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Technology Research Paper: Microprocessors

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EVOLUTION OF THE MICROPROCESSOR

INTRODUCTION

The Collegiate Webster dictionary describes microprocessor as a computer processor contained on an integrated-circuit chip. In the mid-seventies, a microprocessor was defined as a central processing unit (CPU) realized on a LSI (large-scale integration) chip, operating at a clock frequency of 1 to 5 MHz and constituting an 8-bit system (Heffer, 1986). It was a single component having the ability to perform a wide variety of different functions. Because of their relatively low cost and small size, the microprocessors permitted the use of digital computers in many areas where the use of the preceding mainframe—and even minicomputers—would not be practical and affordable (Computer, 1996).

Many non-technical people associate microprocessors with only PCs yet there are thousands of appliances that have a microprocessor embedded in them—telephone, dishwasher, microwave, clock radio, etc. In these items, the microprocessor acts primarily as a controller and may not be known to the user.

The Breakthrough in Microprocessors

The switching units in computers that were used in the early 1940s were the mechanical relays. These were devices that opened and closed as they did the calculations. Such mechanical relays were used in Zuse's machines of the 1930s.

Come the 1950s, and the vacuum tubes took over. The Atanasoff-Berry Computer (ABC) used vacuum tubes as its switching units rather than relays. The switch from mechanical relay to vacuum tubes was an important technological advance as vacuum tubes could perform calculations considerably faster and more efficient than relay machines. However, this technological advance was short-lived because the tubes could not be made smaller than they were being made and had to be placed close to each other because they generated heat (Freiberger and Swaine, 1984).

Then came the transistor which was acknowledged as a revolutionary development. In "*Fire in the Valley*", the authors describe the transistor as a device which was the result of a series of developments in the applications of physics. The transistor changed the computer from a giant electronic brain to a commodity like a TV set. This innovation was awarded to three scientists: John Bardeen, Walter Brattain, and William Shockley.

As a result of the technological breakthrough of transistors, the introduction of minicomputers of the 1960s and the personal computer revolution of the 1970s was made possible.

However, researchers did not stop at transistors. They wanted a device that could perform more complex tasks—a device that could integrate a number of transistors into a more complex circuit. Hence, the terminology, integrated circuits or ICs. Because physically they were tiny chips of silicon, they came to be also referred to as chips. Initially, the demand for ICs was typically the military and aerospace industries which were great users of computers and who were the only industries that could afford computers (Freiberger and Swaine, 1984).

Later, Marcian “Ted” Hoff, an engineer at Intel, developed a sophisticated chip. This chip could extract data from its memory and interpret the data as an instruction. The term that evolved to describe such a device was “microprocessor”. Therefore, the term “microprocessor” first came into use at Intel in 1972 (Noyce, 1981). A microprocessor was nothing more than an extension of the arithmetic and logic IC chips corporating more functions into one chip (Freiberger and Swaine, 1984). Today, the term still refers to an LSI single-chip processor capable of carrying out many of the basic operations of a digital computer.

Infact, the microprocessors of the late eighties and early nineties are full-sclae 32-bit and 32-bit address systems, operating at clock cycles of 25 to 50 MHz (Heffer, 1986).

What led to the development of microprocessors?

As stated above, microprocessors essentially evolved from mechanical relays to integrated circuits. It is important to illustrate here what aspects of the computing industry led to the development of microprocessors.

(1) Digital computer technology

In the History of Computing class, we studied, throughout the semester, how the computer industry learned how to make large, complex digital computers capable of processing more data and also how to build and use smaller, less expensive computers. The digital computer technology had been growing steadily since the late 1940s.

(2) Semiconductors

Like the digital computer technology, semiconductors had also been growing steadily since the invention of the transistor in the late 1940s. The 1960s saw the integrated circuit develop from just a few transistors to many complicated tasks, all of the same chip.

(3) The calculator industry

It appears as if this industry grew overnight during the 1970s from the simplest of four-function calculators to very complex programmable scientific and financial machines.

