INTEL DESIGNS A GRAPHICS CHIP FOR BOTH CAD AND BUSINESS USE

LOOSELY COUPLED PARALLEL ARCHITECTURE IS KEY TO PERFORMANCE

Two completely different kinds of end customers seem to be fueling the embryonic graphics chip market: the personal computer user in business, who primarily is interested in manipulating text but wants to include more sophisticated graphics, and the designer on a work station, who demands more sophisticated graphics but increasingly wants text-handling capabilities. Intel Corp., long reported to be developing a graphics-oriented microprocessor, is finally announcing its 82786 graphics coprocessor for both applications. It tailored its graphics chip to meet most needs of both the computer-aided-design market as well as of the business and high-end personal computer markets.

The requirements of the two markets are not that different, according to Mark Olson, Intel's product manager. "Both require the ability to perform high-quality graphics and text chores as well as the ability to merge the two in the same display," he says. "And both applications require a high degree of multitasking—the ability to perform two or more complex tasks at the same time and to shift back and forth between them virtually simultaneously."

Users in both markets are also demanding productivity, he says. "What this translates to in the real world of business and engineering is, no waiting." To meet these requirements, Intel designed the 82786 with a loosely coupled parallel architecture that combines flexibility with high speed and sophisticated graphics manipulation as well as powerful text-processing capabilities.

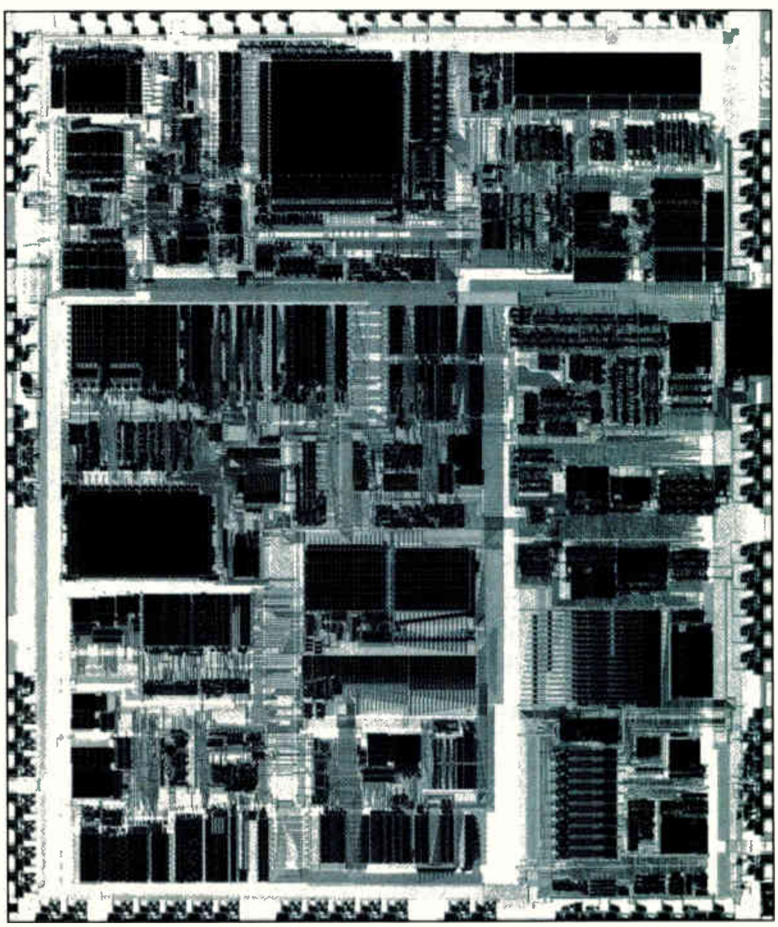
The 82786 is flexible enough to let a designer choose from a wide range of system central processing units—from the 16-bit 8086 to the 32-bit 80386—as well as graphics memories and displays, depending on the cost and performance requirements of the application. And it is designed to run applications based on the American National Standards Institute's Video Device Interface and Graphics Kernel System, as well as those written for the de facto standard IBM Corp. Color Graphics Adapter for the Personal Computer. Such programs can be run simultaneously, each displayed within its own window on the same screen.

