# New CRT Graphics Display Technology Broadens Uses

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Although interactive CRT graphics systems are becoming increasingly familiar in a wide range of engineering, scientific and industrial applications, many people in these fields, and in computer operations as well, are not familiar with how these systems work and how they can be put to work.

The capabilities of 2-D and 3-D graphics displays can help impart a great deal of information exchange between the computer and the operator. Not all data lends itself to the graphics format, of course, but graphics, and the appropriate software, can contribute in an unparalleled way with any data that can be transformed into display format.

To make full use of this technology, some insight into its design and function will make the overall system more readily understood and, thus, more useful.

One of the more advanced CRT graphics display systems available today is our recently announced 3300-Series.

The 3300 may be interfaced with a computer system using standard I/O techniques. The system interacts with a program by accepting inputs from the host computer and/or external devices, and displays the pictorial data on the face of the CRT. The information may be displayed 2-dimensionally, or 3-dimensionally with intensity modulation.

The CPU composes the desired display information into a display list. This is very similar to a computer program, containing instructions and data for drawing lines and characters on the screen, specifying display control parameters, and controlling the sequencing through the display list.

The 3300-Series is of modular design, with modules providing the basic functions of the system, as well as making for convenient incorporation of options into the system (block diagram).

Four modules comprise the interface to the host computer: The I/O interface, micro-programmed controller (MPC), the programmed input/output-direct memory access (PIO/DMA) adapter and the refresh memory. This segment of the system architecture is concerned with control of the display system, the placement of display lists in the refresh buffer for maintaining a picture on the face of the CRT.

Micro-programming (through the MPC) is used to adapt the system to various host computers. By changing the I/O interface board, which provides circuit interfacing to the I/O bus of the host computer, the MPC handles variations in timing and instruction format.

The refresh memory can be on one or two boards, each holding up to 64K 16-bit words of memory. It is a dual-ported memory which can be accessed by both the MPC (for loading of display lists from the host computer), and by the display refresh controller. Originally, computer memory was used to store the display list. This meant that each word of the display list had to be pulled through the computer I/O bus. This could interfere with computer operations and meant that it took longer to access each word in the display list. With the 3300's off-line refresh buffer, it is not necessary to go to the computer; and access to the display list by the display refresh controller is significantly faster. The MPC is micro-programmed to block-transfer information into the buffer, using the DMA facilities of the host computer.

