INTEL 4004

1969: The assignment

In 1969, Nippon Calculating Machine Corporation approached Intel to design 12 custom chips for its new Busicom 141-PF\* printing calculator. Intel engineers suggested a family of just four chips, including one that could be programmed for use in a variety of products, setting in motion an engineering feat that dramatically altered the course of electronics.

The Intel solution

Intel designed a set of four chips known as the MCS-4. It included a central processing unit (CPU) chip—the 4004—as well as a supporting read-only memory (ROM) chip for the custom applications programs, a random-access memory (RAM) chip for processing data, and a shift-register chip for the input/output (I/O) port.

1971: Era of integrated electronics

Intel purchased the rights from Nippon Calculating Machine Corporation and launched the Intel® 4004 processor and its chipset with an advertisement in the November 15, 1971, issue of Electronic News: ”Announcing A New Era In Integrated Electronics.”

That’s when the Intel® 4004 became the first general-purpose programmable processor on the market—a "building block" that engineers could purchase and then customize with software to perform different functions in a wide variety of electronic devices.

FEATURES:

4-bit microprocessor

» 740 KHz

» 4 KB program memory

» 640 bytes data memory

» 3-level deep stack

» No interrupts

45 instructions

16-pin DIP(Dual inline package)

PMOS(P-type metal-oxide-semiconductor ) Technology

The 4004 had a 4-bit [processor](http://searchcio-midmarket.techtarget.com/definition/processor). The [instructions](http://searchcio-midmarket.techtarget.com/definition/instruction) were stored in [ROM](http://searchcio-midmarket.techtarget.com/definition/read-only-memory) (read-only memory), while the [data](http://searchdatamanagement.techtarget.com/definition/data) was stored in an external [register](http://whatis.techtarget.com/definition/register). The 4004 used a 4-bit [address](http://searchnetworking.techtarget.com/definition/address) [bus](http://searchstorage.techtarget.com/definition/bus). Other features included:

* Maximum [clock speed](http://searchcio-midmarket.techtarget.com/definition/clock-speed) of 740 kHz.
* Up to 92600 instructions per second.
* Separate [program](http://searchsoftwarequality.techtarget.com/definition/program) and data storage.
* 12-bit addresses.
* 8-bit instructions.
* 4-bit [words](http://searchcio-midmarket.techtarget.com/definition/word).

One of the most noteworthy aspects of this microprocessor was the so-called silicon gate structured design method, which made it possible to design smaller and more efficient chips than previously possible.

**Intel 8008**

The Intel 8008, originally called the 1201, was one of the first [microprocessors](http://searchcio-midmarket.techtarget.com/definition/microprocessor) ever developed. The chip originally appeared in 1972 and carried a price tag of $120.00. It served as the heart of the Mark-8 hobby computer, described by graduate student Jonathan Titus in the July 1974 issue of *Radio-Electronics* magazine. The Intel 8008 was also used in calculators, terminals, certain industrial machines, and simple data processors.

The 8008 comprised an 8-bit [CPU](http://searchcio-midmarket.techtarget.com/definition/CPU) (central processing unit) with an external 14-bit [address](http://searchnetworking.techtarget.com/definition/address)[bus](http://searchstorage.techtarget.com/definition/bus) that could access up to 16KB of combined [ROM](http://searchcio-midmarket.techtarget.com/definition/read-only-memory) (read-only memory) and [RAM](http://searchmobilecomputing.techtarget.com/definition/RAM) (random access memory). The chip came in two designs, called the 8008, which could execute up to 100,000 [instructions](http://searchcio-midmarket.techtarget.com/definition/instruction) per second, and the 8008-1, which could execute up to 160,000 instructions per second.

 The first 8-bit microprocessor, Intel 8008 (i8008) was released 5 months after [Intel 4004](http://www.cpu-world.com/CPUs/4004/index.html). The 8008 was available in two speed grades - 500 KHz and 800 KHz. Because it took the CPU from 5 to 8 cycles to execute each instruction, the effective rate of instruction execution was:

* From 45,000 to 100,000 instructions per second for Intel 8008
* From 72,000 to 160,000 instruction per second for Intel 8088-1

These numbers assume that the CPU uses fast memory and doesn't require wait states to access the memory. Although the effective speed in instructions per second of the 8008 microprocessor sometimes is lower than the effective speed of the 4004 CPU, overall performance of the i8008 was greater due to faster effective speed of some instructions, 8-bit architecture and more efficient instruction set. The 8008 had other advantages over the 4004:

* The processor supported of 16 KB of memory (ROM and RAM combined).
* The size of internal CPU stack was 7 levels in contrast to 3 level-stack for the i4004.
* The Intel 8008 could handle interrupts.