Its performance is equally impressive. The 82786 offers almost instantaneous screen updates. It can draw single-window screens in less than 0.1 second, or 400 ns per pixel. The 82786 can draw all the standard primitives—lines, circles, polylines, polygons, and others—at extremely high rates: lines take 2.5 million pixels per second, circles 2 million pixels/s at 8 bits per pixel. As a text processor, it can simultaneously support multiple character sets and create text at a nominal rate of 25,000 characters per second.

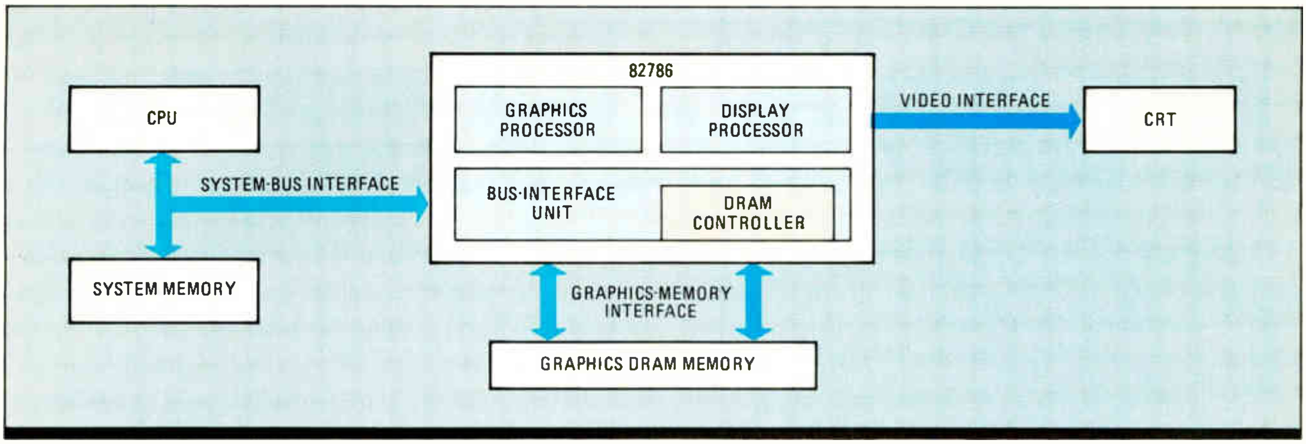
Fabricated using the company's 1.5-μm CHMOS-III process, the graphics chip (Fig. 1) uses either standard dynamic random-access memories for medium-performance, lower-cost applications, or video RAMs for high-resolution systems. It supports display resolution of 640 by 480 pixels using ordinary memories, as well as up to 256 colors for illustration. For dedicated document creation, the 82786 also supports 1,000-by-1,000-pixel monochrome systems with four gray scales, or colors for denser pages. When the 82786 is used with dual-port VRAMs and high-resolution displays, resolution can reach 2,048 by 1,536 pixels with 8 bits per pixel. Higher resolutions and more colors can be achieved by using multiple 82786s.

Demand for multiple-windowing capability is on the rise, especially for multitasking chores in the office environment. The 82786 implements this capability in hardware. Each application can have its text and graphics drawn into separate regions of memory, which are then combined within windows of the same display. Large amounts of overhead associated with graphics tasks can be offloaded from the main system CPU by storing more text and graphics information in memory than is shown in the display.

The 82786 achieves this performance through a loosely coupled architecture consisting of four independent modules (Fig. 2) organized to operate in parallel: a graphics processor, a display processor module, a bus-interface unit, and a DRAM controller. Applications programs use the graphics processor to draw bit maps that create objects in memory. The window-



1. GRAPHICS COPROCESSOR. Intel's 82786 graphics coprocessor supports its family of 16- and 32-bit central processing units.



2. PARALLEL PROCESSOR. In Intel's 82786, four modules—graphics, display, bus-interface, and memory-control—operate in parallel.