From all this, one idea became obvious—if there was an inexpensive digital computer, there would be no need to keep designing different, specialized integrated circuits. The inexpensive digital computer could simply be reprogrammed to perform whatever was the latest brainstorm, and there would be the new product (Freiberger and Swaine, 1984).

The development of microprocessors can be attributed to when, in the early 1970s, digital computers and integrated circuits reached the required levels of capability. However, the early microprocessor did not meet all the goals: it was too expensive for many applications, especially those in the consumer market, and it could not hold enough information to perform many of the tasks being handled by the minicomputers of that time.

How a microprocessor works

According to Krutz (1980), a microprocessor executes a collection of machine instructions that tell the processor what to do. Based on the instructions, a microprocessor does three basic things:

- Using its ALU (Arithmetic/Logic Unit), a microprocessor can perform mathematical operations like addition, subtraction, multiplication and division. Modern microprocessors contain complete floating point processors that can perform extremely sophisticated operations on large floating point numbers.
- A microprocessor can move data from one memory location to another.
- A microprocessor can make decisions and jump to a new set of instructions based on those decisions.

There may be very sophisticated things that a microprocessor does, but those are its three basic activities. Put simply, it fetches instructions from memory, interprets (decodes) them, and then executes whatever functions the instructions direct. For example, if the microprocessor is capable of 256 different operations, there must be 256 different instruction words. When fetched, each instruction word is interpreted differently than any of the other 255. Each type of microprocessor has a unique instruction set (Short, 1987).

Archictecture of a microprocessor

This is about as simple as a microprocessor gets. It has the following characteristics:

- an **address bus** (that may be 8, 16 or 32 bits wide) that sends an address to memory;
- a **data bus** (that may be 8, 16 or 32 bits wide) that can send data to memory or receive data from memory;
- a **RD** (Read) and **WR** (Write) line to tell the memory whether it wants to set or get the addressed location;
- a clock line that lets a clock pulse sequence the processor; and
- a reset line that resets the program counter to zero (or whatever) and restarts execution.

A typical microprocessor, therefore, consists of: logical components—enable it to function as a programmable logic processor; program counter, stack, and instruction register—provide for the management of a program; the ALU—provide for the manipulation of data; and a decoder & timing and control unit—specify and coordinate the operation of other components.

The connection of the microprocessors to other units—memory and I/O devices—is done with the Address, Data, and control buses.

Generation of microprocessors

Microprocessors were categorized into five generations: first, second, third, fourth, and fifth generations. Their characteristics are described below:

First-generation

The microprocessors that were introduced in 1971 to 1972 were referred to as the first generation systems. First-generation microprocessors processed their instructions serially—they fetched the instruction, decoded it, then executed it. When an instruction was completed, the microprocessor updated the instruction pointer and fetched the next instruction, performing this sequential drill for each instruction in turn.

Second generation

By the late 1970s (specifically 1973), enough transistors were available on the IC to usher in the second generation of microprocessor sophistication: 16-bit arithmetic and pipelined instruction processing. Motorola’s MC68000 microprocessor, introduced in 1979, is an example. Another example is Intel’s 8080. This generation is defined by overlapped fetch, decode, and execute steps (Computer 1996). As the first instruction is processed in the execution unit, the second instruction is decoded and the third instruction is fetched.

The distinction between the first and second generation devices was primarily the use of newer semiconductor technology to fabricate the chips. This new technology resulted in a five-fold increase in instruction, execution, speed, and higher chip densities.

Third generation

The third generation, introduced in 1978, was represented by Intel's 8086 and the Zilog Z8000, which were 16-bit processors with minicomputer-like performance. The third generation came about as IC transistor counts approached 250,000. Motorola's MC68020, for example, incorporated an on-chip cache for the first time and the depth of the pipeline increased to five or more stages. This generation of microprocessors was different from the previous ones in that all major workstation manufacturers began developing their own RISC-based microprocessor architectures (Computer, 1996).

Fourth generation

As the workstation companies converted from commercial microprocessors to in-house designs, microprocessors entered their fourth generation with designs surpassing a million transistors. Leading-edge microprocessors such as Intel's 80960CA and Motorola's 88100 could issue and retire more than one instruction per clock cycle (Computer, 1996).

