

**NVIDIA Windows® Display
Drivers for AMD64 Processors**

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Executive Summary

AMD64 is a new computing platform that extends the ubiquitous x86 architecture to 64-bits. Formerly known as x86-64, AMD's enhancements to the x86 architecture allow users of 32-bit laptops, desktops, workstations and servers to migrate seamlessly to the superior performance of 64-bit technology. NVIDIA has ported their graphics display drivers to Windows® XP Professional and Server for AMD64 to support software developers and end users. Developer versions of these drivers are available today directly from NVIDIA.

64-bit Computing on the Desktop

A design engineer working at one of the nation's auto manufacturers today likely has at least two computer systems in his office: a desktop PC running 32-bit productivity applications such as word processing, e-mail and spreadsheets as well as a dedicated, Unix-based, proprietary workstation running sophisticated, 64-bit computer aided design (CAD) applications. Working with NVIDIA, the worldwide leader in visual processing solutions, AMD aims to provide this business professional with an AMD Opteron™ processor-based computing solution that offers outstanding performance on both everyday office applications and compute-intensive design applications - all on one system. Users can now have one workstation that allows them to natively run their 32-bit PC applications while simultaneously running 64-bit applications like those previously relegated to expensive, proprietary Unix-based systems.

AMD and NVIDIA have been working together since 1993. NVIDIA's platform products group produces platform processors, also called core-logic chipsets. These products provide the technology that powers computer motherboards (with the exception of the microprocessor), including graphics, video, audio and networking functionality. As the leading supplier of graphics technology to both consumer and professional computing environments, NVIDIA counts among its customers many Fortune 500 companies including top auto manufacturers, many of the world's largest banks and financial institutions, major Hollywood film studios and special effects houses as well as medical imaging companies.

“AMD is our number one technology partner because we share a vision of providing customers with the highest level of computing performance. We're looking forward to taking the next step with the AMD Opteron processor and being able to offer the leap in performance that 64-bit computing will bring.”

Drew Henry
Senior Director of Platform Products, NVIDIA Corporation

AMD64 Instruction Set Architecture Overview

AMD64 defines a new class of computing by combining x86 compatibility, a high-performance 64-bit architecture, and economics of an industry standard processor. AMD64 allows the technology industry to build solutions focused on customer needs while removing barriers to future innovation. The AMD Opteron and upcoming AMD Athlon™ 64 processors are AMD's first milestones in building this new class of computing. Investments in 32-bit x86 applications are preserved as they can run on AMD64 platforms. Over time, 64-bit applications can be phased-in, allowing customers to control development and deployment costs and migrate gradually according to business needs.

To enable 32-bit compatibility along with 64-bit native applications, the AMD64 Instruction Set Architecture (ISA) supports a new execution mode called *long mode* that supports 64-bit computing. Long mode has two sub-modes: *64-bit mode* and *compatibility mode*. 64-bit mode supports native 64-bit applications that can take advantage of the extended registers and 64-bit addressing. Compatibility mode enables 32-bit applications to run at full speed in hardware alongside 64-bit applications. Users will preserve their investment in 32-bit software while leveraging 64-bit applications that can offer significant performance improvements. The AMD64 operating modes are shown in Table 1 below.