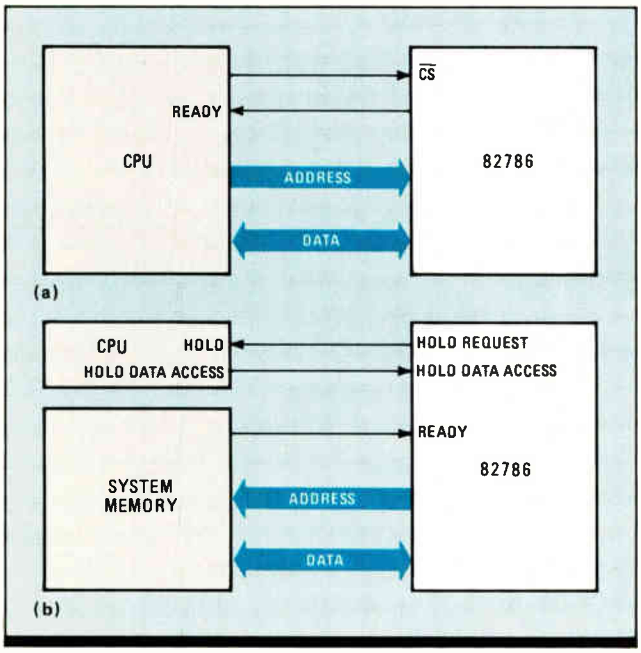
manager software uses the display processor to control display contents. The bus interface and DRAM control modules are invisible to the CPU software after initialization. These two modules permit parallel processing of simultaneous tasks for graphics functions.

New graphics may be drawn into memory at the same time that existing portions of memory are being displayed on a monitor. This separation of functions is what makes possible the high performance of the 82786.

ASYNCHRONOUS COMMUNICATION

The modules communicate over a built-in asynchronous bus. When the graphics processor module receives a list of commands from the CPU, it sequentially executes them and draws into one or more bit maps, regardless of what is currently being displayed on the screen. The bus-interface unit arbitrates graphics-memory requests to maintain the integrity of the display contents. The DRAM control module directly handles up to 4 megabytes of graphics memory while providing full refresh. Virtually any size or configuration of DRAM, either standard or video and up to 1 Mb, is supported. Static column and fast page modes are directly supported for serial access of memory blocks.

The most common configuration allows the CPU access to the system while the 82786 accesses its dedicated graphics memory. The CPU can also access graphics memory and the 82786 can access the system memory, although not at the same time. If direct memory access is also provided in the system, it interfaces to the 82786 exactly as the CPU does.



3. SLAVE OR MASTER. The graphics coprocessor can work with Intel 16- and 32-bit microprocessors in either slave (a) or master (b) modes.

The 82786 works with the CPU in two ways. In the slave mode—that is, when the CPU accesses the 82786—the graphics chip looks to the CPU like an intelligent DRAM controller (Fig. 3a). The CPU generates a chip-select signal, which the 82786 acknowledges when the cycle is complete by generating a Ready signal to the CPU. In the master mode (Fig. 3b), the 82786 looks like a second CPU controlling the local bus. When the CPU receives a signal from the 82786 to request control of the system bus, the graphics coprocessor takes over the bus. When it is finished, it sends a signal to the CPU, which takes back control of the bus.

FLEXIBLE GRAPHICS PROCESSING

The graphics processor module is powerful enough to handle a wide range of tasks. It accepts commands that allow it to maintain multiple bit maps in memory, to draw the text and graphics objects, to copy images from one piece of memory to another, and to fill the objects. The programming interface supports subroutines and the use of a stack for nesting these subroutines. Registers can be dumped to and reloaded from memory to allow switching between applications tasks. Applications need only assign as much memory to a bit map as is necessary for color support because bit maps do not all need to have the same bit-per-pixel depth.

Key to its power and flexibility is a set of on-chip graphics-oriented commands for primitives—including point, line, polyline, polygon, rectangle, circle, and arc—to relieve the CPU of the chore of creating these figures from scratch. To be displayed on the screen, each figure requires only a single 16-bit request from the CPU incorporating the unique parameters of the graphics primitive, as well as one point of reference, called the current drawing point, to be used as the starting point. For example, a circle's critical parameter is the radius, and a rectangle's the diagonally opposite point. With these two reference points, the graphics processor is intelligent enough to complete the drawing.