One of the drawbacks of the Intel 8008 was the absence of direct memory addressing. To access data in memory the memory address had to be stored in H and L registers, and only then the processor could indirectly access the memory. This limitation was removed in [Intel 8080](http://www.cpu-world.com/CPUs/8080/index.html).

Intel 8008 microprocessor was used in Mark-8 computer, which is considered to be the first personal computer.

8008 major features and related families:

|  |  |  |  |
| --- | --- | --- | --- |
| **Previous Generation** |  | **Related Family**  [4004](http://www.cpu-world.com/CPUs/4004/index.html)   * » 4-bit microprocessor * » 4 KB program memory * » 640 bytes data memory * » No interrupts * » 3-level deep stack | **Next Generation**  [8080](http://www.cpu-world.com/CPUs/8080/index.html)   * » 8-bit microprocessor * » Up to 4 MHz * » 64 KB RAM * » Stack in RAM * » 256 I/O ports   40-pin DIP |
| **8008**   * » 8-bit microprocessor * » Up to 800 KHz * » 16 KB memory * » 7-level deep stack * » 8 In / 24 Out ports   18-pin DIP |
|  |

**Continue reading about the Intel 8008:**

[Nils Eilers](http://home.germany.net/nils.eilers/8008/) maintains an Intel 8008 support page.

[CPU World](http://www.cpu-world.com/CPUs/8008/index.html) provides historical data concerning the Intel 8008 family.

**Intel 8080**

Intel 8080 microprocessor is a successor to the [Intel 8008](http://www.cpu-world.com/CPUs/8008/index.html) CPU. The 8080 was designed by Federico Faggin and Masatoshi Shima. Stan Mazor contributed to chip design. The work on 8080 microprocessor was started at the end of 1972, and the CPU was released in April of 1974. Original version of the 8080 had a flaw - it could only drive low-power TTL devices. After the flaw was discovered Intel released updated version of the CPU - 8080A, which could drive standard TTL devices.

The Intel 8080/8080A was not object-code compatible with the 8008, but it was source-code compatible with it. The 8080 CPU had the same interrupt processing logic as the 8008, which made porting of old applications easier. Maximum memory size on the Intel 8080 was increased from 16 KB to 64 KB. The number of I/O ports was increased to 256. In addition to all 8008 instructions and addressing modes the 8080 processor included many new instructions and direct addressing mode. The 8080 also included new Stack Pointer (SP) register. The SP was used to specify position of external stack in CPU memory, and the stack could grow as large as the size of memory. Thus, the CPU was no longer limited to 7-level internal stack, like the 8008 did.

The Intel 8080 microprocessor was very popular and was second-sourced by many manufacturers. Clones of the 8080 processor were made in USSR, Poland, CSSR, Hungary and Romania.

**Computers**

Altair 8800, IMSAI 8080, CompuColor II, Byte Computers Byt-8

8080 major features and related families:

|  |  |  |  |
| --- | --- | --- | --- |
| **Previous Generation**  [8008](http://www.cpu-world.com/CPUs/8008/index.html)   * » 8-bit microprocessor * » Up to 800 KHz * » 16 KB memory * » 7-level deep stack * » 8 In / 24 Out ports   18-pin DIP |  | **Related Family**  [6800](http://www.cpu-world.com/CPUs/6800/index.html)   * » Up to 2 MHz * » No I/O ports   [Z80](http://www.cpu-world.com/CPUs/Z80/index.html)   * » Up to 33 MHz * » Single voltage * » 8080 compatibility mode | **Next Generation**  [8085](http://www.cpu-world.com/CPUs/8085/index.html)   * » 8-bit microprocessor * » Up to 8 MHz * » 64 KB RAM * » Single voltage * » On-chip peripherals * » 256 I/O ports * » 8080 object-code compatible   40-pin DIP 44-pin PLCC |
| **8080**   * » 8-bit microprocessor * » Up to 4 MHz * » 64 KB RAM * » Stack in RAM * » 256 I/O ports   40-pin DIP |
|  |

This is part of a series of posts about the circumstances leading up to the launch of the Altair 8800 in the January, 1975 issue of Popular Electronics. In my last few posts, I talked about the invention of the concept of the personal computer, the creation of the 4004, the world's first microprocessor, and the development of the earliest machines that could claim to be early PCs.