Fifth generation

Microprocessors in their fifth generation, employed decoupled super scalar processing, and their design soon surpassed 10 million transistors. In this generation, PCs are a low-margin, high-volume-business dominated by a single microprocessor (Computer, 1996).

Companies associated with microprocessors

Overall, Intel Corporation dominated the microprocessor area even though other companies like Texas Instruments, Motorola, etc also introduced some microprocessors. Listed below are the microprocessors that each company created.

(A) Intel

As indicated previously, Intel Corporation dominated the microprocessor technology and is generally acknowledged as the company that introduced the microprocessor successfully into the market.

Its first microprocessor was the 4004, in 1971. The 4004 took the integrated circuit one step further by locating all the components of a computer (CPU, memory and input and output controls) on a minuscule chip. It evolved from a development effort for a calculator chip set. Previously, the IC had had to be manufactured to fit a special purpose, now only one microprocessor could be manufactured and then programmed to meet any number of demands. The 4004 microprocessor was the central component in a four-chip set, called the 4004 Family: 4001 – 2,048-bit ROM, a 4002 – 320-bit RAM, and a 4003 – 10-bit I/O shift register. The 4004 had 46 instructions, using only 2,300 transistors in a 16-pin DIP. It ran at a clock rate of

740kHz (eight clock cycles per CPU cycle of 10.8 microseconds)—the original goal was 1MHz, to allow it to compute BCD arithmetic as fast (per digit) as a 1960's era IBM 1620 (Computer, 1996).

Following in 1972 was the 4040 which was an enhanced version of the 4004, with an additional 14 instructions, 8K program space, and interrupt abilities (including shadows of the first 8 registers). In the same year, the 8008 was introduced. It had a 14-bit PC. The 8008 was intended as a terminal controller and was quite similar to the 4040. The 8008 increased the 4004's word length from four to eight bits, and doubled the volume of information that could be processed (Heath, 1991).

In April 1974, 8080, the successor to 8008 was introduced. It was the first device with the speed and power to make the microprocessor an important tool for the designer. It quickly became accepted as the standard 8-bit machine. It was the first Intel microprocessor announced before it was actually available. It represented such an improvement over existing designs that the company wanted to give customers adequate lead time to design the part into new products. The use of 8080 in personal computers and small business computers was initiated in 1975 by MITS's Altair microcomputer. A kit selling for $395 enabled many individuals to have computers in their own homes (Computer, 1996). Following closely, in 1976, was 8048, the first 8-bit single-chip microcomputer. It was also designed as a microcontroller rather than a microprocessor—low cost and small size was the main goal. For this reason, data was stored on-chip, while program code was external. The 8048 was eventually replaced by the very popular but bizarre 8051 and 8052 (available with on-chip program ROMs). While the 8048 used 1-byte instructions, the 8051 had a more flexible 2-byte instruction set, eight 8-bit registers plus an accumulator A. Data space was 128 bytes and could be accessed directly or indirectly by a register, plus another 128 above that in the 8052 which could only be accessed indirectly (usually for a stack) (Computer, 1996).

In 1978, Intel introduced its high-performance, 16-bit MOS processor—the 8086. This microprocessor offered power, speed, and features far beyond the second-generation machines of the mid-70's. It is said that the personal computer revolution did not really start until the 8088 processor was created. This chip became the most ubiquitous in the computer industry when IBM chose it for its first PC (Frieberger and Swaine, 1984).

In 1982, the 80286 (also known as 286) was next and was the first Intel processor that could run all the software written for its predecessor, the 8088. Many novices were introduced to desktop computing with a "286 machine" and it became the dominant chip of its time. It contained 130,000 transistors.

In 1985, the first multi-tasking chip, the 386 (80386) was created. This multi-tasking ability allowed Windows to do more than one function at a time. This 32-bit microprocessor was designed for applications requiring high CPU performance. In addition to providing access to the 32-bit world, the 80386 addressed 2 other important issues: it provided system-level support to systems designers, and it was object-code compatible with the entire family of 8086 microprocessors (Computer, 1996). The 80386 was made up of 6 functional units: (i) execution unit (ii) segment unit (iii) page unit (iv) decode unit (v) bus unit and (vi) prefetch unit. The 80386 had

34 registers divided into such categories as general-purpose registers, debug registers, and test registers. It had 275,000 transistors (Noyce, 1981).

