERFORMANCE PROGRAMMED REMOTE DISPLAY TERMINAL*

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Introduction

This paper does not herald a new breakthrough in the art of computer graphics. Instead, it presents our effort in utilizing the existing technology to fabricate a display terminal with high performance characteristics and reasonable flexibility.

We started with several requirements for a display:

1. Remote terminal. The display must be capable of operating remotely from the main computers.

2. Display buffer. Both for text editing and image modification, we have found it necessary to be able to modify the image within very short periods of time; and storage tube display terminals requiring long erase time and slow vector drawing rate were unsatisfactory. Using regenerative displays one can modify the image within 30 ms. However, the number of vectors that one can display flicker free on such a display are a function of the size of the display buffer and the vector drawing rate. We found it desirable to have a display capable of displaying 3,000 to 4,000 characters flicker free or about the same number of vectors of 1 to 2 inches long.

3. Display processor. Our experience, and that of others, has shown specialized display processors without general purpose computing abilities sooner or later run into limitations which require the intervention of the main computer. This has led us to the use of a minicomputer (PDP-11) in conjunction with a specially designed display processor.

4. Arbitrary character set. Most terminals predetermine the character set to a single fixed one. We have found this to be a most constraining aspect of display terminals. Not only would we like a large character set, but also a user definable character set which can be changed under program control.

5. High-speed communications. A main disadvantage of remote display terminals is that they are often limited to a maximum of 1200 bps telephone lines, which proves to be the main bottleneck in the efficient use of high performance display terminals.

6. Expandibility. The bus structure of the system must make it possible to add other devices, such as a light pen, tablet, or a mouse without much difficulty.

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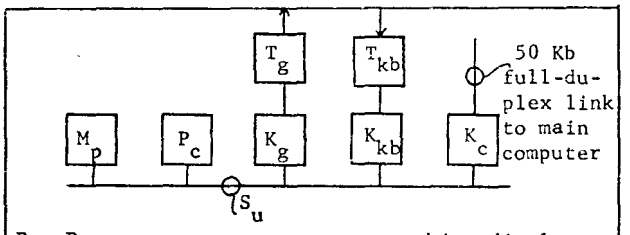
7. The cost should be less than $10,000.

A survey showed that only two terminals were even close to the above requirements: one was the storage tube, and the second was the programmed computer display terminal. The storage tube displays have a fixed character set and a slow vector drawing rate. The programmed terminal with its own CPU and display buffer was more suitable, but the main limitations were speed, fixed character set, and limited architecture of the processor.

The Display Terminal

The display terminal consists of a modified PDP-11 processor and a VT04 display terminal, both of which are manufactured by Digital Equipment Corporation, and a MICROSWITCH keyboard designed by the Stanford Artificial Intelligence project, permitting a total of 1024 different combinations of input characters (10 bits). In the normal mode of operation, two of these bits are used as control keys, permitting a total of 256 different characters to be represented. The PMS diagram for the modified PDP-11 with display controller is given below:



Processor

The display processor has several registers which are program addressable. These are:

Control Status Register	/CSR <15:0>
Control Status Auxiliary Register	/CSAR <15:0>
X Position Register	/XR <9:0>
Y Position Register	/YR <9:0>
Vector Buffer Register	/VBR <15:0>
Vector Pointer Register	/VPTR <15:0>
Interrupt Status Register	/STAT <15:0>
Character Buffer Register	/CBR <15:0>
Character Pointer Register	/CPTR <15:0>
Dispatch Table Pointer Register	/DTPTR <15:0>

In addition to the above Unibus addressable registers there are six internal registers as follows:

Shift Register	/SHR <9:0>
Deflection Register	/DFR <9:0>
Scaling Register	/SCR <2:0>
Direction Register #1	/DIR1 <2:0>
Direction Register #2	/DIR2 <2:0>
Vector List Enable	/VLE <0>