If the introduction of the Intel 8008 led to a variety of interesting devices that can be considered the first early PCs, it was its successor—the Intel 8080 microprocessor—that really became the foundation on which the early PC industry was based.

Compared to the Intel 4004 and 8008 which preceded it, the 8080 was a far more powerful chip. Compared with the 4004's 2,300 transistors, the 8080 would end up with more than 4,500 transistors and could run at up to 2MHz. But more importantly, many of the things that required extra chips surrounding the 4004 and the 8008 were now integrated.

But perhaps the biggest difference is that while the 4004 and 8008 were designed as custom processors for a single company—the 4004 for Busicom's calculator and the 8008 for Datapoint's computer terminal—the 8080 was designed for a more general set of customers. In short, it was designed to be a building block for any company that wanted it—and this flexibility made it particularly suited for what would become the nascent PC industry.

Developing the 8080

The concepts for the 8080 go back to 1971 when Intel had finished the 4004 chip and was still working on the 8008, which would be formally launched in April 1972.

After the stories about the "CPU on a chip" came out, Intel was beginning to see interest in the microprocessor from all sorts of customers. According to Michael S. Malone's The Intel Trinity, "the entire electronics industry seemed to undergo an awakening."

"Suddenly, as if overnight, engineers they visited understood the meaning of the microprocessors," Malone wrote. "They had read the articles, heard the speeds, talked to their peers, and as if as one, jumped about the silicon bandwagon."

In the late summer of 1971, Federico Faggin, who led the design of the 4004 and would become the primary architect of the 8080, was giving some technical seminars on the 4004 and the 8008 and was visiting customers. In those visits, he said, "I received a fair amount of criticism—some of it valid—about the architecture and performance of the microprocessors. The more computer-oriented the company I visited was, the nastier people's comments were."

"They were seeing many limitations in our microprocessors, and particularly the interrupt structure. It was highly criticized and rightly so, because the 8008 had a very primitive, barely functional interrupt structure." Customers were also complaining about the size of the package and that the company was multiplexing addresses and data. "And of course, they wanted much higher speed. The speed of the 8008 at 0.5 megahertz was not adequate."

Faggin says that by the time he returned home, "I had an idea of how to make a better 8-bit microprocessor than the 8008, incorporating many of the features that people wanted: most important, speed and ease of interfacing. I could have boosted both of these features if I had used a 40-pin package instead of the 8008's 18-pin package and integrated the functions of the support chips."

In other words, he was considering making what would be, by most accounts, the first real "computer-on-a-chip."

Around this point, Intel had developed "n-channel technology"—a more efficient method of manufacturing transistors—primarily for its 4K dynamic memory, and Faggin thought that would allow him to have more and faster transistors in the package. He also thought about integrating a stack pointer and additional instructions to improve performance, as well as the 40-pin package, which made it possible to have a 16-bit address and 8-bit data bus.

In the spring of 1972, as the 8008 was wrapping up, Faggin sent a memo to his boss, Les Vadasz, asking to start work on the next project.

But surprisingly and frustratingly to Faggin, Intel didn't approve the project. Faggin says that Intel wanted to see how the market would react to the 4004 and 8008 first, while others noted the problems Intel was having getting its latest generation of memory chips out the door and wanted to focus on that.

As a result, Intel didn't approve the 8080 project until late September or early October of 1972, at which point Faggin (with Vadasz's approval) had hired Masatoshi Shima, the former Busicom engineer who had worked closely with Faggin on the development of the 4004.

According to Ted Hoff, he and Stanley Mazor, who were behind the early concepts for the 4004 and were trying to sell the concept to customers, were getting a lot of requests for help from companies that "were looking at the 8008 and trying to push it beyond its capabilities." Mazor says Intel actually had a number of options for the follow-on to the 8008, including a completely new design, but ended up picking an "enhanced 8008" because it would take less time to design.

