New Graphics Chips Speed Up Windows

New Products Offer Local Bus, Accelerated Graphics Functions

By Linley Gwennap

This article is part 1 of 2 on accelerated PC graphics chips. It compares recently-announced graphics chips from Weitek, S3, Avance and Chips and Technologies. Next issue, part 2 will cover similar products from ATI, Western Digital, IIT, and LSI's Headland division, and will include a summay comparison of the products from both parts 1 and 2 (see ***061301.PDF****).*

The growing popularity of the graphical user interface of Microsoft Windows has increased PC users' demands for fast, high-resolution graphics. Frustrated with the limited 640 × 480 pixel VGA standard, users are moving to 1024 × 768 or 1280 × 1024 to get more information and multiple applications on the screen, as well as better resolution for small fonts. In addition, many users want 8-bit, 16-bit, or even 24-bit color for more realistic images. This combination of higher resolution and more color requires a new approach to PC graphics because ISA-bus VGA devices cannot keep up with these demands.

Responding to this need, several vendors have recently announced graphics acceleration chips, many of which are second- or third-generation products. Weitek has begun shipping its Power 9000, a high-performance PC graphics chip. Not to be outdone, S3 has announced (but is not yet sampling) a similar accelerator chip called the 86C928. Both target Windows and CAD applications that require fast, high-resolution graphics far beyond the ability of standard VGA designs. S3 is sampling two lower-cost chips, the 86C801 and 86C805, which offer less performance than the '928 but are still superior to VGA. A new entrant, Avance Logic, is sampling its GUI Ultra chip, which is similar to S3's 805. Chips and Technologies (C&T) has started shipping its 82C481 as an add-on accelerator to its Wingine (say "Win-jen") chip, announced last March.

All of these chips (with the exception of the standalone Wingine) provide on-chip hardware that handles common graphics functions such as bit block transfer (BitBLT), line drawing, clipping, and filling. To use this hardware, the processor transfers commands to a special set of registers on the accelerator chip, which then does a series of pixel manipulations automatically. Not only does this free both the processor and the bus for other functions, but the graphics chip is optimized to handle these operations very quickly. This technique alone can improve graphics performance by 10 times or more.

C&T's Wingine does not provide hardware acceleration but instead acts as a simple frame buffer. This strategy requires that the processor handle all graphics operations itself. Although this can result in lower graphics performance, particularly in slower 386 systems, C&T claims that the lack of acceleration hardware reduces the die size, and thus the cost, of the chip. Indeed, Wingine costs just $18, while even the bottom-of-the-line 86C801 costs $29. Furthermore, as processor performance increases, so does the performance of Wingine; for example, on the WinMark benchmark (see sidebar below) a 66MHz DX2 system using Wingine is 60% faster than a 33MHz 486DX system. Other graphics accelerators tend to be limited by the speed of the bus (which doesn't change in this example) and the speed of their internal circuitry, resulting in a much smaller change with different CPUs.

Most of these new chips connect directly to the processor's local bus, as shown in Figure 1, to take advantage of its higher bandwidth. The local bus has a sustainable bandwidth of over 30 Mbytes per second, compared to about 5 Mbytes per second for the ISA-bus connection used by traditional VGA devices, shown in Figure 2. This added bandwidth greatly improves mem-

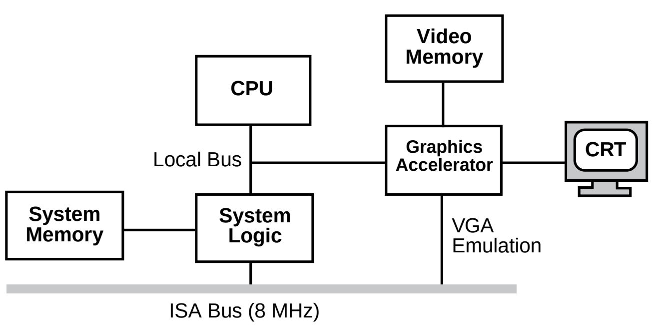

Figure 1. Local bus graphics connection.