The 486 (80486) generation of chips really advanced the point-and-click revolution. It was also the first chip to offer a built-in math coprocessor, which gave the central processor the ability to do complex math calculations. The 486 had more than a million transistors. In 1993, when Intel lost a bid to trademark the 586, to protect its brand from being copied by other companies, it coined the name Pentium for its next generation of chips and there began the Pentium series—Pentium Classic, Pentium II, III and currently, 4.

(B) Motorola

The MC68000 was the first 32-bit microprocessor introduced by Motorola in early 1980s. This was followed by higher levels of functionality on the microprocessor chip in the MC68000 series. For example, MC68020, introduced later, had 3 times as many transistors, was about three times as big, and was significantly faster. Motorola 68000 was one of the second generation systems that was developed in 1973. It was known for its graphics capabilities. The Motorola 88000 (originally named the 78000) is a 32-bit processor, one of the first load-store CPUs based on a Harvard Architecture (Noyce, 1981).

(C) Digital Equipment Corporation (DEC)

In March 1974, Digital Equipment Corporation (DEC) announced it would offer a series of microprocessor modules built around the Intel 8008.

(D) Texas Instruments (TI)

A precursor to these microprocessors was the 16-bit Texas Instruments 1900 microprocessor which was introduced in 1976. The Texas Instruments TMS370 is similar to the 8051, another of TI's creations. The only difference between the two was the addition of a B accumulator and some 16-bit support.

Microprocessors Today

Technology has been changing at a rapid pace. Everyday a new product is made to make life a little easier. The computer plays a major role in the lives of most people. It allows a person to do practically anything. The Internet enables the user to gain more knowledge at a much faster pace compared to researching through books. The portion of the computer that allows it to do more work than a simple computer is the microprocessor.

Microprocessor has brought electronics into a new era and caused component manufacturers and end-users to rethink the role of the computer. What was once a giant machine attended by specialists in a room of its own is now a tiny device conveniently transparent to users of automobile, games, instruments, office equipment, and a large array of other products.

From their humble beginnings 25 years ago, microprocessors have proliferated into an astounding range of chips, powering devices ranging from telephones to supercomputers (PC Magazine, 1996). Today, microprocessors for personal computers get widespread attention—and have enabled Intel to become the world's largest semiconductor maker. In addition, embedded microprocessors are at the heart of a diverse range of devices that have become staples of affluent consumers worldwide.

The impact of the microprocessor, however, goes far deeper than new and improved products. It is altering the structure of our society by changing how we gather and use information, how we communicate with one another, and how and where we work. Computer users want fast memory in their PCs, but most do not want to pay a premium for it.

Manufacturing of microprocessors

Economical manufacturing of microprocessors requires mass production. Microprocessors are constructed by depositing and removing thin layers of conducting, insulating, and semiconducting materials in hundreds of separate steps. Nearly every layer must be patterned accurately into the shape of transistors and other electronic elements. Usually this is done by photolithography, which projects the pattern of the electronic circuit onto a coating that changes when exposed to light. Because these patterns are smaller than the shortest wavelength of visible light, short wavelength ultraviolet radiation must be used. Microprocessor features are so small and precise that a single speck of dust can destroy the microprocessor. Microprocessors are made in filtered clean rooms where the air may be a million times cleaner than in a typical home (PC World, 2000)).

Performance of microprocessors

The number of transistors available has a huge effect on the performance of a processor. As seen earlier, a typical instruction in a processor like an 8088 took 15 clock cycles to execute. Because of the design of the multiplier, it took approximately 80 cycles just to do one 16-bit multiplication on the 8088. With more transistors, much more powerful multipliers capable of single-cycle speeds become possible ( ).

More transistors also allow a technology called pipelining. In a pipelined architecture, instruction execution overlaps. So even though it might take 5 clock cycles to execute each instruction, there can be 5 instructions in various stages of execution simultaneously. That way it looks like one instruction completes every clock cycle (PC World, 2001).

