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WHITE PAPER

The AMD Opteron Processor and the Transition to Industry-Standard 64-Bit Workstation Computing

Sponsored by: Advanced Micro Devices Inc.

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May 2004

IDC OPINION

Over the past few years, buyers of technical workstations have moved toward platforms based on industry-standard processors, with proprietary workstations increasingly relegated to highly specialized applications that rely on system capabilities that require 64-bit functionality. As technical applications grow more complex, IDC forecasts that systems based on standard 64-bit processors will make up a growing share of the technical workstation market.

Advanced Micro Devices Inc. (AMD) will play an important role in this market transition with its AMD Opteron™ processor line. This role is one of bringing 64-bit capabilities to the x86 workstation world and bridging the gap between 32-bit and 64-bit environments with simultaneous support for both environments. AMD is targeting users who wish to make a gradual transition from 32-bit to 64-bit computing with systems that can run both 32-bit and 64-bit applications in native mode.

Market factors that contribute to the opportunity for AMD in the technical workstation space include:

- Users' desires to attain standardization despite escalating application demands
- Affinity in the high-performance computing community for new processor technologies
- Widespread availability of 64-bit Linux implementations
- Growth in independent software vendor (ISV) support of 64-bit application certification and optimization

With these market factors in place, many technical users are seeking to add 64-bit computing capabilities to their environments. For these users, the introduction of integrated 32-bit/64-bit technical workstations based on standard processors is welcome. As vendors such as IBM and Fujitsu Siemens begin to roll out AMD Opteron processor–based workstations for this segment, AMD is positioned to benefit from these market trends.

IN THIS WHITE PAPER

This white paper discusses the migration from proprietary to standard processor families in the technical workstation market. It covers issues such as the drivers behind the adoption of standard processor platforms in the technical workstation market, the motivation behind retaining proprietary 64-bit platforms, and factors that will come into play as users seek to move to standard 64-bit platforms.

In addition, the white paper examines the attributes of the AMD Opteron processor, including its system performance and balance and its dual 32-bit/64-bit compatibility, which allows for easier adoption into a standards-based environment.

The document also profiles several application segments within the technical workstation market that can benefit most from the increased memory address space and performance of 64-bit computing. These application areas include:

- Oil and gas exploration
- Electronic design automation (EDA)
- Life sciences and drug discovery
- Digital content creation
- Manufacturing, including structural analysis, mechanical computer-aided design (MCAD), and computational fluid dynamics (CFD)

Further, the white paper identifies the challenges and opportunities for AMD in the technical workstation market.

SITUATION OVERVIEW

The high-performance workstation market continues to migrate away from systems based on proprietary 64-bit processors in favor of standard, or volume, 32-bit processors. IDC uses the term *standard*, or *volume*, computer processors to describe CPUs designed and manufactured by chip companies such as AMD that sell these components to a large community of computer systems vendors for integration into a wide range of computer products.

Drawn by lower price per CPU and a nonproprietary environment, technical workstation users have opted for these relatively less expensive standard processor–based workstations for all but the most demanding applications, for which they retain their high-end Unix workstations. IDC forecasts the trend toward standards-based systems to continue through 2005 (see Figure 1).

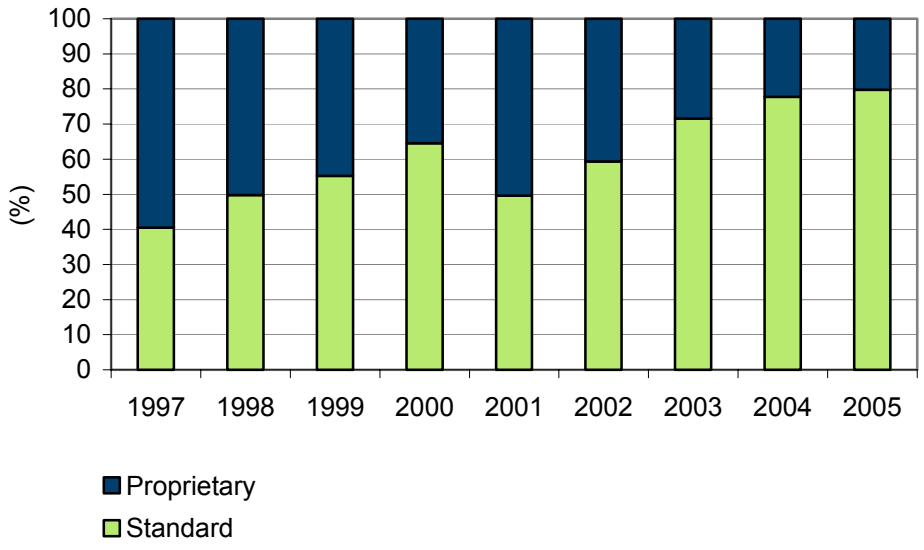
Many organizations have retained 64-bit workstation environments because of the need to support applications that require 64-bit capabilities and that cannot be easily migrated to a 32-bit architecture. At the same time, data sets in certain technical segments have continued to grow. This growth has inhibited the movement of these

applications onto standard platforms, mainly because 32-bit operating environments limit applications to 4GB of memory address space per operating system kernel.