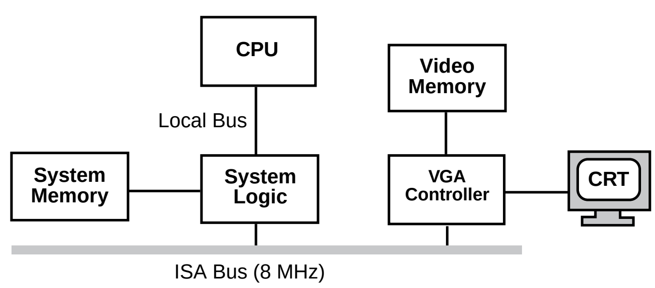

Figure 2. Traditional ISA graphics connection.

Resolution	Color Depth (bits per pixel)			
	4-bit*	8-bit	16-bit	24-bit
640 × 480	256K	512K	1M	2M
800 × 600	256K	512K	1M	2M
1024 × 768	512K	1M	2M	4M
1280 × 1024	1M	2M	4M	4M
*not supported by the Power 9000				

Table 1. Video memory required for various configurations.

ory-to-screen transfers, but graphics functions accelerated in hardware will not see much improvement, as their bandwidth requirements are reduced by the accelerator. Overall, localbus attachment improves performance by 20%-30% over ISA-bus for graphics chips with hardware accelerators.

C&T uses a third strategy: connecting through the memory system as shown in Figure 3. One reason that Wingine does not attach to the local bus is that local-bus standards weren't yet formed when the product was designed, but the recent announcement of VESA's VL-Bus standard *(see* ***060902.PDF****)* relieves this problem. Most of the newer chips support VL-Bus, and C&T plans to offer VL-Bus support in the future.

More Colors, Higher Resolution

All of these new graphics chips offer support for 8-bit (256 colors), 16-bit (64K colors), and 24-bit (16M colors). The latter mode is known as "true color" because it provides a sufficient range of colors to display photo-realistic images. Although 24-bit color is the standard for high-end graphics, the 86C928 and 82C481 chips support up to 32 bit color for future 32-bit RAMDACs.

These chips allow for various combinations of screen resolution and color planes based on the amount of video memory used, up to the maximum memory supported by the chip. For example, at 1024 × 768 resolution with 16 color planes, 1024 × 768 × 16bits = 1536 Kbytes of memory needed to store the screen image. Since video memory is usually supported only in powers of two, this combination requires 2M of memory, with the excess available for off-screen storage. Table 1 shows the standard resolution and color combinations and the amount of video memory required. Note that some chips are limited to 1M or 2M of memory and therefore do not support combinations that require more memory.

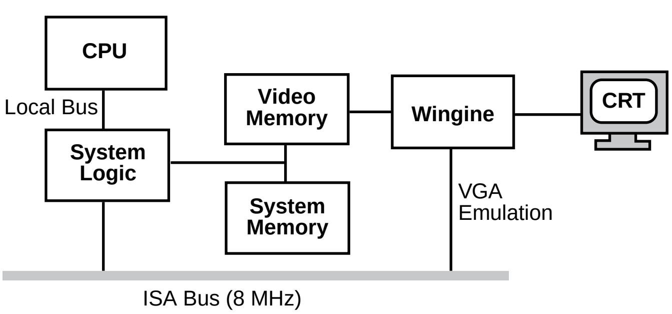

Figure 3. "Wingine" graphics system configuration.

This added resolution does not come without cost. Besides the cost of the graphics chip itself, video memory must be expanded beyond the 256K required for standard VGA. Low-cost accelerators usually use DRAM video memory, which costs about $20–$25 per Mbyte. Unfortunately, as screen size and depth increases, screen-refresh accesses begin to conflict with processor accesses to video memory. In a standard VGA configuration, screen refresh can use 5–10% of the available DRAM cycles, but this figure can increase to 30% or more in a 1024 × 768 × 8 configuration. Refresh becomes more of a factor as displays change from 60 Hz to the 70–72 Hz refresh rates that have become standard in Europe and elsewhere.

