Intel Microprocessor

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Microprocessor and Microcontroller
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Contents

Abstract

Semiconductors and microprocessors are essential to modern technology; their absence would halt every aspect of modern life. Advances and improvements in the semiconductor industry have fueled the technological revolution of the 1990s. The decrease in the cost and size of transistors allowed for an every increasing amount of transistors to be put onto a silicon chip, thereby allowing for faster processors. The ability to fit more transistors on a silicon wafer approximately follows Moore's Law, which is named after Gordon Moore, co-founder of Intel Corporation. Moore's Law states that the number of transistors on a silicon chip doubles every 18-24 months.

1 Introduction

Intel Corporation was founded on July 18, 1968 by semiconductor pioneers Robert Noyce and Gordon Moore (of Moore's law) and is associated with the executive leadership and vision of Andrew Grove. The company's name was conceived as portmanteau of the words *int*egrated and *el*ectronics, with co-founder Noyce having been a key inventor of the integrated circuit (the microchip). The fact that "intel" is the term for intelligence information also made the name appropriate. Intel was an early developer of SRAM and DRAM memory chips, which represented the majority of its business until 1981. Although Intel created the world's first commercial microprocessor chip in 1971, it was not until the success of the personal computer (PC) that this became its primary business.

Intel supplies microprocessors for computer system manufacturers such as Apple, Lenovo, HP, and Dell. Intel also manufactures motherboard chipsets, network interface controllers and integrated circuits, flash memory, graphics chips, embedded processors and other devices related to communications and computing.

Intel Corporation is an American multinational corporation

and technology company headquartered in Santa Clara, California, in Silicon Valley. It is the world's largest and highest-valued semiconductor chip manufacturer on the basis of revenue, and is the developer of the x86 series of microprocessors, the processors found in most personal computers (PCs). Intel ranked No. 46 in the 2018 *Fortune* 500 list of the largest United States corporations by total revenue. Intel is incorporated in Delaware.

Figure 1: Timeline of Intel Processors

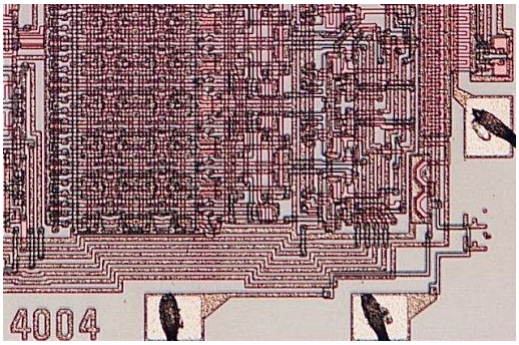
2 1971-1981: 4004 (8-bit)

The 4004, manufactured from 1971 to 1981, was the first commercially available processor as well as the first complete CPU on a single chip. The chip was packaged in a 16-pin ceramic dual in-line package and was initially released with a clock speed of 108 KHz (and scaled up to 740 KHz). Produced in a 10 m (10,000 nm) process, the 4004 had 2,300 transistors and delivered a performance of 0.07 MIPS.

The 8-bit 8008 replaced the 4004 in 1972 with 0.5 to 0.8 MHz clock speed and 3,500 transistors, and was primarily used in the TI 742 computer. The 8080 followed in 1974 with 4,500 transistors in 6,000 nm with up to 2 MHz

and became famous for being used in the Altair 8800 as well as in Boeing's AGM-86 cruise missile.

None of these chips were sold in considerable volumes.



3 1978-1982: iAPX 86 – 8086, 8088 and 80186 (16-bit)

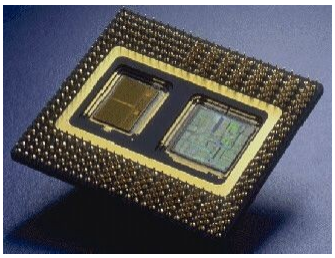
The 8086, also known as the iAPX 86, was Intel's first commercial 16-bit CPU and is considered to be the chip that launched the era of x86 processors. With 29,000 transistors built in a 3,000 nm design, the 8086 was clocked from 5 to 10 MHz and achieved up to 0.75 MIPS in computers such as the IBM PS/2.

The IBM 5150, the first PC, came with the 8088 (5-8MHz), which was identical to the 8086 with the exception of its 8-bit internal bus. In 1982, Intel launched the 80186 CPU, which was also based on the 8086, but was built in 2,000 nm and hit more than 1 MIPS at 6 MHz clock speed. The Tandy 2000 was among the first PCs that used the 80186.

4 1995: Pentium Pro (P6, i686)

the Pentium Pro was a largely misunderstood processor. Many believed that the Pro was intended to replace the P5. However, as a precursor to the Pentium II Xeon, the Pentium Pro was tailored to deal with workloads typical for servers and workstations.

The Pentium Pro's architecture was different from the regular Pentiums and supported out of order execution, the Pentium Pro had a 36-bit address bus, which supported up to 64GB of memory. The Pentium Pro was built in 350 nm, had 5.5 million transistors, and came in several variants with clock speeds ranging from 150 and 200 MHz.



