HIGH PERFORMANCE RASTER SCAN DISPLAYS

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ABSTRACT

A brief discussion of contemporary raster scan display system architecture followed by a detailed description of the Ramtek 9400, an ultra-high-performance raster scan display generator. While the 9400 is well suited for image processing applications, this article focuses most of its attention on the graphic features of the system. Those readers who are searching for a pure image processing solution are encouraged to read further. This article is intended for those seeking a pure graphic or combined graphic and imaging solution such as the projection of a map onto a satellite image, etc.

PERFORMANCE CRITERIA

Display system performance is most often measured in terms of resolution, picture quality, shading and/or color capability, draw speed and functional capability or intelligence. While all of these factors are important, their relative importance can vary depending upon the application being served. For example, resolution might be of paramount importance to the engineer who is designing an integrated circuit, but of little importance to the station operator who is controlling a nuclear power plant. In general, resolution should match the detail of the most complex picture; however, the most advanced systems provide features that allow the user to work with virtual pictures that are much larger (or more detailed) than the screen resolution. Thus, the optimum performance equation can change drastically in favor of draw speed and functional capability, especially when these features are independently required. Picture quality is important to most applications, but more so when the operator’s attention will be focused on the display for extended periods of time. Factors such as brightness, contrast ratio, flicker (refresh frequency vs. phosphor persistence), smear, convergence and linearity should be considered. It is sometimes necessary to trade one or more of these factors for another in order to configure the optimum system. Ambient room lighting is yet another factor that must be considered when making these decisions. As for color, it is generally acknowledged that color enhances the users ability to interpret graphical output, especially when the picture is extremely complex. Thus, color allows greater picture density.
RASTER SCAN TECHNOLOGY

Of the four contemporary display technologies, raster scan is considered by many to be the most practical. While each technology imposes certain limitations, this technology fits the widest possible range of applications. Although somewhat resolution limited, raster scan otherwise offers excellent picture quality, shading and color capability; and moderate, but acceptable, draw speed. Since such display systems usually contain dual-ported refresh memories that are loaded and scanned asynchronously, the technology lends itself to the use of microprocessor technology, i.e., because the draw electronics need not match the speed of the scan electronics.

Figure 1 illustrates a typical raster scan display system architecture. Commands are generated by the Host Computer and sent to the Draw Electronics where they are interpreted and processed into the Refresh Memory. The Refresh Memory stores the resultant picture frame in raster scan/dot matrix format. Each cell in the Refresh Memory contains one or more data bits that describe the color or intensity of a particular picture element (pixel) on the display surface. Finally, the Scan/Video Electronics scan the Refresh Memory from left-to-right/top-to-bottom while producing the necessary analog video and synchronization signals that drive the CRT monitor. Thus, the programmed picture is displayed on the CRT.

DRAW ELECTRONICS

While few vendors base their products on strict hardware implementations, most rely heavily upon the raw computational strength of their internal microprocessor, its pre-programmed functions and/or its user programmability. Arguments can be waged on both sides of the hardware/software issue. Hardware implementations are generally fastest, but extremely limited. Micro-programmed processor implementations are fast and powerful, but not easily user programmable. Finally, general-purpose microprocessor implementations are slow, but extremely flexible and user programmable. In truth, the optimum solution requires a combination of hardware and microprocessor technology. Certain functions such as vector elimination are most practically solved in the microprocessor while functions such as clipping of complex objects and entity detection (an interactive technique) are best solved in hardware. Otherwise, throughput would be greatly diminished, and response time significantly increased.

Typical graphic functions performed by the draw Electronics include character, vector and conic generation. More advanced products will provide a flood algorithm for filled polygons. Finally, the most advanced products will provide an internal display list facility, a virtual coordinate system, a decluttering capability, local viewing transformations (translate, rotate and scale), clipping and entity detection.
A UNIQUE ARCHITECTURE

The Ramtek 9400 offers a unique architecture in that the draw electronics incorporate dual microprocessors and extensive hardware support logic (Figure 2). The first processor, the Display Processor (DP) consists of a general-purpose Z80 microcomputer system with extensive memory capacity (up to 352K bytes paged in 4K byte increments). Those who at first question the use of a 4MHz, 8-bit microprocessor should understand that the DP front-ends a second 16-bit bipolar microprocessor, the Memory Control Processor (MCP), which is based on AMD 2900 bit slice technology. The horizontal organization of its 56-bit microcode word allows complex instructions to execute at extremely high rates, typically 284-nsecs. By no accident, this speed allows the vector algorithm to match the 1.12 usec (typical) refresh memory access time. Thus, points along a vector are drawn maximum speed.