Many modern processors have multiple instruction decoders, each with its own pipeline. This allows multiple instruction streams, which means more than one instruction can complete during each clock cycle. This technique can be quite complex to implement, so it takes lots of transistors.

The trend in processor design has been toward full 32-bit ALUs with fast floating point processors built in and pipelined execution with multiple instruction streams. There has also been a tendency toward special instructions (like the MMX instructions) that make certain operations particularly efficient. There has also been the addition of hardware virtual memory support and L1 caching on the processor chip. All of these trends push up the transistor count, leading to the multi-million transistor powerhouses available today. These processors can execute about one billion instructions per second! (PC World, 2000))

With all the different types of Pentium microprocessors, what is the difference? Three basic characteristics stand out:

- Instruction set: The set of instructions that the microprocessor can execute.
- bandwidth: The number of bits processed in a single instruction.
- clock speed**:** Given in megahertz (MHz), the clock speed determines how many instructions per second the processor can execute.

In addition to bandwidth and clock speed, microprocessors are classified as being either RISC (reduced instruction set computer) or CISC (complex instruction set computer).

Other uses of microprocessors

There are many uses for microprocessors in the world today. Most appliances found around the house are operated by microprocessors. Most modern factories are fully automated—that means that most jobs are done by a computer. Automobiles, trains, subways, planes, and even taxi services require the use of many microprocessors. In short, there are microprocessors everywhere you go.

Another common place to find microprocessors is a car. This is especially applicable to sports cars. There are numerous uses for a microprocessor in cars. First of all, it controls the warning LED signs. Whenever there is a problem, low oil, for example, it has detectors that tell it that the oil is below a certain amount. It then reaches over and starts blinking the LED until the problem is fixed. Another use is in the suspension system. A processor, controls the amount of pressure applied to keep the car leveled. During turns, a processor, slows down the wheels on the inner side of the curb and speeds them up on the outside to keep the speed constant and make a smooth turn.

An interesting story appeared in the New York Times dated April 16 and goes to show that there's no limit to what microprocessors can do and that resarchers and scientists are not stopping at the current uses of microprocessors. The next time the milk is low in the refrigerator, the grocery store may deliver a new gallon before it is entirely gone. Masahiro Sone, who lives in Raleigh, N.C., has won a patent for a refrigerator with an inventory processing system that keeps track of what is inside and what is about to run out and can ring up the grocery store to order more (NY Times, 2001).

Where is the industry of microprocessors going?

Almost immediately after their introduction, microprocessors became the heart of the personal computer. Since then, the improvements have come at an amazing pace. The 4004 ran at 108 kHz—that's kilohertz, not megahertz—and processed only 4 bits of data at a time. Today's microprocessors and the computers that run on them are thousands of times faster. Effectively, they've come pretty close to fulfilling Moore's Law (named after Intel cofounder Gordon Moore), which states that the number of transistors on a chip will double every 18 months or so. Performance has increased at nearly the same rate (PC Magazine, 1998).

Can the pace continue? Well, nothing can increase forever. But according to Gerry Parker, Intel's executive vice president in charge of manufacturing, “we are far from the end of the line in terms of microprocessor performance. In fact, we're constantly seeing new advances in technology, one example being new forms of lithography that let designers position electronic components closer and closer together on their chips. Processors are created now using a 0.35-micron process. But next year we'll see processors created at 0.25 microns, with 0.18 and 0.13 microns to be introduced in the years to come.” (PC Magainze, 1998)

However, it's not just improvements in lithography and density that can boost performance. Designers can create microprocessors with more layers of metal tying together the transistors and other circuit elements. The more layers, the more compact the design. But these ultracompact microprocessors are also harder to manufacture and validate. New chip designs take up less space, resulting in more chips per wafer. The original Pentium (60/66 MHz) was 294 square millimeters, then it was 164 square millimeters (75/90/100 MHz), and now it's 91 square millimeters (133- to 200-MHz versions) (PC Magazine, 1998).