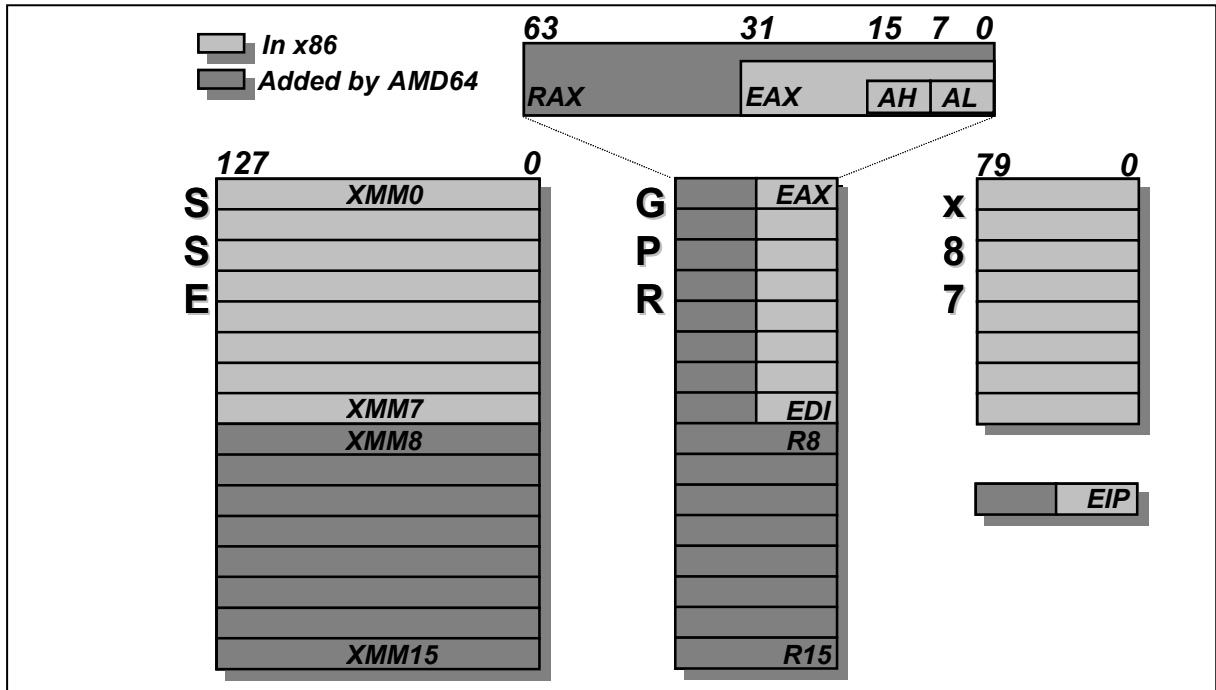
Table 1 - AMD64 Operating Modes

Operating Mode		OS Required	Application Recompile Required	Defaults		Register Extensions	Typical GPR Width
				Address Size (bits)	Operand Size (bits)		
Long Mode	64-bit Mode	New 64-bit OS	Yes	64	32	yes	64
	Compatibility Mode		No	32		no	32
				16	16		16
Legacy Mode	Protected Mode	Legacy 32-bit OS	No	32	32	no	32
				16	16		
	Virtual-8086 Mode	Legacy 16-bit OS		16	16		16
	Real Mode						

The AMD64 programming model, shown in Figure 1, is based on the industry-standard 32-bit x86 model enhanced to support 64-bit programming. The eight General Purpose Registers (GPRs) have been widened to 64-bits to support 64-bit addressing and 64-bit integer math. The Extended Instruction Pointer (EIP) has also been widened to support execution of code beyond the lower 4 GB addressing range. Additionally, eight other General Purpose Registers, referred to as the extended GPRs, and eight XMM registers, referred to as the extended XMM registers, have been added. These additional registers are available to native 64-bit programs only.

All x86 instructions have been brought forward into the AMD64 ISA. These instructions have been extended to support 64-bit data types where applicable. Only a handful of other instructions have been added, mostly to support sign extension to 64-bits.