AMD has observed this trend and is positioning AMD Opteron processor–based workstations as a vehicle for introducing 64-bit capabilities without disrupting an existing 32-bit environment.

FIGURE 1

Percentage of Workstations Using Standard Versus Proprietary RISC Processors by Worldwide Revenue, 1997–2005



Source: IDC, 2004

THE BENEFITS OF 64-BIT COMPUTING

The primary benefit of 64-bit computing is its ability to address large amounts of memory. Workstations based on 32-bit architectures can address a total of 4GB of memory per operating system. However, part of that memory needs to be allocated to the kernel and other system resources, which can limit the size of problems that a 32-bit architecture can address. If an application exceeds this limitation, it needs to start swapping data to disk in virtual memory, reducing the application's performance.

On a 64-bit architecture, this limitation is removed, extending the theoretical limit of memory addressability to hundreds of terabytes for a single data file. Therefore, systems vendors have no practical limit to the amount of memory they could configure into their systems. Working with larger memory spaces enables scientists, engineers, and designers to work with more complex models, potentially increasing productivity and innovation.

Another benefit of 64-bit computing is increased precision of calculations. Many scientific and engineering applications take advantage of the additional precision of 64-bit floating-point computations in building more accurate models or more realistic simulations.

Furthermore, several application segments in the technical workstation market have experienced growth in the average size of data files associated with their applications. The following sections describe the application areas in which 64-bit computing provides the greatest potential benefit.

Oil and Gas Exploration

Oil and gas companies use high-performance computing tools to help find new energy resources and optimize the extraction of these resources. The applications fall into two primary categories: seismic processing and reservoir simulation. Seismic processing applications analyze seismic waves captured from the detonation of underground explosions to help determine the location of oil reserves, improving the success rates in drilling. Reservoir simulation applications then model the oil reservoirs to help oil and gas companies devise the best strategies for extracting these reserves.

Geologists can study these models at low resolutions on 32-bit workstations, but the data sizes are growing and higher fidelity — especially for reservoir simulation — is desired. The full data sets can range up to hundreds of gigabytes in size. To view these models, many oil and gas companies have dedicated systems or environments for 64-bit visualization. A transition to 64-bit computing would provide geologists with more power to study complete subterranean models at the workstation level.

Life Sciences and Drug Discovery

Most life sciences users migrated from proprietary 64-bit platforms to lower-cost, open source, 32-bit platforms in the late 1990s and early 2000s for their computational tasks. But at that time, most data sets associated with common biosciences applications such as BLAST and GAMESS fit comfortably within a 4GB memory allocation.

Today, those data sets are getting larger — some of them up to the 10GB range — and the market itself also has some different dynamics. Genomics is giving way to proteomics, a more complicated discipline with larger data sets. Proteomics makes extensive use of visualization for molecular imaging and 3D simulations. Also, biosciences firms are incorporating drug discovery into their business models, again with an increase in data. Selective migration of certain applications to 64-bit computing would allow these companies to optimize their performance levels, but they will do so only if these applications can be integrated into their existing 32-bit environments.

The trend in clinical diagnostics is to incorporate imaging with other diagnostic tools, including genomics. These integrated medical stations require increased processing power and the ability to handle large files such as radiology or CT scans. Because several applications must coexist, this market will adopt 64-bit computing only if it also supports 32-bit applications.

Digital Content Creation

Digital content creation for the entertainment industry has also largely migrated to industry-standard computing, currently deploying proprietary 64-bit solutions only for the highest-end jobs. As the demands of complex special effects increase, however, filmmakers faced the challenge of producing the highest-quality images possible, without slowing down the entire production pipeline, which could lead to delays and potential cost overruns.

Digital artists seek to work with images that are as close to the final product as possible, and rendering these complex images can take long periods. Rendering applications can realize a performance benefit from a 64-bit environment, allowing artists to work with more lifelike images in real time, which increases creative control over the final output while speeding the production pipeline. In addition, feature films require increasingly sophisticated methods of asset management to handle the large amounts of digital assets involved. Multiple artists often work on different sections of the same image simultaneously, and the large databases that manage the complex interdependences and huge data volumes can benefit from 64-bit memory addressability.