When will all this end? Interestingly, it may not be the natural limits of technology that will eventually refute Moore's Law. Instead, it's more likely to be the cost of each successive generation. Every new level of advancement costs more as making microprocessor development is a hugely capital-intensive business. Currently, a fabrication plant with the capacity to create about 40,000 wafers a month costs some $2 billion. And the rapid pace of innovations means equipment can become obsolete in just a few years. Still, there are ways of cutting some costs, such as converting from today's 8-inch silicon wafers to larger, 300-mm (roughly 12-inch) wafers, which can produce 2.3 times as many chips per wafer as those now in use. Moving to 300-mm wafers will cost Intel about $500 million in initial capital. Still, nothing lasts forever. As Parker notes, “the PC industry is built on the assumption that we can get more and more out of the PC with each generation, keep costs in check, and continue adding more value. We will run out of money before we run out of technology. When we can't hold costs down anymore, then it will be a different business” (PC Magazine, 1998).

At the beginning of last year, the buzz was about PlayStation 2 and the Emotion Engine processor that would run it. Developed by Sony and Toshiba, experts predicted the high-tech processor would offer unprecedented gaming power and more importantly, could provide the processing power for the PlayStation 2 to challenge cheap PCs as the entry-level device of choice for home access to the Web. PlayStation2 is equipped with the 295MHz MIPS-based Emotion engine, Sony's own CPU designed with Toshiba Corp., a 147MHz graphics processor that renders 75 million pixels per second, a DVD player, an IEEE 1394 serial connection, and two USB ports. Sony will use DVD discs for game titles and gives consumers the option of using the product for gaming, DVD movie playing and eventually Web surfing (PC World, 2000).

Soon, instead of catching up on the news via radio or a newspaper on the way to work, commuters may soon be watching it on a handheld computer or cell phone. Early January this year, Toshiba America Electronic Components announced its TC35273XB chip. The chip has 12Mb of integrated memory and an encoder and decoder for MPEG-4, an audio-video compression standard. According to Toshiba, the integrated memory is what sets this chip apart from others. With integrated memory, the chip consumes less power, making it a good fit for portable gadgets. This chip is designed to specifically address the issues of battery life which can be very short with portable devices. The chip will have a RISC processor at its core and running at a clock speed of 70MHz (PC World, 2000).

Toshiba anticipates that samples of this chip will be released to manufacturers in the second quarter, and mass production will follow in the third quarter. Shortly after this release, new handheld computers and cell phones using the chip and offering streaming media will be expected (CNET news).

It is reported in CNET news, that in February this year, IBM started a program to use the Internet to speed custom-chip design, bolstering its unit that makes semiconductors for other companies.

IBM, one of the biggest makers of application-specific chips, would set up a system so that chip designs are placed in a secure environment on the Web, where a customer's design team and IBM engineers would collaborate on the blueprints and make changes in real time.

Designing custom chips, which are used to provide unique features that standard processors don't offer, requires time-consuming exchanges of details between the clients that provide a basic framework and the IBM employees who do the back-end work. Using the Internet will speed the process and make plans more accurate. IBM figures that since their customers ask for better turnaround time and better customer satisfaction, this would be one way to tackle this. As a pilot program, this service was to be offered to a set of particular, selected customers initially, and then would include customers who design the so-called system-on-a-chip devices that combine several functions on one chip (CNET news).

A new microprocessor unveiled in February 2000 by Japan’s NEC, offers high-capacity performance while only consuming small amounts of power, making it ideal for use in mobile devices. This prototype could serve as the model for future mobile processors. The MP98 processor contains four microprocessors on the same chip that work together in such a way that they can be switched on and off depending on the job in hand. For example, a single processor can be used to handle easy jobs, such as data entry, through a keypad, while more can be brought online as the task demands, with all four working on tasks such as processing video. This gives designers of portable devices the best of both worlds—low power consumption and high capacity (PC World, 2000).

However, it should be noted that the idea of putting several processors together on a single chip is not new as both IBM and Sun Microsystems have developed similar devices. The only difference is that MP98 is the first working example of a “fine grain” device that offers better performance. Commercial products based on this technology are likely to be seen around 2003 (PCWorld, 2000).