For more specialized drawing functions, the graphics processor also includes such commands as Bit-Block Transfer, Incremental Point, and Fill. When the CPU requests it, the 82786 can perform a bit-block transfer (Fig. 4) from one portion of a bit map to another, either within the same bit map or in another bit map, at a rate of 24 Mb/s. Using the Bit-Block Transfer mode, pictures can be composed quickly on the screen by copying portions of those figures currently resident in the display's bit-map memory, including other portions of the picture currently being composed.

An Incremental Point command can draw virtually any complex figure, such as a logo, for example. In such an operation, the pixels to be drawn are listed as displacements in the X and Y directions. On receiving an incremental-point list from the CPU describing the figure's shape, the graphics processor module draws the figure at a rate of 2 million pixels/s, taking into account all currently active drawing attributes such as the texture, bits per pixel, and masking of bits.

GRAPHICS MODES

The 82786 hardware incorporates a number of graphics modes that other graphics processors usually handle in software. These include clipping, a pick mode to support mouse operations, bit-plane masking, logical operations, and virtually unlimited character-set support.

With the clipping mode, the 82786 can draw partial sections of complete figures such as lines, circles, and more complex objects without generating all of the pixels needed for the complete figure. During execution of drawing commands by the graphics processor module, the CPU calculates addresses of all the pixels to be altered that fall within an area called the clipping rectangle.

To pick an object on the screen with the mouse, the graphics processor module is given a command list to execute, which describes the same picture as that on the screen. The graphics processor goes through the calculations for the drawing, but does not update any of the pixels. Instead, it generates an interrupt if any attempt to select a particular object is made within the currently defined clipping rectangle. This mode reduces considerably the CPU overhead spent on picking up or selecting objects on the screen because the 82786 does all the processing and the CPU is interrupted only when the picked object is identified.

At the same time that the 82786's graphics processor module performs bit-block transfers, it can do such on-the-fly operations as bit-plane masking and logical operations. The first allows copying of the original picture into only selected bit planes without touching others. It can also write text with special fonts, where the writing involves doing bit-block transfers from the location where the character font is stored to the writing location.

Logical operations permit figures to be copied in a bit-complemented mode—that is, if a figure is displayed in a white-on-black background, logical operations allow the figure to be copied in the reverse video, black on white. Using the Fill command, the 82786's graphics processor module can fill in any shape with horizontal lines. The figure's shape is given as a set of parameters, each specifying the beginning point on the X axis and the fill length on the Y axis.

The 82786 supports an unlimited range of character sets, all stored in the display RAM. The number is determined by the amount of memory, and any set can be activated by a single command. Proportional spacing is built into each character set, with the height and width of each character defined independently from 1 to 16 pixels. Not only can the spacing between characters vary, it can also be negative—that is, characters can be positioned to overlap one another, useful for effects such as kerning, that is, squeezing or stretching character spacing.

To manage the screen contents—particularly the tricky task of windowing—Intel designers built a display processor module into the 82786. The module is designed to operate independently of the graphics processor module. The display processor gets its commands from the CPU and has no knowledge of what the graphics processor is drawing.

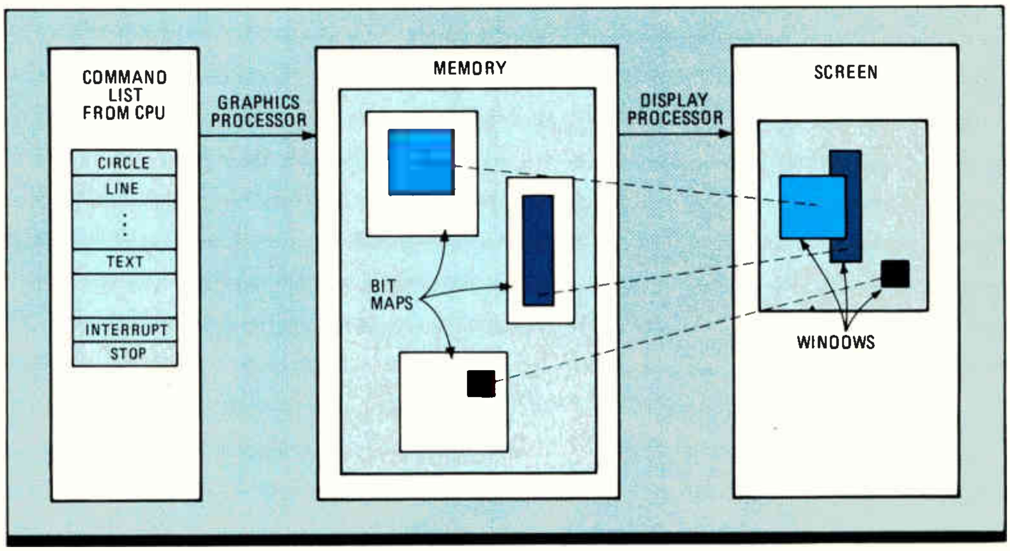
The display processor uses its instruction list to retrieve pixel information from multiple bit maps in memory and place the contents at precise screen locations. Bit maps that contain fewer than 8 bits per pixel are automatically padded to achieve full color. The display processor adds a hardware cursor, zooms the indicated bit-map contents, and provides colored borders around the windows. This produces rapid display changes with minimum system overhead because the windows can be moved a pixel at a time; all the CPU does is manipulate pointers within the instruction list in memory.