Manufacturing

The performance and memory benefits of 64-bit computing apply to several manufacturing disciplines, including mechanical CAD (MCAD); computer-aided engineering (CAE); computational fluid dynamics (CFD); finite element analysis (FEA); crash testing; noise, vibration, and harshness (NVH) testing; and structural analysis.

The biggest benefit of 64-bit workstations in manufacturing environments is their ability to handle larger models at the personal computing level at a predictable level of application performance. Bolstered by the success of computational analysis, manufacturers are moving toward a complete cycle of virtual (or computational) prototyping in the design and testing phases. To benefit from the improvements in the testing phase, designers are increasing the completeness of their models in the design phase. They are modeling entire products, not sections, with increased structural detail. Also in the design phase, analysis tools integrate with the MCAD programs and create demand for scalable multiprocessing on large memory models.

In the testing phase, detailed analysis of the model's behavior is done with both static and animated images. With several seconds of behavior being modeled at a time, the file sizes grow dramatically. Because the engineer is looking for precise behaviors, the workstation must have fast access to memory to avoid jerky movement.

Electronic Design Automation

The goal of EDA is the ability to design, test, and revise the design as quickly as possible. When performed rapidly, these design-turn iterations can dramatically shorten time to market. As a result, EDA professionals have sought high-performance workstations to support these demanding requirements. At the same time, integrated circuit designs continue to get more complex. A single design today might incorporate

more than 100 million individual devices. The associated data files are growing, and many EDA users have retained 64-bit environments to more effectively manage them.

As design complexity grows and device geometries shrink with large data sets, verification becomes a bottleneck. To meet the demand for more compute power created by the EDA tools, many organizations have deployed workstation and server farms running around the clock. Such solutions, however, are cost-prohibitive, leading the move toward lower-cost, 32-bit x86-based hardware. As a result, there is a considerable presence of industry-standard hardware already in the EDA segment.

Other High-Performance Computing

Many universities and research labs have homegrown applications, in a variety of disciplines, that are subject to data bloat. In situations where large servers are shared resources, scientists and engineers will frequently need to work as much as possible on their own workstations, reserving time on the central resources only when necessary. A 64-bit workstation with additional memory can help researchers do more work on their own while waiting for an allocation of system time. Universities and research labs may also find 64-bit capability beneficial in data visualization applications.

THE AMD OPTERON™ PROCESSOR AND THE AMD64 INSTRUCTION SET ARCHITECTURE

AMD has designed many features into the AMD Opteron processor and its AMD64 Instruction Set Architecture (ISA) that are applicable to the technical workstation market. Some of the key features of the AMD Opteron processor for this market are:

- Strong floating-point and integer performance
- The ability to run both 32-bit and 64-bit applications in native mode under a single 64-bit operating system
- An industry-standard ISA built on top of the x86 ISA
- System costs that are comparable to those of competing 32-bit processors
- AMD's Direct Connect Architecture, which integrates the memory controller directly into the CPU and provides dedicated HyperTransport links from I/O to CPU and from CPU to CPU

For technical workstations, performance and price/performance are frequently the top-line purchasing criteria. AMD Opteron processors offer integer and floating-point performance near the top of the industry at costs below those of competing 64-bit processors.

For most users, however, true capability is more important than theoretical performance. Users who need to incorporate 64-bit computing into their environments will require the ability to run their existing 32-bit applications without degradation in performance. It is in this area that the AMD Opteron processor, or more specifically the AMD64 ISA, offers its greatest strengths: It allows 32-bit and 64-bit applications to

run on the same processor and 32-bit applications to run without modification or performance penalty.

The AMD64 ISA is an implementation of the x86 ISA that includes the addition of "long-mode" execution on the processor. Long-mode execution enables applications to run either in "64-bit mode," which allows maximum memory addressability and increased floating-point precision, or in "compatibility mode," which allows 32-bit programs to run natively in hardware at full speed under the same 64-bit operating system.

Because AMD64 ISA is a straightforward extension to x86, 32-bit applications do not need to be recompiled to run natively — even to run in long mode under a 64-bit operating system. Because the applications run in native mode on essentially an x86 instruction set, they do not experience the degradation in performance that is common to 32-bit applications that are run under 64-bit operating environments in 32-bit emulation modes.

Some 32-bit applications can perform even better in AMD64 ISA compatibility mode than they do on 32-bit processors because AMD64 ISA allows the operating system kernel to run in a different virtual memory space than the application does. This allows the application to take advantage of the full memory space without conflicts.