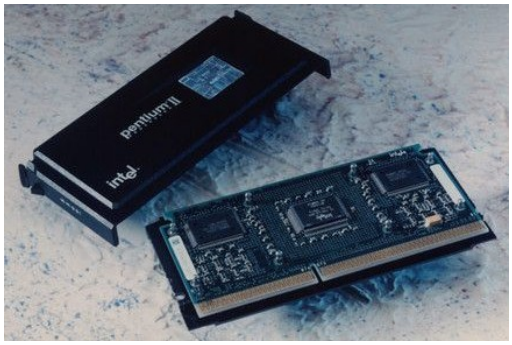
5 1997: Pentium II and Pentium II Xeon

The Pentium II was a consumer-focused processor developed on top of the sixth-generation P6 architecture, and the first Intel CPU that was delivered in a

cartridge-like slot module and not a socket device. The Pentium II had 2 million more transistors (7.5 million) than the P6, significantly improving 16-bit execution, which was a problem in the initial P6 release, and carried on the MMX instruction set that was introduced with the Pentium.

The Pentium II was released with the 350 nm Klamath core (233 and 266 MHz). Deschutes arrived as a shrink to 250 nm and clock speeds up to 450 nm in 1998, and was also offered as Pentium II Overdrive as an upgrade

option for the Pentium Pro. Mobile Pentium II processors got the 250 nm Tonga and 250 nm and 250nm/180 nm Dixon cores. In the same year, Intel also offered the Deschutes core as a Pentium II Xeon with larger cache and dual-processor support.



6 1998: Celeron

Celeron was launched in 1998 as a variant of the Pentium II processor. While Celerons are based on the company's current processor technology, they usually come with substantial downgrades, such as less cache memory, which positions them as processors that are just "good enough" for the most basic PC applicationsThe first Celeron series was based on the 250 nm Covington core for desktops and the 250 nm Mendocino core for notebooks. The processors were available from 266 to 300 MHz on the desktop and up to 500 MHz on the mobile side, and were updated well into the days of the succeeding Pentium III. Today's Celerons are based on Sandy Bridge architecture.

7 2000: Pentium 4

The Pentium 4 arguably took Intel on a path that led to the most dramatic transformation of Intel in the company's history. Launched in 2000 with the 180 nm Willamette core (42 million transistors), the chip's Netburst architecture was designed to scale with clock speed, and Intel envisioned that the foundation would allow the company to hit frequencies of more than 20 GHz by 2010. Netburst, however, was more limited than initially thought, and by 2003, Intel knew that the current leakage and power consumption was increasing with higher clock speeds too fast.

Netburst launched with 1.3 and 1.4 GHz, increased to 2.2 GHz with the 130 nm Northwood core (55 million transistors) in 2002, and to 3.8 GHz with the 90 nm Prescott core (125 million transistors) in 2005. Intel also launched the first Extreme Edition processors with the Gallatin core in 2003.

Over time, the Pentium 4 series became increasingly confusing, with Mobile Pentium 4-M processors, Pentium 4E HT (hyperthreading) processors with support for a virtual

second core, and Pentium 4F processors with the 65 nm Cedar Mill core (Pentium 4 600 series) in 2005. Intel planned to replace the Pentium 4 family with the Tejas processor, but canceled the project when it was clear that Netburst would not be able to reach clock speeds beyond 3.8 GHz. Core, the following architecture, was a dramatic turnaround to much more efficient CPUs with a strict power ceiling that put Intel's gigahertz machine in reverse.

8 2001: Xeon

The first Xeon that did not bring the Pentium brand along was based on Pentium 4's Netburst architecture and debuted with the 180 nm Foster core. It was available with 1.4 to 2.0 GHz clock speeds. The Netburst architecture continued until 2006, when Intel had expanded Xeon to a full line of UP and MP processors with the 90 nm Nocona, Irwindale, Cranford, Potomac and Paxville cores and the 65 nm Dempsey and Tulsa cores.

Similar to its desktop processors, the Netburst processors suffered from excessive power consumption, which forced Intel to revise its processor architecture and strategy. The Netburst Xeons died with the dual-core Dempsey CPU with a clock speed of up to

3.73 GHz and 376 million transistors.

Today's Xeons are still based on the technology foundation that is also used for desktop and mobile processors, but Intel keeps them in a tight power envelope. The 2006

dual-core Woodcrest chip, a variant of the desktop Conroe chip, was the first

representative of this new idea. The current Xeons are based on 32 nm Sandy Bridge and Sandy Bridge EP architecture, and Westmere processor designs. The CPUs have up to 10 cores and clock speeds up to 3.46 GHz, as well as up to 2.6 billion transistors.

9 2001: Itanium

The Itanium has been Intel's most misunderstood processor that actually survived over a long period of time. While it follows the idea of the i860 and iAPX 432, it has found some powerful supporters and not been cut yet. The processor was launched as Intel's first

64-bit processor and was believed to be Intel's general idea for a 64-bit platform. However, the Itanium suffered in the 32-bit department and was heavily criticized for its lack of performance in this segment.

