RAM Allocation with Microsoft Windows XP and HP Commercial Desktops
V1.1

This white paper discusses the limitation of RAM allocation using a 32-bit operating system such as Microsoft Windows XP on HP x86-based commercial desktop PCs. Intel 945-based chipset and older commercial desktop systems are covered by this paper.

In the current world of operating systems (OS), there are 32-bit OSes and 64-bit OSes. Microsoft Windows XP, both Home and Professional, are 32-bit OSes. Microsoft Windows XP Professional x64 is a 64-bit OS.

Windows XP Home / Professional, along with all other 32-bit OSes, supports a memory address range of up to 4GB for both virtual and physical memory addresses. In practice, available RAM is always less than 4GB. This is because system components require some of the available memory addresses so that less is available for the operating system. The reasons for this limitation are explained below.

HP commercial desktop systems with Intel 865, Intel 915, Intel 945, and ATI RS480 chipsets support up to 4GB of RAM.

Windows XP Professional x64 is a 64-bit operating system and it supports up to 32GB of memory addressing. But this is just one component to large addressing. In addition to the OS, the entire system must also supports greater than 4GB memory addressing for large addressing to occur. This includes the processor, chipset, physical memory capacity, etc.

There are currently no HP commercial desktop systems that support more than 4GB of RAM. Certain systems can physically accommodate more than 4GB of RAM on the system board, but the excess memory will not be used because of the 32-bit desktop chipset limitations.

Why is 4GB the Limit?

In addition to the 64-bit OS requirement necessary to support greater than 4GB system memory, there are also other hardware requirements. These hardware requirements include the processor, chipset, and the amount (greater than 4GB) of physical system memory configured in the PC.

All 32-bit x86 processors have 32-bits of addressing capability. With 32 address lines, 4GB of memory space can be addressed logically:

$2^{32} = 4,294,967,296 = 4GB$

In order to go beyond the 4GB limit, a processor must have greater than 32-bit addressing. There are two ways of accomplishing this: PAE and 64-bit processing.

Physical Address Extension (PAE) is a mode allowing a 32-bit x86 processor to use an additional 4 bits for addressing creating a 36-bit address.

$2^{36} = 68,719,476,736 = 64GB$

A 64-bit capable x86 processor such an Intel Pentium4 with EM64T uses 64-bit addressing. These processors can run 64-bit OSes.

$2^{64} = 18,446,744,073,709,551,616 = 16EB$ (exabyte 10^{18})

Note: Although a processor can address up to 16EB in theory, the OS and the chipset it is supporting can have a much lower limit. For example, Microsoft Windows Professional x64 can only address up to 32GB and a 32-bit chipset is still limited to 4GB.

Note: Total physical memory and memory addressing is not to be confused with the amount of virtual memory available to the OS. No matter how much physical memory is in the system, 32-bit OS will have 4GB of virtual memory through paging.

How Does the Limit Work?

Physical memory addresses are divided into two sections: the PCI memory address range (also known as Memory Mapped I/O) and the RAM available to the operating system. This is why even with 4GB of memory, available RAM is less than 4GB.

PCI memory address space is used by the BIOS, I/O cards, networking, PCI hubs, bus bridges, PCI Express, and graphics cards to transfer data. It starts at the top of memory at 4GB and takes memory addressing to lower address ranges. PCI Express alone takes up 256MB of address space and each component also takes up an additional amount. Therefore, it is very easy for a system with 4GB of physical memory to lose 512MB or more address space before any RAM addressing is allocated.

RAM addressing starts at 0MB and takes memory addresses to higher address ranges up to the bottom of PCI memory address space, which is around 3GB to 3.4GB. The bottom of PCI memory address space may fall outside of this range depending on system configuration, especially if more than one graphics card is installed.

Address Range Map
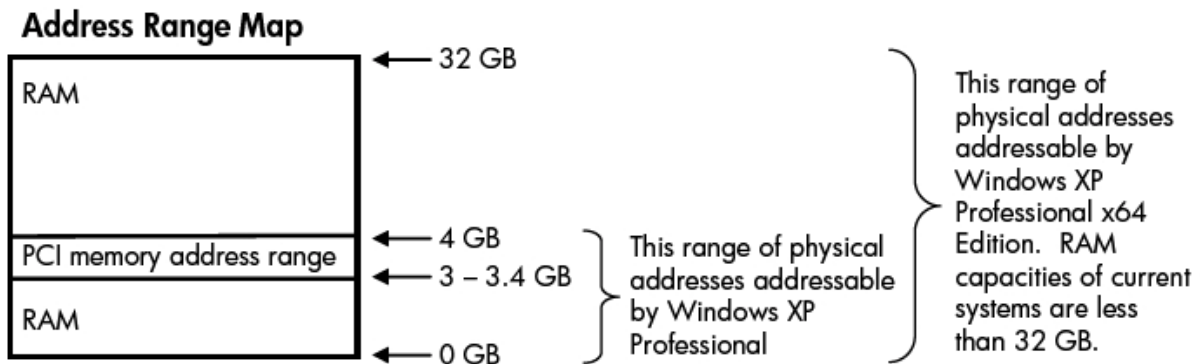
What Is Being Done?

The 4GB memory limitation is a well known industry architectural problem and HP is working towards a 64-bit commercial desktop solution. In the near future, HP commercial desktop PCs will have all the components (processor, chipset, and OS) necessary to support 64-bit computing with greater than 4GB of physical memory.

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