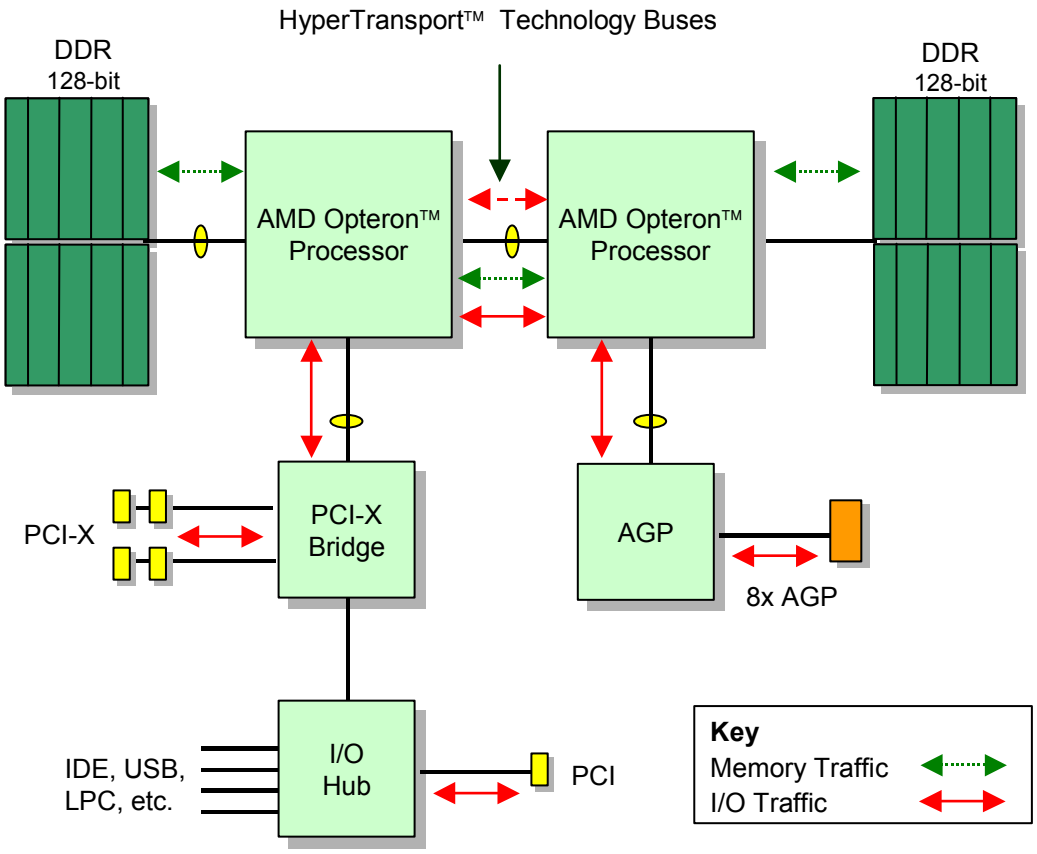
In addition to its long mode, the AMD64 ISA has a "legacy mode" that supports 32-bit (and 16-bit) applications under 32-bit operating systems. The result is a fully integrated 32-bit and 64-bit environment, in which software vendors or end users can migrate selected applications to 64-bit computing at their own pace, as dictated by individual application needs. Many of the initial deployments of AMD Opteron processor–based workstations are expected to run 32-bit operating systems with an upgrade to a 64-bit operating system in the future.

Workstation users have more significant memory, I/O, and processing needs than do desktop users. Desktop systems typically do not provide the balance between memory performance, I/O performance, and CPU performance required by technical workstation users. To provide efficiency in memory, I/O, and CPU communication, AMD has addressed these needs in the following ways with its Direct Connect Architecture:

- The memory controller is integrated with the CPU, and the memory path is distinct from the I/O bus.
- The I/O bus is directly connected to the processor die over its own HyperTransport link.
- In dual-processor configurations, the CPUs are also directly connected to each other with a dedicated HyperTransport link that supports interprocessor communication for both memory and I/O traffic (see Figure 2).

FIGURE 2

AMD Opteron Processor–Based 2P Workstation



Source: Advanced Micro Devices Inc., 2004

64-BIT LINUX

Another market dynamic working in favor of the AMD Opteron processor is the increasing presence of 64-bit Linux. AMD is targeting user segments that are driven by a desire for standardization, and this desire extends to the operating environment as well.