In PCWorld, it was reported that, last September, a Japanese dentist received U.S. and Japanese patents for a method of planting a microchip into a false tooth. The one-chip microprocessor embedded in a plate denture can be detected using a radio transmitter-receiver, allowing its owner to be identified. This is useful in senior citizen’s home where all dentures are usually collected from their owners after meals, washed together and returned. In such a case, it is important to identify all the dentures to give back to their correct owners without any mistake (PC World, 2000).

In March this year, Advanced Micro Devices (AMD) launched its 1.3-GHz Athlon processor. Tests on this processor indicated that its speed surpassed Intel’s 1.5GHz Pentium 4. The Athlon processor has a 266-MHz front side bus that works with systems that use 266-MHz memory. The price starts from $2,988 (PCWorld, 2001).

Intel’s Pentium 4, which was launched in late 2000, is designed to provide blazing speed—especially in handling multimedia content. Dubbed Intel NetBurst

Micro-architecture, it is designed to speed up applications that send data in bursts, such as screaming media, MP3 playback, and video compression.

Even before the dust had settled on NetBurst, Intel released its much awaited 1.7 GHz Pentium 4 processor on Monday, April 23. The is said to be the company's highest-performance microprocessor for desktops. Currently priced at $325 in 1,000 unit quantities. The vice president and general manager of Intel was quoted as saying, "the Pentium 4 processor is destined to become the center of the digital world. Whether encoding video and MP3 files, doing financial analysis, or experiencing the latest internet technologies—the Pentium 4 processor is designed to meet the needs of all users" (PC World, 2001).

Gordon Moore, co-founder of Intel, over thirty years ago, announced that the number of transistors that can be placed on a silicon would double every two years. Intel maintains that it has remained true since the release of its first processors, the 4004, in 1971.

The competition to determine who has produced the fastest and smallest processor between Intel and AMD continues. Infact, Intel Corp. predicts that PC chips will climb to more than 10GHz from today's 1GHz standard by the year 2011. However, researchers are paying increasing attention to software. That's because new generations of software, especially computing-intensive user interfaces, will call for processors with expanded capabilities and performance.

References

Short, Kenneth L.. *Microprocessors and Programmed Logic*. Prentice-Hall, Inc. (New Jersey: Englewood Cliffs, 1987).

Noyce, Robert N. and Marcian E. Hoff, Jnr. c1981. *A History of Microprocessor Development at Intel*. IEEE Micro, pg. 8–22.

Krutz, Ronald L. *Microprocessors and Logic Design*. John Wiley & Sons. (New York: NY, 1980)

Heath, Steve. *Microprocessor Architectures and Systems*: RISC, CISC and DSP. (Newnes: UK, 1991)

Heffer, D.E., King, G.A., and Keith, D.C. (c1986). *Basic Principles and Practice of Microprocessors*

Miller J. Michael. *Microprocessors March On*. PC Magazine (e-journal) December 1998. Available on line: www.howstuffworks.com/microprocessor5.htm (accessed May 2001)

Tredennick, Nick. *Microprocessor-Based Computers for Professionals*. October 1996, Vol. 29, No. 10 pg. 27-36

"The First Electronic Tooth? *PCWorld*, (e-journal). September 2000. Available online: www.idg.net (accessed April 2001)

"We Like Speed, but Price Drives Memory Choice, *PCWorld*, (e-journal) October 2000. Available online: www.idg.net (accessed April 2001)

"NEC Chip Cures Mobile Power Problems". *PCWorld*, (e-journal), February 2000. Available online: www.idg.net (accessed April 2001)

"The Sony Emotion Engine: We're Talking Gigaflops" *PCWorld*, (e-journal), January 2000. Available online: www.idg.net (accessed April 2001)

"AMD's 1.3-GHz Athlon Beats Fastest Pentiums", *PCWorld*, (e-journal), March 2001. Available online: www.idg.net (accessed April 2001)

"Several kitchen inventions try to save time and space and reduce guesswork with automation". Apr 16, 2001. *New York Times*. Available online: www.nytimes.com (accessed May 2001)