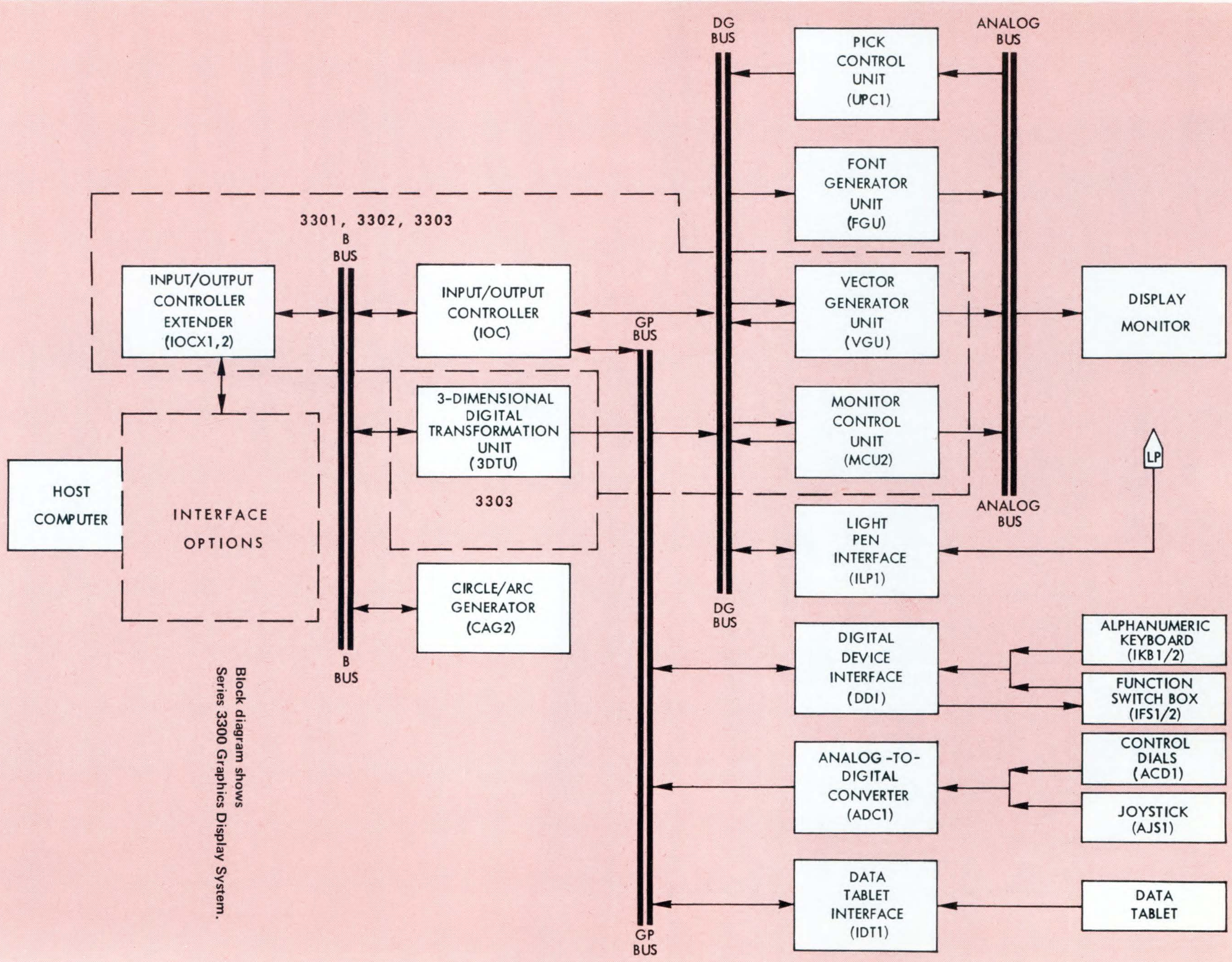
Through the use of a dual-ported memory, rather than one memory going to one common bus, loading the memory from the computer creates virtually no interference in the running of a display list. It is possible to run display lists from one part of the buffer, while simultaneously loading another display list, without that loading affecting information on the face of the CRT.

The PIO/DMA adapter basically controls display controller access to the refresh buffer and passes through the programmed I/O to the computer.

The input/output controller extender (IOCX) and the I/O controller (IOC) are the heart of the display refresh controller, which is based on bipolar bit-slice micro processors with a 16-bit wide data path and 1K words of 48-bit control firmware stored in PROMs. The B bus is the internal processing bus of the IOC, and is used for all of the internal transfers between registers, etc. It is a synchronous bus that is totally controlled by the IOC.

The 3300 utilizes a "pipeline" approach, rather than a common bus. The common bus approach employs one data bus, extending from the I/O interface to the vector generators. Each unit transferring data from or to another unit, must become master of the bus, and enter its data on the bus. Each data transfer uses bus time that might otherwise be used by the display controller to transfer data to the vector generator. With the pipeline approach, where each transfer has a dedicated bus, the MPC can transfer data from the computer to the refresh buffer, while a display list word is being accessed from the refresh memory into the front-end of the IOC circuitry.

Simultaneously, with the previous word being processed in the IOC, prior words are being processed in the 3-dimensional transfer unit, and the vector generator is drawing the line processed previously. None of these transfers interfere




Block diagram shows Series 3300 Graphics Display System.

with each other.

If, for example, the vector generator is drawing an extremely long line, which takes a relatively long period of time, the other units can be stacking up the next vectors, ready to proceed when the line is completed. This also prevents interference between front-end loading and the drawing of vectors.

The IOC has several basic responses: first, there are programmed I/O requests from the computer. In response to these requests, outputs will, typically, start display lists, acknowledge interrupts and initialize the address pointer into the refresh buffer.

A second function of the IOC is to handle peripherals. For example, when a switch on a function switch box is activated, or a key on the keyboard is depressed, an interrupt is sent back to the IOC. The IOC then reads in the appropriate information and stores it. If that key or switch is supposed to interrupt the computer, then the IOC sends the interrupt to the computer. In addition, requests for analog values are handled by the IOC. This function is performed on the GP bus, which is a 16-bit bus with full interrupt protocol.