One strategy to reduce refresh bandwidth is to use an interlaced display. These displays refresh only every other line on each pass, halving the number of video memory cycles required for refresh. Unfortunately, many users don't like the "flicker" of an interlaced display. A second, more popular strategy is to use VRAMs for video memory. Although VRAM chips are more expensive at $40–$50 per Mbyte, they include a serial data port as well as the normal parallel data I/O, allowing screen refresh to take place transparently through the serial port while graphics operations occur in parallel. With the screen refresh cycles hidden, overall performance is better using VRAM, particularly for larger screen sizes. Because of this, many 2 Mbyte and all 4 Mbyte configurations require the use of VRAM. Only S3 supports as much as 2 Mbyte of DRAM with non-interlaced displays.

All of these chips require a RAMDAC to drive the video signals to the display. A VGA card can use a simple $1–$2 RAMDAC such as a Bt475. More advanced graphics cards may need a faster dot clock, a wider data interface, and a larger color palette, driving the cost to $8–$15 or even more for some high-end RAMDACs.

Finally, the increased color and resolution put additional stress on video subsystem bandwidth. In fact, moving from a 640 × 480 VGA display to a 1024 × 768 display increases the bandwidth requirement by about 2.5 times. Moving from 8-bit color to 24-bit color adds another factor of three. These factors are forcing the move to hardware acceleration and/or local-bus connection.

The larger memory sizes supported by these new chips have forced a change in the way that software accesses the video memory. The VGA model requires that accesses to screen memory go through a single 64-KByte "window," adding overhead when using larger video memories. All the new chips break free from this limitation by offering linear addressing, allowing direct access to the entire video memory space supported by the chip.

Weitek PC Graphics Chips

The Power 9000 borrows its high performance core from Weitek's workstation graphics products. The chip provides hardware support for BitBLT, line and polygon drawing, polygon fills, patterning, raster operations, clipping, and cursor support. It supports 1 to 4 Mbytes of VRAM, but, the maximum memory is supported only in a two-bank interleaved mode. Thus, the largest logical video memory size is 2M. The 9000 connects directly to the 386/486 local bus without additional glue logic, supporting local bus operation at up to 33 MHz. The 9000 is being fabricated by Hewlett-Packard in a 0.8-micron CMOS process and is packaged in a 208-pin quad flat pack (QFP). It has been sampling since August and should reach full production volumes by mid-October.

The 9000 is rated at 33 WinMarks using 2M of VRAM in interleaved mode. When using only 1M, as other chips do for the baseline configuration, performance declines by about 15% to 28 WinMarks. The cost of the extra VRAM will make the faster configuration attractive to only those users who require the best possible performance. The lower WinMark rating is more comparable in cost to other chips' configurations.

For lower-cost systems, Weitek also sells the W5286. This chip provides a more restricted set of graphics functions, with only BitBLT and line draw supported in hardware. It interfaces to ISA or EISA bus but not the faster processor local bus. It supports either DRAM or VRAM, giving the system designer flexibility to meet various cost targets. With VRAM, the chip reaches 7 WinMarks. Due to its simpler design, the chip is priced at just $15, compared to $70 for the Power 9000. The W5286 is packaged in a 160-pin plastic quad flat pack (PQFP).

One drawback of the 9000 is that it does not have a built-in VGA emulator, which is needed to boot DOS or other applications that do not support the accelerator. The 9000 has a "pass-through" mode that allows a W5286 (or other chip) to handle VGA emulation. Weitek is bundling an older chip, the W5186, to handle VGA mode for the Power 9000. When purchased as part of a set, the W5186 is priced at under $10. This cost must be considered when designing the 9000 into a PC environment.