The display processor can display either a point, a vector, a list of vectors, or a list of lists of vectors. The last option can also be thought of as being a list of characters, each character being represented by a list of vectors. Loading XR and YR with the appropriate coordinates will cause the beam to be shifted to that location. Loading the VBR will cause a vector to be drawn; loading VPTR will set VLE and cause a list of vectors beginning at that address to be drawn. The list is usually terminated by a vector of 0 length. Loading CPTR with the beginning address of a list of characters will cause that list to be drawn. This constitutes a double loop in the normal programming terminology. The characters are accessed through CPTR and the location of its vector description is calculated by adding twice the character code to the contents of DTPTR and loading the result into VPTR. If VPTR<0> = 0 then a list of vectors representing that character will be drawn. If VPTR<0> = 1 then an interrupt will be generated. The interrupt vector for this type of interrupt is the word pair composed of VPTR and STAT where VPTR<0> is always read 0 by the Unibus. By using this escape mechanism one can provide special software functions as well as extending the looping capability to lists of lists of vectors by adding two more registers (not necessarily hardware).

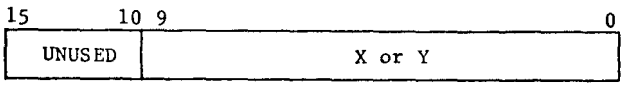
The Control Status Register

The CSR consists of error indications of various types, the scaling factor, interruption control, format specification, and the Blank-Unblank Bit. The following is a map of the CSR:

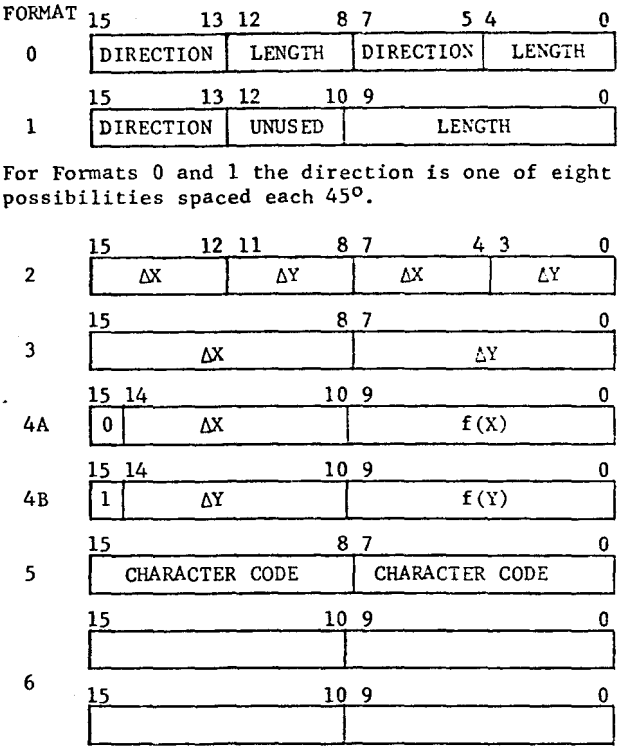
Error	/ERR := CSR <15>
Scale Overflow	/SV := CSR <14>
Register Overflow	/RV := CSR <13>
Non-Existent Memory Access	/NXM := CSR <12>
RV Supress	/RVS := CSR <11>
Scaling Factor	/SCL := CSR <10:8>
Done Indicator	/DONE := CSR <7>
Done Interrupt Enable	/DIE := CSR <6>
Error Interrupt Enable	/EIE := CSR <5>
Character Mode Indicator	/CM := CSR <4>
Format Specification	/FORM := CSR <3:1>
Blank-Unblank Bit	/BLK := CSR <0>

Data Formats

The X and Y Position Registers are 10 bits long and have the following format:



The point 0,0 is in the center of the display area. The Vector Buffer Register may contain data in four of the formats specified by FORM in the CSR. Formats 4-6 do not require use of VBR.



For Formats 0 and 1 the direction is one of eight possibilities spaced each 45°.

When displaying data in Formats 0 and 1 a vector of length 0 is considered control functions and the direction field is decoded as follows:

0 - Vector list terminator; ($\neg$ CM $\wedge$ DIE) $\Rightarrow$ INTERRUPT
2 - Beam $\leftarrow$ 0
3 - Beam $\leftarrow$ 1
4 - Intensify the present point (XR,YR)

Conclusion

In addition to wide availability of inexpensive character terminals, it is our belief that there is a growing need for a high performance graphics (vector display terminal which can be used remotely from the main processor. A fully general purpose minicomputer has to be an integral part of such a display terminal for sophisticated display generation. It is our hope that this effort will lead into considering production of such display terminals.

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