The display processor module can create an almost unlimited number of windows on the screen. It works from a configuration list supplied by the main CPU specifying the window map for the screen and what portions of which bit maps are to be shown in each window. The module then constructs the windows for every frame during the scan operation. This is done in real time, giving the illusion of moving windows and allowing the contents of any window to be panned or scrolled in any direction.

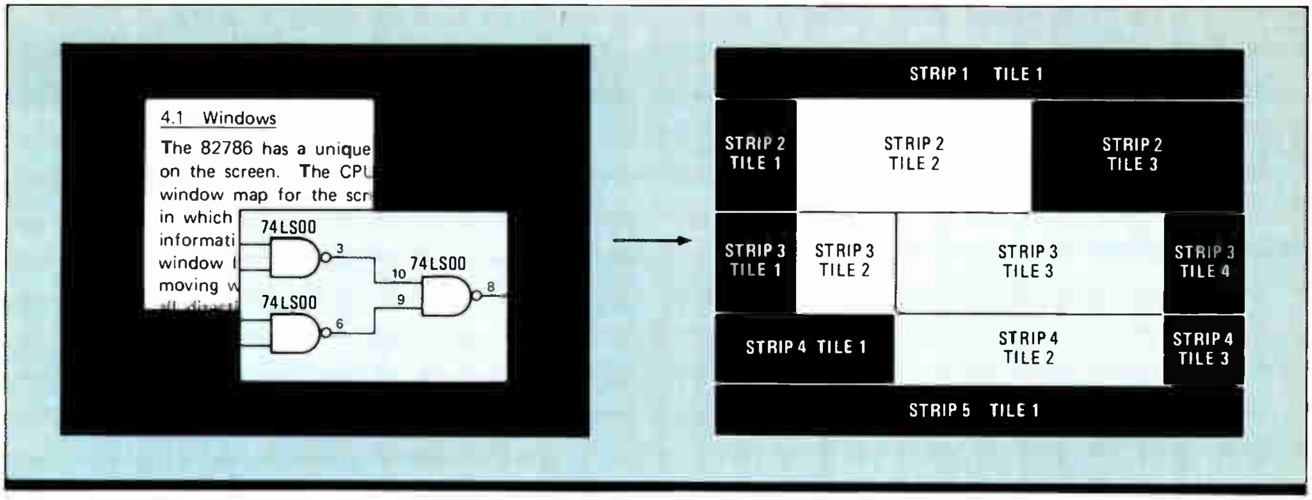
STRIPS AND TILES

To do this, the display processor module divides the screen into strips and tiles (Fig. 5). Each strip is divided into one or more tiles, dividing the screen into a mosaic of tiles, with each window a collection of tiles. For a given screen, the main CPU provides a screen descriptor list to the 82786's display processor. This consists of a set of strip descriptors specifying the number of scan lines and the number of tiles in each strip, and a set of tile descriptors specifying the width, contents, and attributes associated with the objects being displayed.

