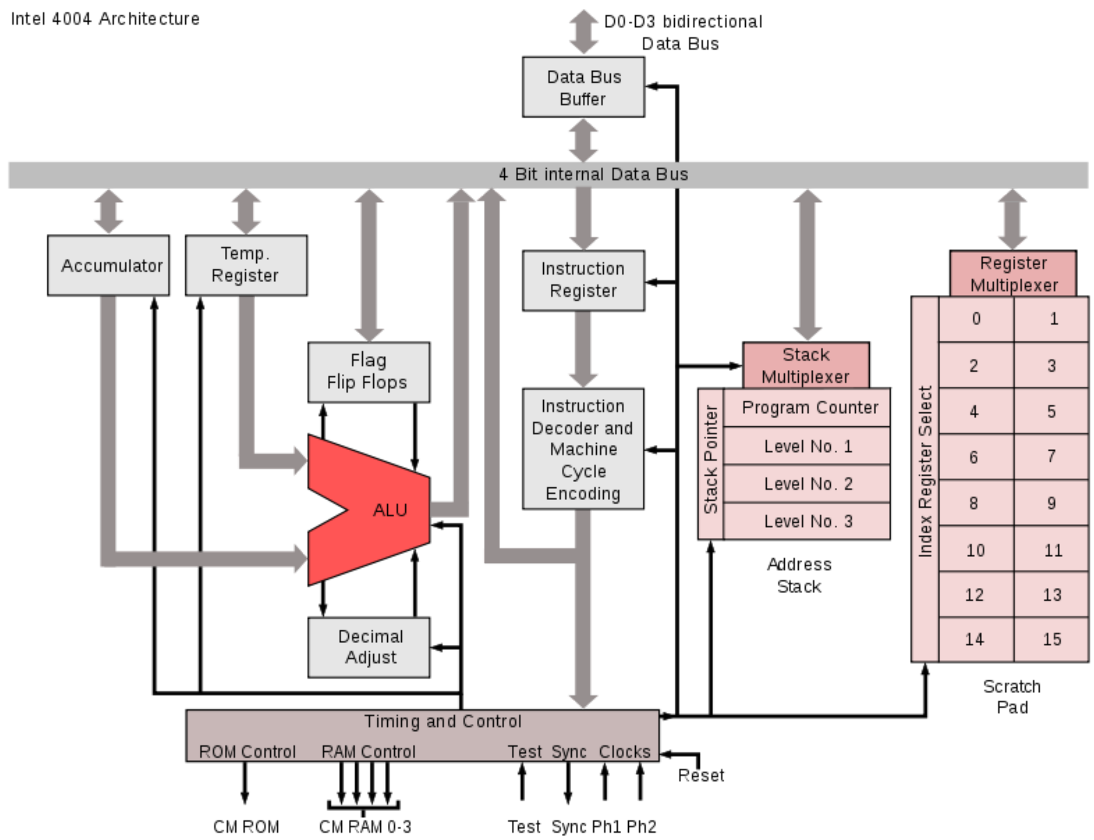
Intel 4004
1971



The pre-predecessor to the Intel 8080 which would be the first widely adopted CPU in the computing industry. Whilst IBM had been mass producing transistors since 1960 for integrated circuits and for electronics, this was the first major step to a mass-produced model that was accepted and used.

For reference:
> The first IC was demonstrated in September 1958.
> IBM start mass producing transistors in 1960.
> Intel was founded in 1968.
> AMD was founded on May 1, 1969. [1]

Before the Intel 8008, the Intel 4004 was released on November 15, 1971, the first microprocessor. The 4004 was one of the first commercially available microprocessors, and the first by Intel. [2]

The reason this was the first processor of its kind was due to the recent silicon gate technology (or self-aligned gates) developed in 1968, allowing for twice the number of random-logic transistors and up to five times the speed compared to the now outdated MOS aluminium gate technology. The inventor of

[1] History of Computer Processors - https://www.computerhope.com/history/processor.htm
[2] History of the 4004 - www.intel.co.uk/content/www/uk/en/history/museum-story-of-intel-4004.html

the silicon gate, Federico Faggin (along with Tom Klein), also improved upon speed and circuit density afterwards (in comparison to the aluminium gate).[3]