As a result, he said, they aimed for a chip that wouldn't have strict machine code capability but would make the assembly language convertible, so if someone wrote a program for the 8008, they could convert it to the 8080.

Work on the architecture occurred early in 1972, and Faggin credits Shima, Mazor, Hoff, and 8008 circuit designer Hal Feeney as contributing a lot in the early discussions and specification of the chip. When Shima joined Intel in the fall of 1972, he began working for Faggin on the circuit design for the chip.

While the 4004 and 8008 would be manufactured using a 10 micron process, the 8080 would use a 6 micron process, allowing for much more miniaturization. (The process distance theoretically measures the size of features within the processor, such as the distance between transistors. Today's latest processors are produced at 14nm, with 10nm products being developed. Those would be theoretically 1,000 times closer together.) The four-chip package of the 8008 had 3,500 transistors, but the 8080 would have 5,000. And it would run at 2MHz, a huge leap in performance.

As a result, the 8080 was the first microprocessor whose instruction set and memory-addressing capability approached those of the minicomputers of the day.

Selling the Microprocessor

The first production of the chip was in December 1973, and after working out some typical last-minute issues, Intel introduced the product in March 1974.

The 8080 was initially priced at $360 for a chip, which some have suggested was set to suggest a comparison with the IBM System /360. By that point, Intel knew there was market for the chip. Intel's Hal Feeney said the company provided over 400 customers with the 8080 specification before the chip was even completed.

By that point, Intel had engaged in a big marketing effort, led by Ed Gelbach and Regis McKenna, who marketed it as the "first computer on a chip." As part of this, there was a greater emphasis on development systems, such as Intel's Intellec machines, and software for such systems, including the work by Gary Kildall on the PL/M language and what would become the basis for CP/M.

Intel saw software as a way to sell chips, not as a business on its own. According to Paul Freiberger and Michael Swaine's Fire in the Valley, "when [Kildall] asked Intel executives if they had any objections to his marketing it on his own, they shrugged and told him to go ahead. They weren't going to sell it themselves."

Around this time, Intel was becoming more worried about competitors in the microprocessor business. Rockwell had introduced its PPS-4, a 4-bit processor in 1972, and Texas Instruments was working on a chip of its own. And, unknown to Intel, Motorola was working on its 6800 8-bit processor, which came out in the middle of 1974, just a few months after the 8080. In Faggin's estimation, the 6800 had the better architecture but used a process technology that made the chip large and slow, relative to the 8080.

One question that comes up is why Intel didn't choose to get into the PC business itself.

In an interview I did with Gordon Moore in 1997, he described the Altair as "just a hobby device where the inputs were toggle switches and the outputs were LEDs. You could demonstrate the way a computer worked, but a tough way to do any practical computing."

"I even turned down the idea of a home computer in that time period sometime," Moore said. "One of our engineers came up with the idea that you could build a computer and you could put it in the home, and I kind of asked him what it was good for, and the only application I got back was that the housewife could put her recipes on it. I could imagine my wife sitting there with a computer by the stove...it didn't really look very practical.

"In fact, even when Steve Jobs came over and showed us what was going on at Apple, you know I viewed it as just...one more of the hundreds of applications that existed for microprocessors and didn't appreciate that it was a significant new direction."

Noyce had a similar view, saying "The whole consumer business was an area we just didn't see in the beginning. It just seemed impossible that this phenomenal level of electronic sophistication represented by the microprocessor could ever be reduced enough in cost so that simple consumer requirements could be met."

Not long after the introduction of the 8080, Faggin left Intel to found Zilog, taking Shima with him. Together, they created the Z-80 microprocessor, which was designed to have binary compatibility with the 8080, so it could run the same software. The Z-80 itself would go on to be used in many of the early personal computers in the late 1970s, mostly running CP/M.

Meanwhile, the 8080 would get used in the first of the machines that would really gain the attention of the hobbyists who built the personal computer business, starting with the Altair 8800.

I'm not sure that the 8080 was really "the most important single product of the twentieth century," as Michael Malone calls it. But it was surely a product that changed the world

**Intel 8085**

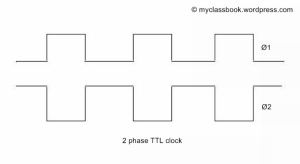
8085 microprocessor is an 8 bit microprocessor. I.e. it can accept or provide 8 bit data simultaneously.