Screens are constructed in real time, without the delay usually involved in reading out the contents of a bit map located in memory and reproducing it on the screen. It does this by reading the strip and tile descriptors and filling an on-chip first-in first-out cache with pixel data from the bit maps in the tile descriptors. The FIFO cache is then emptied onto the video screen. The contents of up to 16 tile descriptors can be cached on the chip. As a result, when it is necessary to move a window or windows or to scroll the contents of a



4. INDEPENDENT MODULES. Operating independently, 82786 graphics and display modules manage bit maps and windows on screen as commanded by the CPU.



5. STRIPS AND TILES. The 82786 handles an unlimited number of windows by manipulating a mosaic of strips and tiles as directed by the CPU.

window, only the strip and tile descriptors need to be changed; the bit-map contents need not be touched.

Speed and performance of the 82786 also derive from the integration of all the DRAM control logic to handle either standard or video DRAMs. By incorporating this function on chip, says Olson, no cycles are lost between the various subunits, and very fast read-modify-write cycles are possible for pixel writing, eliminating the need for two separate cycles for read and write. In the standard configuration, the chip can control up to 32 DRAMs directly. "Even the damping resistors normally needed to suppress ringing are integrated," says Olson. In the full configuration, the DRAMs are organized in four rows and two ranks.

When higher performance is required, the 82786 can support video RAMs, which are DRAMs with an extra serial port through which an entire row of the DRAM can be shifted in or out. While a row is being shifted out, the VRAM is accessible through the parallel port. Although more expensive than the standard page-mode or static-column DRAMs, VRAMs provide several advantages to the 82786.

"First, since the data to the monitor goes directly from the serial port of the VRAM, the display-processing module doesn't use any memory bandwidth," Olson says. "This means that almost 100% of the memory bandwidth is available to the graphics-processing module, giving it much more time to draw, and resulting in faster speeds." Second, much higher resolutions are possible. For example, using thirty-two 64-K-by-4-bit VRAMs results in a resolution of 2,000 by 2,000 pixels at 2 bits per pixel or 1,000 by 1,000 pixels at 8 bits per pixel. □

INTEL'S FLOATING CRAP GAME

The design effort involved in the development of Intel Corp.'s 82786 graphics coprocessor resembled a floating crap game in which one or two main players stay in the game continuously, joined at various times by other participants who come and go as the rules and the goals change.

The two main players were 29-year-old Martin Randall, design manager for Intel's next-generation graphics products group, and 30-year-old Richard Hansen, project manager for the 82786. Randall, with a BSc from the University of Southampton in England, was principal architect and design engineer of the 82786. Hansen, who graduated from the State University of New York at Stony Brook with a BSEE, was principal architect of the bus-interface unit on the chip.

In addition to Randall and Hansen, working on the project at any one time was a revolving group of 5 to 10 engineers whose mix of disciplines changed as the product moved through the various stages of development.

According to Randall, the flexibility and free-form nature of the team reflected the basic architecture of the internal bus, which was designed to allow various functions to be loosely coupled, just as it allows the modules to operate independently.

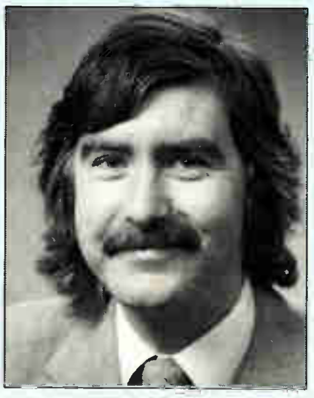
"Once we had defined the overall structure of the device," says Randall, "the features we wanted and how to partition the functions, all that was necessary was to assign design teams to each module and send them on their way, without worrying about how it would interconnect with the other modules."

As the interface between the various groups, Randall and Hansen ensured that each of the modules met the handshaking protocols for the internal bus.

In addition to the architecture, Randall claims that the 82786 incorporates several conceptual breakthroughs. One is in the way it handles windows. Rather than use frame-buffer logic, the 82786 uses a display processor to manage the windows. Another is an internal programmable prioritization scheme that allows the system designer to rearrange the communications-processing priorities of the modules to optimize the chip for an application.

Although Intel is marketing the 82786 mainly as a sophisticated graphics coprocessor for use with its 16- and 32-bit central processing units, Randall claims it can be adapted easily to work with the company's 8-bit designs as well. "The resolution may not be anything to write home about compared to a high-end system, but it sure can do windows."

RICHARD HANSEN



MARTIN RANDALL