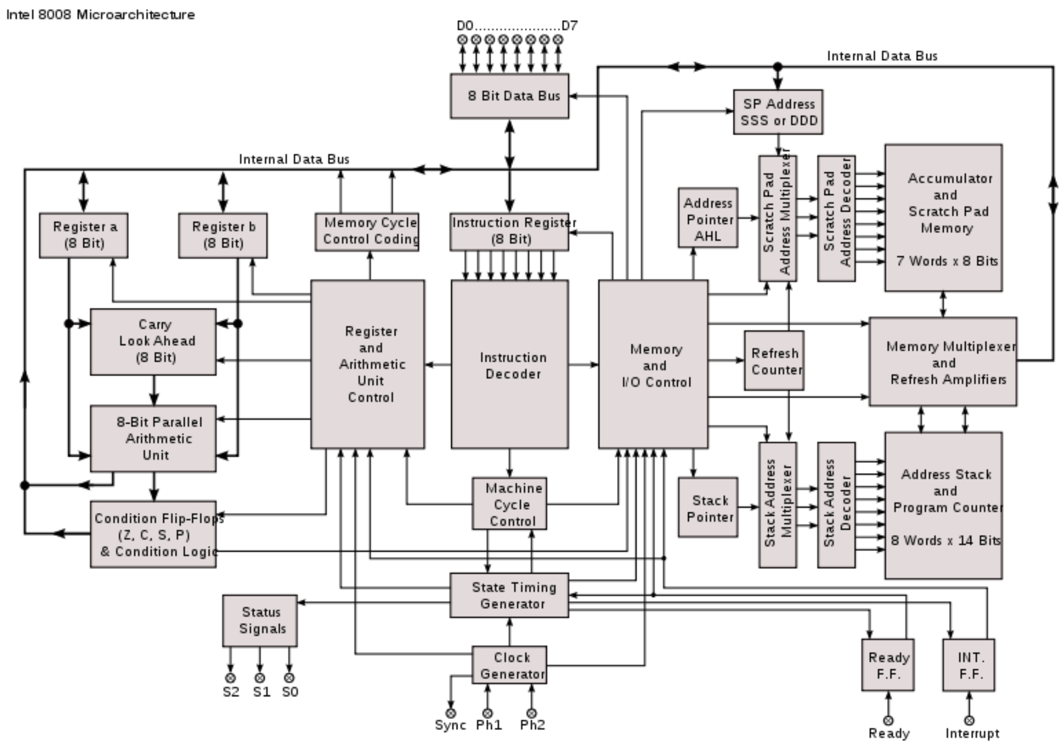
The 4004 chip sported a max clock rate of 740kHz (despite early documentation advertising 750kHz) and held 2300 transistors, packaged with a 4-bit BCD-oriented (binary-code decimal) instruction set on a 16-pin DIP. It could handle 8 clock cycles per machine cycle and had a general instruction execution time of 1-2 machine cycles (meaning anywhere between 45000 and 92500 instructions per second).[4]

The chip also used a single multiplexed 4-bit bus for transferring data, contrary to Harvard architecture designs. It was capable of addressing 32768 bits of ROM and had an instruction set of 46 instructions. The ROM was the only part of the 4004 that was capable of storing executable code as it could not be stored in the RAM, as well as being used for general purpose storage.

[3] Info about Faggins and silicon-gate technology - http://www.intel4004.com/The_MOS_Silicon_Gate_Technology_and_the_First_Microprocessors.pdf

[4] Intel 4004 datasheet - http://www.applelogic.org/files/4004Data.pdf

Intel 8008
1972



The Intel 8008 was released on April 1st, 1972. This was the stepping stone to the critically acclaimed and loved 8080 chip that would release exactly 2 years later.

The 8008 had a max clock rate of 0.8MHz and used a new specific instruction set for itself. It had 3,500 transistors and was packaged into an 18-pin DIP design. It also featured 16KB of memory.

The CPU was the choice of the very first non-calculator personal computers, showing off its power and potential. A good example of the 8008 being utilised is the *MCM/70*, a personal microcomputer system created in Canada, released in 1973. This computer had a single-line plasma display, a built-in keyboard, a battery allowing it to save anything that was being worked on when powered off and could hold up to 8 KB of RAM and 2 cassette drives, weighing in at 20 pounds.

Instructions on the 8008 took between 5 and 11 'T-States'[5], where a T-state was 2 clock cycles. This is explained in the 8008 User Manual:

> *"Typically, a machine cycle consists of five states, two states in which an address is sent to memory (T1 and T2), one for the instruction or data fetch (T3), and two states for the execution of the instruction (T4 and T5) …*
>
> *Many of the instructions of the 8008 are multi-cycle and do not require the two*

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[5] Intel 8008 Opcodes - http://www.pastraiser.com/cpu/i8008/i8008_opcodes.html (also includes good footnotes about 8008 features)

execution states, T4 and T5. As a result, the states are omitted when not needed and the 8008 operates asynchronously with respect to the cycle length...