New Products from S3

The new chips from S3 are follow-ons to the successful 86C911 (see µPR 6/26/91, p. 11). For low-cost applications, S3 provides the '801 and '805 chips. These chips have a full set of accelerated graphics functions similar to the Power 9000's, but only support up to 2M of memory and use DRAM instead of VRAM. The '801 can connect only to the ISA bus, while the '805 includes EISA and local-bus interfaces. A VGA emulation mode is also included. Performance of the '801 is about 14 WinMarks, and the '805 yields 16.5 WinMarks in the local-bus configuration. Like the Power 9000, these chips are manufactured in HP's 0.8-micron CMOS process. They are planned for production in October. The '801 uses a 160-pin PQFP while the '805 requires a 184-pin PQFP.

The high-end '928 is announced but has not yet reached first silicon. It leverages heavily from the '805 and includes all the same acceleration hardware. The performance improvement comes from the addition of VRAM support and up to 4 Mbytes of memory. Like the '805, the '928 supports ISA, EISA, or local-bus interconnect. Due to the similarities with the '805, S3 hopes that the first '928 chips will be sampled by the end of September, with volume production in November. Packaging is a 208-pin PQFP. Simulated WinMarks show the '928 with similar price/performance as the Power 9000, but the proof requires actual silicon.

The WinMark Benchmark

When graphics accelerators first became popular, their performance was often calculated by measuring dozens of individual graphics operations individually and then averaging the result. This is akin to calculating the execution time of each CPU instruction and coming up with an average rating. Because graphics chips, like CPUs, tend to spend most of their time doing a few operations, a better method was needed to estimate the speedup delivered on real Windows applications.

To better measure Windows performance, PC Magazine developed a suite of programs called WinBench that have become generally accepted by the industry. The suite consists of 13 individual tests, with weightings as follows:

Memory-To-Screen Source Copy	25.0%
Memory-To-Screen Pattern Copy	10.0%
Memory-To-Screen Pattern Invert	10.0%
Memory-To-Screen Dest. Invert	10.0%
Memory-To-Screen Whiteness	10.0%
Horizontal Line Draw	3.0%
Vertical Line Draw	3.0%
Diagonal Line Draw	1.2%
Horizontal Polygon Draw	6.0%
Vertical Polygon Draw	6.0%
Diagonal Polygon Draw	1.8%
Random Rectangle Fill	14.0%

The weights are based on the usage of these functions by a typical VGA driver running Windows. The overall WinMark rating is calculated as the weighted geometric mean of the individual test results. Each WinMark represents one million pixels per second. Tseng Labs' ET4000, rated at about 1.8 WinMarks, is generally considered the fastest standard VGA controller and is often used as a baseline for comparison with graphics accelerators.

Although WinMarks can be measured in any configuration, all the results given in this article are for a 1024 × 768, 8-bit color, 70-Hz refresh, non-interlaced display using a 33-MHz 486 CPU with cache and WinBench 2.5.

Avance Announces New GUI Chip

Avance was founded (and financed) by George Wu in 1991, combining engineers in Taiwan, in Hong Kong, and at its headquarters in Fremont, California. It is part of Wu's larger business group, which includes operations in chemicals, pharmaceuticals, and consumer products as well as ICs. Avance's sole target is the graphics accelerator market for Microsoft Windows, X-Windows, and OS/2.

Avance's GUI-Ultra is a follow-on to its original GUI Engine product. It is quite similar to S3's '805 chip, with a large set of accelerated graphics functions and bus interfaces, and up to 2M of DRAM support. For configurations that require 2M of video memory, only interlaced displays are supported to reduce the video refresh demands on the DRAM. VGA emulation mode is included. At 20 WinMarks on local bus and 15 on EISA, the chip's performance is about the same as the VRAM-based '481 from C&T and a bit higher than S3's DRAM-based chips. The packaging is a 160-pin PQFP.

The GUI-Ultra can be purchased from Avance as a chip set, complete with 16-bit RAMDAC (ImgDAC) and clock chip (ALG3102). The GUI-Ultra supports other standard RAMDACs and clock chips as well. Although this combination is convenient, Avance, which is less than a year old, does not have the broader product line that other graphics chip companies offer.