Most of the technical segments in which 64-bit computing is relevant — such as life sciences, oil and gas, and EDA — show a high degree of Linux affinity, and high-end systems vendors with Linux solutions are pushing the ISV community toward 64-bit Linux certification. Many technical computing users and ISVs are running 32-bit Linux in production mode already, and 64-bit Linux is a natural migration forward.

The availability of certified 64-bit Linux solutions provides a comfortable landing pad for ISVs and workstation users who wish to migrate from 32-bit to 64-bit computing. If 64-bit Linux continues to grow in functionality and market share, AMD will benefit.

CHALLENGES/OPPORTUNITIES

With growing momentum around industry-standard 64-bit architectures, AMD is introducing the AMD Opteron processor at a time of emerging opportunity. IBM is the first major systems vendor to release an AMD Opteron processor–based workstation, and IBM, Sun, and HP all offer AMD Opteron processor–based servers. Thus, AMD has the opportunity to strike quickly at a market segment that is new but growing: industry-standard workstations with 64-bit capabilities.

Intel will also gain volume in this segment with Itanium-based solutions, but AMD processors are unique in their ability to run both 32-bit and 64-bit applications in native mode, making AMD a compelling alternative for certain applications. As the market continues to move toward both industry-standard computing and 64-bit requirements, IDC expects AMD to be well-positioned with workstations that use the AMD Opteron processor.

Although the initial focus of the AMD Opteron processor has been in the server market, IDC expects workstation products based on AMD Opteron will become more prevalent. Increased adoption of AMD Opteron in server platforms would bolster the adoption of the processor in the technical workstation space as it receives increased visibility, credibility, and support.

IDC also expects the workstation market will undergo continued price pressure, which will continue to work against proprietary architectures that carry higher cost bases.

AMD must establish its presence in a market where Intel retains a reputation as the provider of the industry vision for industry-standard processors. The features of AMD Opteron are already attracting attention from high-performance workstation users, and technical users are likely to evaluate and adopt new technologies as a way of gaining competitive advantage. This inherent interest in the leading edge should give AMD a receptive audience for establishing itself in the technical workstation market.

AMD must also work to promote a complete ecosystem for AMD Opteron processor–based solutions in the workstation market, including hardware components, platform software, applications, and systems. At present, an entrenched market of industry-standard, 64-bit workstations does not exist; therefore, AMD has the opportunity to move in early and grow with the market. Support from IBM is a positive sign for AMD; AMD must aim for broader product offerings and more OEMs for AMD Opteron to continue to gain momentum.

IDC believes the emergence of more 64-bit workstation applications will influence the growth of 64-bit workstations. AMD has made significant progress in this area already. A number of ISVs have announced support for native applications for the AMD Opteron processor, including Linux applications from Cadence and Mentor Graphics, as well as many development tools. To the extent that the processor design enables simultaneous usage of both 32-bit and 64-bit applications, AMD is hopeful that ISVs will be able to do a fast porting and certification of applications, adding to the support network for AMD Opteron. Another benefit is that the AMD Opteron processor is designed to run 32-bit applications as is, which allows end-user organizations to continue to use existing applications while new 64-bit versions are developed, tested, and deployed.

Further, AMD must continue to demonstrate its financial and technological stability. Recent profitable results are encouraging, as is increased support from key industry players, especially from IBM, HP, and Sun.

CONCLUSION

AMD is positioning its AMD Opteron processor in the workstation space to fill a market need for workstation users who wish either to migrate away from proprietary architectures while still retaining 64-bit capabilities or to integrate 64-bit computing capabilities into their existing 32-bit environments. Users in the latter group desire the ability to make an easy transition from 32-bit to 64-bit as their requirements dictate, which AMD can accommodate with the AMD64 ISA.

The market for standard workstations with 64-bit capabilities is small but growing. The ability of the AMD Opteron processor to run existing applications without modification is a strong capability that will facilitate the transition to 64 bits and appeal to many workstation users who are looking to make the move in an orderly and cost-effective way.

AMD has worked diligently over the past several years to build relationships that will help to support and promote the AMD Opteron processor. Having lined up industry heavyweights such as IBM, Sun, Microsoft, and Oracle, AMD has evolved from its roots as a second source of x86 processors and has become an independent platform developer capable of challenging Intel. However, AMD faces challenges in establishing a strong presence in the technical workstation market over the short term. Most notable are Intel's market reputation as the industry leader in standard architectures and the gradual ramp of 64-bit workstation adoption that IDC anticipates. Still, the introduction of the AMD Opteron processor and its support from key platform providers and software partners come at a time when the market is ready for industry-standard platforms with 64-bit capabilities. There is significant opportunity for AMD to move toward gaining market share and to become a greater presence in the emergence of 64-bit workstation computing.