Itanium was launched with the 180 nm Merced core in 2001 as a mainframe processor with 733 MHz and 800 MHz clock speed and 320 million transistors – more than six times the count of a desktop Pentium at the time. The Itanium 2 followed in 2002 (180 nm McKinley core, as well as 130 nm Madison, Deerfield, Hondo, Fanwood and Madison cores) and wasn't updated until 2010 when Intel launched the Itanium 9000 with the 90 nm Montecito and Montvale cores, as well as the 65 nm Tukwila core with a massive 24 MB on-die cache, as well as more than 2 billion transistors.

Despite persistent rumors that Intel will kill the Itanium at any time, there is a solid service ecosystem surrounding the processor.

10 2003: Pentium M

The Pentium M 700 series, launched with the 130 nm Banias core in 2003, was targeted at mobile computers but carried the philosophy of an Intel that did not focus its processors on

clock speed anymore, but on power efficiency. The processor was developed by Intel's design team in Israel, which was led by Mooly Eden and David Perlmutter, who both hold key executive roles at Intel today.

Banias dropped its clock speed to 900 MHz to 1.7 GHz, down from 2.6 GHz of the Pentium 4 Mobile. However, the processor was rated at just 24.5 watts TDP, while the Pentium 4 chip was at 88 watts. The 90 nm shrink was called Dothan and dropped its thermal design power to 21 watts. Dothan had 140 million transistors and clock speeds of up to 2.13 GHz.

The direct successor of Dothan was Yonah, which was released in 2006 as Core Duo and Core Solo, but was not related to the Intel Core micro-architecture. The Banias core and its impact on Intel is seen on the same level as the 4004, 8086 and 386 as the most significant milestones in the company's product history.

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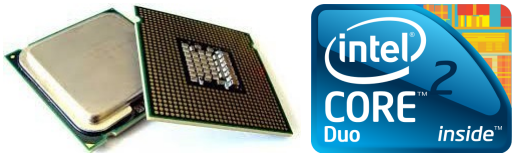
11 2006: Core 2 Duo

Core 2 Duo was Intel's strike back against AMD's Athlon X2 and Opteron processors, which were highly successful at the time. The Core micro-architecture was launched with the 65 nm Conroe (Core 2 Duo E-6000 series) on the desktop, Merom on the mobile side (Core 2 Duo T7000 series), and Woodcrest in the server market (Xeon 5100 series). Intel quickly followed with quad-core versions (Kentsfield Core 2 Quad series for the desktop, Clovertown Xeon 5300 series for servers).

The Core micro-architecture was preceded by one of the most significant restructurings at Intel, as well as a substantial repositioning of the company. While Conroe was developed, Intel positioned its remaining Pentium and Pentium D processors to drive AMD into an unprecedented price war in 2005 and 2006, while the Core 2 Duo processor regained the performance lead over AMD in 2006. Conroe was launched with 1.2 GHz to 3 GHz clock speeds and as a chip with 291 million transistors. The CPUs were updated with a 45 nm Penryn shrink in 2008 (Yorkfield for quad-cores).



12 2008: Core i-Series

Intel's Core-i3, i5 and i7 processors launched with the Nehalem micro-architecture and the company's 45 nm production process in 2008. The architecture was scaled to 32 nm (Westmere) in 2010 and provided the foundation for Intel processors covering the Celeron, Pentium Core and Xeon brands. Westmere scaled to up to eight cores, up to

3.33 GHz clock speed and up to 2.3 billion transistors.

Westmere was effectively replaced by the 32 nm Sandy Bridge architecture in 2011, which shrunk in 2012 to 22 nm in the Ivy Bridge generation (1.4 billion transistors for quad-core processors).

12.1 Intel Core First Generation - Nehalem

- The first Core i7 released by Intel was given the codename "Bloomfield".

- Released in Q4 of 2008.
- 45 nm technology size
- Quad-Core Design with a shared L3 cache between the four different cores.
- Each core has a split 8-way set associat ive L1 cache and a unified 8-way set associat ive L2 cache.
- To further improve the effectiveness of the cache, Intel added prefetching.
- Main memory controller reduced time taken to access main memory.

12.2 Intel Core i7 -Sandy Bridge

- First released in early 2011
- 32 nm technology size
- Similar cache to the Bloomfield generation of i7.
- Integrated Graphics Processor on same die as cores.
- Improved integrated memory controller

12.3 Intel Core i7 - Ivy Bridge

- 22 nm technology size
- Estimated 4%-6% gain in IPC
- Improvement in cache prefetching
- Virtualization of move operations

12.4 Intel Core i7 - Haswell

- 22 nm Technology Size
- Increase in Reservation Stations from 6 to 8
- Additional integer ALUs and branch unit
- One of the highest rates of per-clock throughput at the time

12.5 Intel Core i7 - Broadwell

- 14 nm technology size
- Released in Early 2015
- Estimated 5% increase in IPC
- Increase in L3 cache size
- Not very successful, replaced within a few months

12.6 Intel Core i7 - Sky lake

- 14 nm Technology size
- Released late 2015, a few months after Broadwell
- 10% faster than Broadwell