C&T Accelerates Its Wingine

Wingine, which has been shipping since June, is different from the other chips due to its lack of hardware acceleration features and its unique system connection (see Figure 3). For system designs that require hardware acceleration, C&T has just begun shipping the 82C481. The '481 performs a wide range of graphics functions in hardware, similar to the other hardware accelerator chips. The '481, along with GUI-Ultra, are the only chips that connect directly to Micro Channel as well as ISA and EISA

Because the '481, like the 9000, does not have a VGA emulator on-chip, it works best in PCs when coupled with Wingine. In this configuration, Wingine handles VGA emulation at boot time and for non-supported applications. Both the '481 and Wingine connect to a single video memory, but the processor accesses the '481 through the ISA (or other non-local) bus. The '481 achieves nearly 20 WinMarks in this configuration. C&T is offering a special price of $36 for the '481/Wingine combination, making it competitive with other low-end chips.

Wingine alone is rated at 15 WinMarks, but it has very different performance characteristics than chips that perform hardware acceleration. Wingine scores relatively well in memory-to-screen transfers, while the accelerator chips have much better scores in other areas due to the on-chip assist logic. Frame buffer chips such as Wingine will show strength in applications that frequently download complete images, such as photographs or video. Hardware accelerators will most improve applications that create simple images from lines and use overlapping figures.

Further muddying the water, graphics accelerators are designed to reduce the number of memory-to-screen transfers by doing more operations in video memory and using off-screen storage. Thus, the usage patterns of an accelerator chip will be different from the weightings assigned by the WinMark program. Care should be taken when comparing the WinMarks of frame buffer chips to chips with hardware acceleration, although ratings for different accelerator chips should be comparable.

Wingine (with or without the '481) can only be used with system-logic chip sets from C&T due to its proprietary system connection. When used with PEAK/DM, the current high-end CHIPSet, an additional chip called Winglue is required for the Wingine interface. The next-generation ISA486 CHIPSet, which is currently sampling, integrates the Winglue functions and allows a clean interface to Wingine. It would be relatively difficult and expensive to connect Wingine to non-C&T system designs. C&T plans to offer a VL-Bus version of Wingine in early 1993.

Software Availability

Because these accelerator chips all break away from the simple VGA model, they each require a new and unique set of software drivers for use with various applications. All the chip vendors supply a basic set of drivers, including source code, to graphics-card manufacturers. Some card vendors enhance the drivers to improve performance. Thus, the actual WinMark performance of a particular vendor's card may vary slightly from the numbers quoted here.

One factor that has fostered the proliferation of accelerator chips is the fact that the chip maker can supply a single driver for all Microsoft Windows applications. This greatly increases the number of programs that can use accelerated graphics chips. DOS programs access the display controller directly and must be modified for each new controller.

Besides Microsoft Windows, all the new chips have drivers available for the popular AutoCAD package as well. Both S3 and Avance support other CAD packages such as CADKEY and Versa-CAD, along with DOS programs such as GEM, Lotus 1-2-3, Ventura Publisher, and WordPerfect. The S3 drivers have been selected for distribution in Microsoft's Windows Driver Library.

Conclusions

With over 10,000,000 Windows users today, there is plenty of room for competing graphics accelerators. Companies such as S3 and Avance are entirely focused on the graphics market, while more established players such as

C&T and Weitek move in from other areas. No one company has achieved a dominant position.

Table 2 compares the latest chips. The first columns show which bus interfaces are supported among ISA, EISA, VL-Bus, and Micro Channel. The second group of columns gives the maximum amount of video memory supported by the chips and whether they can handle DRAM, VRAM or both. The next column shows which graphics functions are accelerated in hardware; "many more" means that functions such as raster operations, polygon drawing and filling, clipping, and hardware cursor are included. The "WinMarks" column lists the benchmark rating in a standard configuration (see sidebar "WinMark Benchmark"). For chips that support multiple buses and/or different types of memory, the performance in the best configuration (usually local bus with VRAM memory) is given. Finally, the chip price is given for large quantities; see "Price and Availability" sidebar for details.