In general, the DP receives, interprets, stores and distributes command lists while the MCP draws graphic primitives into refresh memory, and thus onto the face of the display. While throughput is increased because of the simultaneous operation of these processing elements, the greatest throughput is achieved when the DP is placed in WAIT state, and direct communication is established between the Computer Interface or internal display list memory and the Transform Processor and/or MCP. Transfer of such information is initiated by the DP, but controlled by the DMA Sequencer. The bandwidth of its System Bus approaches one million 16-bit words per second, but is limited to the speed of the transmitting and receiving devices. The optional Transform Processor performs 2-D coordinate transformations at speeds of up to 33,000 endpoints per second (estimated). This unit operates in parallel with the MCP which actually draws the vectors into refresh memory. Finally, the bandwidth of the 16-bit parallel Computer Interface varies depending upon the host computer, but often matches the bandwidth of the System Bus and DMA Sequencer.

Some of the more subtle but no less important support hardware can be found between the MCP and the Refresh Memory. This hardware registers the Refresh Memory against the much larger (32K X 32K) virtual coordinate space and performs clipping to arbitrary rectangular boundaries by supressing data that would otherwise be drawn outside of the enable clip window. When placed in a special mode, this same logic interrupts the DP whenever an attempt is made to draw inside the enabled detect window. Thus, the entity detector PICK function is supported by hardware rather than software. Other, more conventional hardware controls pan and zoom, enables portioning of the refresh memory, selects foreground and background color or intensity, and maintains the drawing pen position. Unlike most contemporary display systems, the 9400 allows the image to zoom in integer steps between 1 and 16. This is more advantageous than the binary steps provided by other systems in that more usable zoom ratios can be achieved.
DESIGN RATIONALE

The rationale for the extremely powerful, microprocessor based Draw Electronics extends far beyond raw throughput. In establishing the design goals, equivalent importance was given to providing fundamental graphic solutions in the display system. Thus, the user would be relieved of his often most difficult and least understood problem. Multi-channel operation was also given high priority. The intent here was to reduce the cost-per-workstation where multiple display heads would be physically located in near proximity, such as in a control room. Finally, user programmability was provided by the use a standard microprocessor, the Z80.

Extensive user assignable internal capabilities have also been provided. For example, a user-defined menu might be displayed on a given monitor when a user-assigned key is struck on its associated keyboard, or particular object (such as a resistor) might be drawn at the cursor position. This capability is provided via the Display List option which allows pictures or subpictures to be downline loaded; then called as graphic subroutines, or invoked via local keyboard functions. A similar facility allows special symbols to be downline loaded and generated as if standard ASCII characters.

One of the more powerful concepts of the 9400 allows the user to define his picture in terms of his own coordinate system; then to project that picture onto the screen in terms of a fixed virtual coordinate system that is potentially much larger than the refresh memory or screen resolution. This allows the user to pan about the much larger virtual picture while the picture is reprocessed from the host computer or internal display list memory. Thus, the importance of system throughput. By reducing the scaling ratio, the user is also permitted to view the big picture. This introduces the topic of decluttering. Because the big picture might well be too busy or complex to be viewed within the confines of the screen resolution, the system can be easily programmed to eliminate ever more detail from the picture as it is reduced in scale, and vice-versa.

In addition to scale, the optional coordinate transformation functions include translation and two dimensional rotation. Clipping is required since the viewport will obviously be exceeded as the picture is enlarged. A split screen capability is afforded due to the fact that the viewport or clip window may be set to arbitrary rectangular values. Finally, the most important interactive concept of the system deals with a feature termed entity detection. This feature allows the host computer to identify displayed objects being pointed out by the operator. In general, the operator points to the screen by steering a cursor to the desired object. A number of interactive devices are supported by the 9400 including keyboards, joysticks, trackballs, light pens and digitizing tablets. The host computer is then interrupted and given the cursor coordinates. To determine the object being pointed out, the host computer simply establishes a detect window about the cursor position, enables
entity detect mode, and invokes the display list(s) that created the picture. Providing the picture was properly classified, the display system then responds with information that identifies the particular object to the host computer and points to the instructions in the display list that created the object. Those who have attempted to solve this problem in the host computer can best appreciate the solution.

Figure 1. Contemporary Raster Scan Display Architecture

Figure 2. Ramtek9400 System Architecture