The primary function of the IOC is to process the display list. Given an initial address into the refresh buffer, it can then read out successive words, some of which will modify parameters such as intensity, scale, displacement, 3-D rotation, etc.

The IOC goes through the display lists, picking up successive words. The micro-programming makes instruction and register definitions possible at any time, move registers, etc. Control information is transferred directly from the IOC to the DG bus, and then to the appropriate display generator. Vector information is sent by the IOC, on the B bus, to the 3-D transformation unit. This unit works independently of the IOC to take the X-Y-Z coordinates of each vector endpoint, apply a 3 x 3 transformation matrix and end up with a 3-D transformed end-point. This is then sent directly out on the DG bus to the vector generator. This transformation involves a total of 9 multiplies and 3 summations of 5 terms each. This entire operation is done in approximately 1.4 $\mu$s. It is accomplished by using 3 16-bit x 16-bit bipolar multiplier chips.

The primary module on the DG bus is the vector generator, which handles all vector draws and moves. Individual characters are drawn by the font generator, but spacing between the characters is controlled by the vector generator. The IOC, in processing character information, utilizes PROMs that specify the spacing for each character and each possible size. It takes the constants from the PROMs, sends them through the 3-D transformation unit, as vector information, on to the vector generator. The vector generator then controls the move to the next character. The user can specify special spacing information for a particular character set.

The 3-D transformation of the move means that character information can be moved with a 3-D object on the face of the CRT and, in fact, if the font generator includes the character rotation option, the individual characters can also appear to turn as the object is being rotated.

The font generator is a special vector generator. The difference is that it draws over a relatively small area. Instead of a 4096 x 4096 matrix, it draws over a 32 x 32 matrix. What it draws is based on PROMs on the font generator that are basically a display list. Fonts and/or characters can be changed by changing the PROMs. In addition, there is a programmable font board that can be attached to the font generator that supplies RAM memory. It can be loaded from the display list, through the IOC, and can be substituted for the PROM to draw characters as defined by the user.

The monitor control unit (MCU) performs three basic functions: It selects which display monitor(s) on which portions of the display list are to be displayed, controlling up to six monitors. Another function of the monitor control unit is involved with color monitors. Data in the display list selects colors on the monitors, and the MCU has a special cable that connects to color monitors so that various portions of the display list can be in color.

For some color monitors, the speed at which the vector is drawn is based on the color being drawn. Red must be drawn slower than green, for instance. The MCU has the information and control logic so that, based on the color, information can be sent to the vector generator and the font generator to control the velocity at which the beam moves across the face of the CRT.

The circle-arc generator option is an example of the use of the micro-programmed IOC to generate special display functions. Its logic board comprises PROM look-up tables, and computational circuitry. When circle arc instructions are recognized in the display list, the IOC controls the computation that leads to the desired display. The circle arc option can draw circles based on a point on the circle and the center of the circle. Clockwise and counterclockwise circular arcs can be produced, between a start point and an end point, based on a center point. On-axis elipses can be vertically or horizontally oriented. The CAG can also draw n-sided polygons where n is any number between 2 and 512. Other commands include 2-D and 3-D quadrilateral draws. These commands generate a fan of lines within a quadrilateral area to provide filling or shading.

There are several areas of engineering to which computer graphics has become an almost indispensable tool. Chief among these are computer aided design and structural analysis. CAD used graphics systems in conjunction with automated drafting tables to help develop designs faster and with greater accuracy than the older hand-drawn methods. The speed of the CRT and the computer allow for rapid updates. In addition, the amount of materials used is greatly reduced. CAD is widely used in many major industries, including automobile and aircraft design.

Computer graphics has been valuable in structural analysis work from two angles. On the front end it has allowed engineers to develop complex finite element models for stress and thermal analysis, with a savings of several man-months/model.

Several software packages exist which make use of the power of computer graphics systems to generate these models very rapidly. After processing, graphics systems allow for very effective data reduction and presentation, especially in the animation of structures in dynamic analyses.

Other applications of computer graphics include command control, signal analysis, data reduction, simulation, war gaming, printed circuit layout, architectural design, molecular modeling, medical support and cartography. The uses for computer graphics are being expanded every day.

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