Figure 1 – AMD64 Programming Model

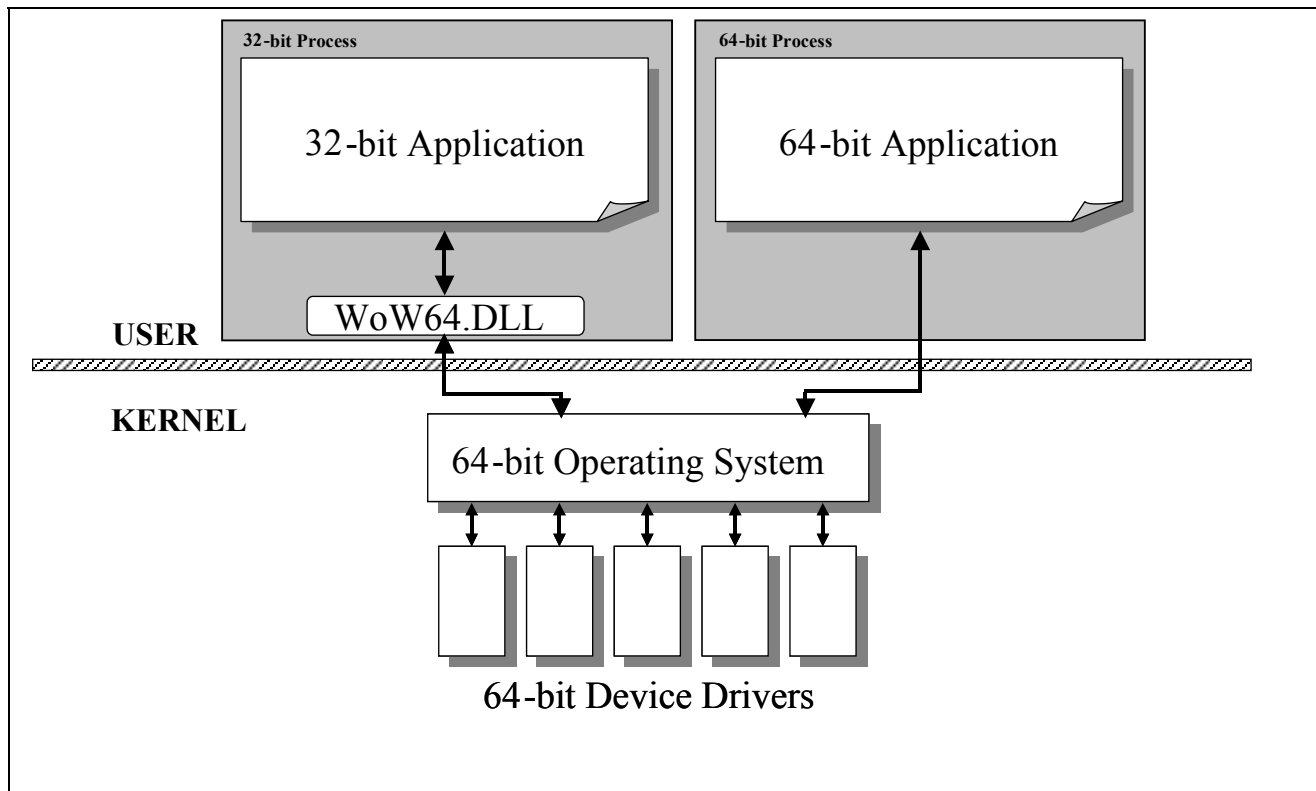


The Need for 64-bit Device Drivers

Most modern operating systems have built-in support for AMD64 Compatibility Mode. Windows supports this through the Windows on Windows subsystem (WoW). The WOW64.DLL converts function arguments from 32-bit to 64-bit and return values from 64-bit to 32-bit. This conversion requires very low overhead as most of the computations involve adding leading zeros or truncating values to 32 bits. Address translation is from flat 32-bit to flat 64-bit. Figure 2 illustrates how 32-bit and 64-bit applications interact with the Windows Operating System and Device Drivers.

All kernel components must be 64-bit in a 64-bit Operation System. Since device drivers are all kernel mode components, then all device drivers must be ported to AMD64 to run on 64-bit versions of Windows.

Figure 2 - Application / OS Interaction



Porting to AMD64

Because the AMD64 ISA is an extension to the x86 instruction set, it allows software engineers to leverage their years of knowledge and experience with the industry-standard x86 ISA. Compared to learning an entirely new architecture, developers have a relatively easy time mastering the AMD64 assembly language, programming tools, and optimization techniques.

The NVIDIA team ported their display driver in three steps. The first step involved getting the driver to recompile properly for AMD64. The NVIDIA graphics drivers are heavily optimized for the x86 ISA and tend to have quite a bit of in-line assembly language. Win64 differs from Win32 in that it does not support in-line assembly language. Instead, a full complement of assembly intrinsics are supported in addition to assembly language source files. The NVIDIA development team used a combination of intrinsics, C language code, or dropping the code entirely using preprocessor constructs. Much of this work had already been done for other platforms so it was turned on for the AMD64 build also.

The next step involved getting the code reasonably stable (mostly eliminating pointer truncation) with many optimizations turned off due to heavy reliance on exact details of the x86 architecture.

The final and ongoing step was to fully optimize the code path for AMD64. This involved moving inline assembly into separate source files and doing preprocessor tricks to abstract 32-bit versus 64-bit register sizes and calling convention differences. Future work involves using the AMD64 extended registers to get additional performance. This may involve forking the source code for selected routines.

“With the AMD team, we have been working passionately on this product to help ensure that it will offer the value and performance that our customers have come to expect. We think the AMD Opteron™ processor will lead the way to bring 64-bit computing to many more users and we’re excited to be a part of that effort.”

**Drew Henry
Senior Director of Platform Products, NVIDIA Corporation**

The AMD64 version of Windows XP Professional is planned to support OpenGL 2.0 as well as Direct X 9 for native 64-bit applications. Additionally, Windows XP Pro for AMD64 is planned to support DirectX 7, DirectX8, and DirectX 9 for 32-bit applications under WoW64.

Developer versions of the AMD64 NVIDIA display drivers are available to registered NVIDIA partners at www.nvidia.com.

AMD Overview

AMD is a global supplier of integrated circuits for the personal and networked computer and communications markets with manufacturing facilities in the United States, Europe, and Asia. AMD produces microprocessors, Flash memory devices, and support circuitry for communications and networking applications. Founded in 1969 and based in Sunnyvale, California, AMD had revenues of approximately \$2.7 billion in 2002. (NYSE: AMD).

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