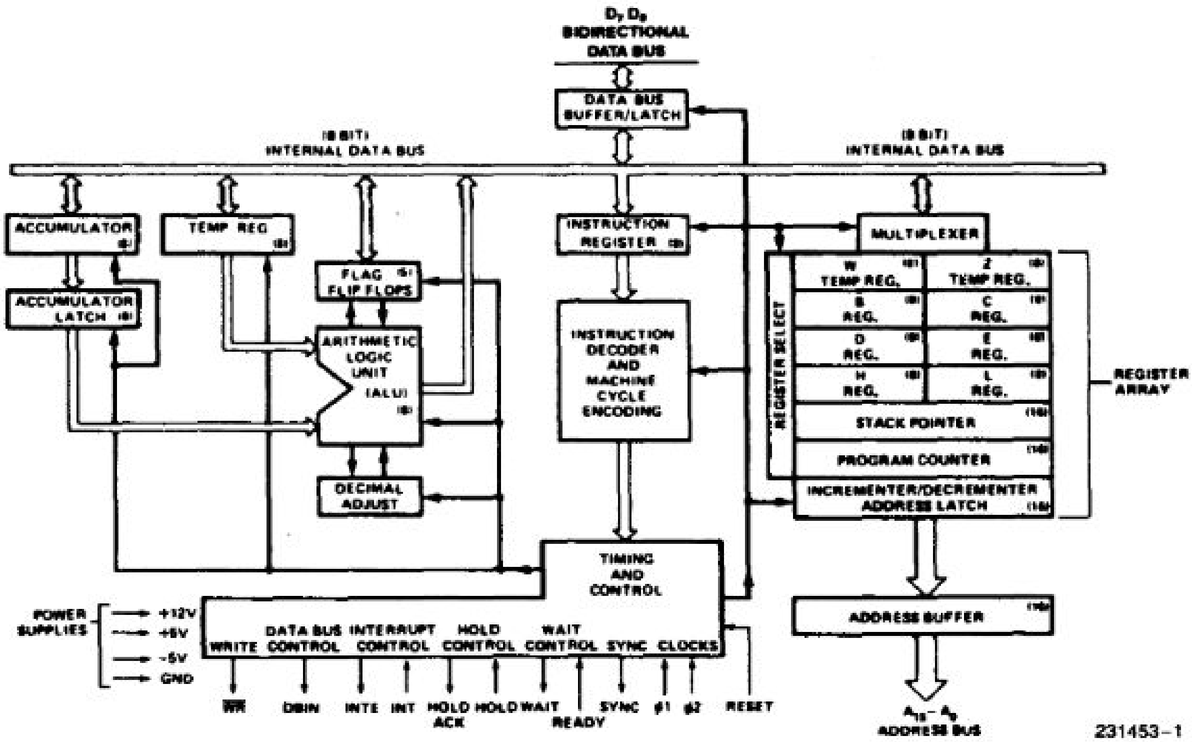
Note that the ***WAIT*** *state and* ***STOPPED*** *state may be indefinite in length (each of these states will be 2n clock periods)."* [6]

Register – register loads and ALU operations took 5T (20µs at 0.5MHz, equivalent of 2x10^-5 seconds), register – memory loads took 8T, and calls and jumps took 11T. The 8008 was therefore slower than the 4004 and 4040 in terms of instructions per second (36,000 vs 80,000 at 0.8MHz).[7] However, it still maintained an advantage as it could process 8 bits at a time and access more memory.

The Intel 8008 did have other drawbacks, such as the absence of direct memory addressing, meaning to access data in the memory, the memory address has to be stored in the H and L registers, and then the processor could access the data, albeit indirectly. This was changed later in the 8080.

[6] Intel 8008 User Manual - http://www.classiccmp.org/8008/8008UM.pdf
[7] General Info - http://www.cpu-world.com/CPUs/8008/index.html

Intel 8080
1974



Most easily comparable to the Intel 4004

The Intel 8080 began production in April 1974.[8] This was the second 8-bit microprocessor designed by Intel and was introduced as an enhanced version of the 8008. From the base, multiple other chips, including the *8085, 8086* and *8088*, would be produced, each bringing in new features.

Despite the Intel 8080 being derived from the 8008, it was not object-code compatible with the 8008, but instead source-code compatible. It also featured the same interrupt processing logic as the 8008, which allowed porting older applications easier to do.

The Intel 8080 was capable of clock speeds up to 3.125 MHz (on its stock model), used 64KB of memory and had 256 I/O ports compared to the 32 of the Intel 4004. It featured roughly 6,000 transistors all on a 40-pin DIP.

The 40-pin package was arguably the largest improvement on the 8008; the increase in pins allowed for more I/O functionality and allowed for a more efficient data bus due to more space being available, with its full 16-bit address bus (vs. the 14-bit address bus of the 8008) allowing it to access a full 64KB of RAM.

[8] Intel 8080 Retail Advertisement - https://upload.wikimedia.org/wikipedia/commons/2/2b/Intel_8080_Advertisement_May_1974.jpg

A major difference that was not so much an improvement was the removal of binary compatibility. This is the sole reason for object-code not being compatible on the 8080 and was part of a push forward to modernise the chips into using larger and more efficient instruction sets – this meant that programming for the 8080 had certain advantages, like the inclusion of a new *Stack Pointer* register. The Stack Pointer was used to specify the position of an external stack in memory, where the stack could grow as large as the memory allowed, an improvement from the limited '7-level internal stack' the 8008 had. [9]

A separate model, the **Intel 8080A**, was released after a flaw was discovered – the Intel 8080 could only drive low-power TTL (transistor-transistor logic) devices. The 8080A allowed for standard-power TTL devices to be used. Interestingly, the *8080A/8080A-1/8080A-2* datasheet advertised a slightly shorted instruction cycle as well, suggesting minor miscellaneous improvements.[10]

The 8080 proved to be so successful that compatibility at assembly language level became a design requirement for the future 8086 when design for it started in 1976.

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[9] General Info - http://www.cpu-world.com/CPUs/8080/

[10] Intel 8080A datasheet - https://www.fecegypt.com/uploads/dataSheet/1481550148_8080.pdf