2)      8085 microprocessor is a single chip, NMOS device implemented with 6200 transistors.

3)      8085 microprocessor requires a single +5V [DC power](http://en.wikipedia.org/wiki/Direct_current) supply.

4)      8085 microprocessor provides on chip clock generator, therefore there is no need of external clock generator, but it requires external tuned circuit like LC, RC or crystal.

5)      8085 microprocessor requires two phase, 50% duty cycle, TTL clock. These clock signals are generated by an internal clock generator (refer following figure).

**[](http://myclassbook.files.wordpress.com/2013/08/phase-ttl-clock.jpg)**

2 Phase TTL clock

6)      The maximum clock frequency of 8085 microprocessor is 3MHz where as minimum clock frequency is [500 KHz](http://en.wikipedia.org/wiki/500_kHz).

7)      8085 provides 74 instructions with the following addressing modes:

* register
* direct
* immediate
* indirect
* implied.

8)      The data bus is multiplexed with the address bus, hence it requires external hardware to separate data lines from address lines (this is one of the disadvantage of 8085).

|  |
| --- |
| * 8-bit microprocessor * » Up to 8 MHz * » 64 KB RAM * » Single voltage * » On-chip peripherals * » 256 I/O ports * » 8080 object-code compatible   40-pin DIP 44-pin PLCC |
|  |

 It is an 8 bit microprocessor (each character is represented by 8 bits or a byte).

 It is manufactured with N-MOS (n-type Metal Oxide Semiconductor) technology implemented with 6200 transistors.

 It has 16-bit address lines - A0-A15 (to point the memory locations) and hence can point up to 2^16 = 65535 bytes (64KB) memory locations.

 The first 8 lines of address bus and 8 lines of data bus are multiplexed AD0-AD7. Data bus is a group of 8 lines D0-D7.

 It provides 5 level interrupts and supports external interrupt request.

 A 16 bit program counters (PC).

 A 16 bit stack pointer (SP).

 It provides 1 accumulator, 2 flag register, six 8-bit general purpose register arranged in pairs: BC, DE, HL and 2special purpose registers.

 It consists of 74 instruction sets.

 It performs arithmetic and logical operations.

 It provides status for advanced control signals, On chip clock generator.

 It requires a signal +5V power supply and operates at 3.2 MHZ single phase clock with maximum clock frequency 6 MHz and minimum clock frequency 500 kHz.

 Serial input/output port.

 1.3 micro sec instruction cycles.

 It is enclosed with 40 pins DIP (Dual in line package).

 It can be used to implement (interface) 3 chip micro-computers (8085, 8155, 8255 and 8355: Peripheral IC's).

9)      8085 microprocessor provides 16 address lines, therefore it can access 2^16 = 64K bytes of memory.

10)   It generates 8 bit I/O address, hence it can access 2^8 = 256 input ports and 256 output ports.

11)   It performs the following arithmetic and logical operations.

* 8 bit, 16 bit binary addition
* 2 digit BCD addition
* 8 bit [binary subtraction](http://en.wikipedia.org/wiki/Binary_number)
* logical AND, OR, EXOR
* complement and shift operations.

12)   8085 microprocessor has five hardware interrupts: TRAP, RST 5.5, RST 6.5, RST 7.5, INTR

13)   The hardware interrupt capability of 8085 microprocessor can be increased by providing external hardware.

14)   8085 microprocessor has capability to share its bus with external bus controller ([direct memory access](http://en.wikipedia.org/wiki/Direct_memory_access) controller); for transferring large amount of data from memory to I/O and vice versa.

15)   8085 microprocessor provides one accumulator, one flag register, 6 [general purpose registers](http://en.wikipedia.org/wiki/Processor_register) and two special purpose registers.

16)   It provides status for advanced control signals. (Advanced control signals are used in large systems).

17)   8085 microprocessor can be used to implement three chip microcomputer (8085, 8155, 8355)

18)   8085 microprocessor provides two serial I/O lines which are SOD and SID; it means, serial peripherals can be interfaced with 8085 microprocessor directly.