Of the high-end chips, the Power 9000 offers the best performance, particularly with two banks of VRAM. The cost of the extra VRAM, along with the VGA emulation chip required by the 9000, makes this an expensive solution. For a single-bank graphics card, S3's '928 may offer similar performance at a lower cost due to its built-in VGA emulation. At this time, the '928 is a riskier solution because it has not yet been fabricated and is at least a month behind schedule.

At the low end, S3 offers a range of solutions that are available today. Avance's GUI-Ultra is a point product with price/performance that beats S3's chips. The '481/Wingine combination also has good performance but there are many hidden costs due to Winglue, the use of VRAM, and the requirement for system-logic chip sets from C&T.

At the very low end, Wingine has much better performance than Weitek's W5286 in the configuration studied here, but Wingine's performance varies widely depending on the type of CPU. Wingine excels on different applications than other chips due to its dissimilar design. Finally, Wingine has hidden costs as noted previously.

Price & Availability

The Power 9000 is expected to reach full production by mid-October. The W5186 and W5286 are in production. Pricing is $70 for the 9000, $15 for the W5286 in quantities of 1,000. When purchased with the 9000, the W5186 is under $10 in quantities of 1,000. Contact Weitek at 1000 E. Arques Ave, Sunnyvale, CA 94086; 408/738-8400, fax 408/738-1185.

The 86C801 and the 86C805 are currently sampling with production expected in October, and the 86C928 is expected to sample by the end of September. Pricing is $29 for the '801, $35 for the '805, and $65 for the '928 in quantities of 1,000. Contact S3 at 2880 San Tomas Expwy, Santa Clara, CA 95051; 408/980-5400, fax 408/980-5444.

The GUI-Ultra (ALG2201) is currently sampling with production quantities expected by early November. Pricing is $25 in quantities of 5,000. The ImgDAC (ALG1101) and clock chip (ALG3203) are in production and priced at $5 and $1.50 respectively. Contact Avance Logic at 46750 Fremont Blvd, Suite 105, Fremont, CA 94538; 510/ 226-9555, fax 510/226-8039.

Wingine (64000), Winglue (64201) and 82C481 are all in production. Pricing is $7 for Winglue, $18 for Wingine and $32 for the '481. A special price of $36 is available for Wingine and the '481 as a set. All pricing is in quantities of 10,000. Contact Chips and Technologies at 3050 Zanker Road, San Jose, CA 95134; 408/434-0600.

The standardization of VL-Bus should increase the demand for local-bus graphics chips, as they can offer a significant performance improvement at very little cost. Most vendors also plan to support Intel's new PCI bus *(see **060902.PDF**)* by mid-1993, about the time that PCIbased systems are expected to reach the market. No one is sure whether PCI solutions will outperform VL-based graphics, but both should co-exist in the market for some time. No matter which bus is used, hardware-acceleration products will have to work hard to stay ahead of frame buffer chips attached to fast 486s and P5 processors. ♦

Manufacturer / Chip Name	Bus Interfaces Supported				Max Memory		Accelerated Functions	WinMarks	Chip Price
	ISA	EISA	VL	MCA	DRAM	VRAM			
Weitek Power 9000	✔	✔	✔	—	—	4M	BitBLT, line draw, many more	28/33*	$70+$15**
Weitek W5186	✔	✔	—	—	1M	1M	BitBLT, line draw	5	$15
S3 86C928	✔	✔	✔	—	—	4M	BitBLT, line draw, many more	29 (est.)	$65
S3 86C805	✔	✔	✔	—	2M	—	BitBLT, line draw, many more	16.5	$35
S3 86C801	✔	—	—	—	2M	—	BitBLT, line draw, many more	14	$29
Avance GUI Ultra	✔	✔	✔	—	2M	—	BitBLT, line draw, many more	20	$25
C&T 82C481	✔	✔	—	✔	—	4M	BitBLT, line draw, many more	20	$32+$4**
C&T Wingine	C&T proprietary only				—	2M	none	15	$18

*Higher number assumes 2M of VRAM; all others use 1 M. **Cost of VGA emulation chip (not included in main chip).

Table 2. Summary comparison of PC graphics accelerator chips from Weitek, S3, Avance, and Chips and Technologies.

