1.1 Evolution from 8080/8085 to 8086

In 1978, Intel Corporation introduced a 16-bit microprocessor called the 8086. This processor was a major improvement over the previous generation 8080/8085 series Intel microprocessors in several ways:

First, the 8086's capacity of 1 megabyte of memory exceeded the 8080/8085 's capability of handling a maximum of 64K bytes of memory.
Second, the 8080/8085 was an 8-bit system, meaning that the microprocessor could work on only 8 bits of data at a time. Data larger than 8 bits had to be broken into 8-bit pieces to be processed by the CPU. In contrast, the 8086 is a 16-bit microprocessor.
Third, the 8086 was a pipelined processor, as opposed to the non pipelined 8080/8085. In a system with pipelining, the data and address buses are busy transferring data while the CPU is processing information, thereby increasing the effective processing power of the microprocessor.

Evolution from 8086 to 8088

The 8086 is a microprocessor with a 16-bit data bus internally and externally, meaning that all registers are 16 bits wide and there is a 16-bit data bus to transfer data in and out of the CPU.
Although the introduction of the 8086 marked a great advancement over the previous generation of microprocessors, there was still some resistance in using the 16-bit external data bus since at that time all peripherals were designed around an 8-bit microprocessor.
In addition, a printed circuit board with a 16-bit data bus was much more expensive. Therefore, Intel came out with the 8088 version. It is identical to the 8086 as far as programming is concerned, but externally it has an 8-bit data bus instead of a 16-bit bus. It has the same memory capacity, 1 megabyte.

Other microprocessors: the 80286, 80386, and 80486

With a major victory behind Intel and a need from PC users for a more powerful microprocessor, Intel introduced the **80286** in 1982. Its features included 16-bit internal and external data buses; 24 address lines, which give 16 megabytes of memory (2^{24} = 16 megabytes); and most significantly, virtual memory.

The 80286 can operate in one of two modes: **real mode** or **protected mode**. **Real mode** is simply a faster 8088/8086 with the same maximum of 1 megabyte of memory. **Protected mode** allows for 16M of memory but is also capable of protecting the operating system and programs from accidental or deliberate destruction by a user, a feature that is absent in the single-user 8088/8086.

Virtual memory is a way of fooling the microprocessor into thinking that it has access to an almost unlimited amount of memory by swapping data between disk storage and RAM.

With users demanding even more powerful systems, in 1985 Intel introduced the **80386** (sometimes called 80386DX), internally and externally a 32-bit microprocessor with a 32-bit address bus. It is capable of handling physical memory of up to 4 gigabytes (2^{32}). Virtual memory was increased to 64 terabytes (2^{46}). All microprocessors discussed so far were general-purpose microprocessors and could not handle mathematical calculations rapidly. For this reason, Intel introduced numeric data processing chips, called math coprocessors, such as the 8087, 80287, and 80387.

Later Intel introduced the **386SX**, which is internally identical to the 80386 but has a 16-bit external data bus and a 24-bit address bus which gives a capacity of 16 megabytes (2^{24}) of memory. This makes the 386SX system much cheaper. With the introduction of the **80486** in 1989, Intel put a greatly enhanced version of the 80386 and the math coprocessor on a single chip plus additional features such as cache memory. Cache memory is static RAM with a very fast access time. Table 1-1 summarizes the evolution of Intel's microprocessors. It must be noted that all programs written for the 8086/88 will run on 286, 386, and 486 computers.

Table 1-1: Evolution of Intel's Microprocessors

Product	8080	8085	8086	8088	80286	80386	80486
Year introduced	1974	1976	1978	1979	1982	1985	1989
Clock rate (MHz)	2 - 3	3 - 8	5 - 10	5 - 8	6 - 16	16 - 33	25 - 50
No. transistors	4500	6500	29,000	29,000	130,000	275,000	1.2 million
Physical memory	64K	64K	1M	1M	16M	4G	4G
Internal data bus	8	8	16	16	16	32	32
External data bus	8	8	16	8	16	32	32
Address bus	16	16	20	20	24	32	32
Data type (bits)	8	8	8, 16	8, 16	8, 16	8, 16, 32	8, 16, 32

Notes:

1. The 80386SX architecture is the same as the 80386 except that the external data bus is 16 bits in the SX as opposed to 32 bits, and the address bus is 24 bits instead of32; therefore, physical memory is 16MB.

2. Clock rates range from the rates when the product was introduced to current rates; some rates have risen during this time.

1.2 INSIDE THE 8088/8086

In this section we explore concepts important to the internal operation of the 8088/86, such as pipelining and registers. See the block diagram in Figure 1.1.

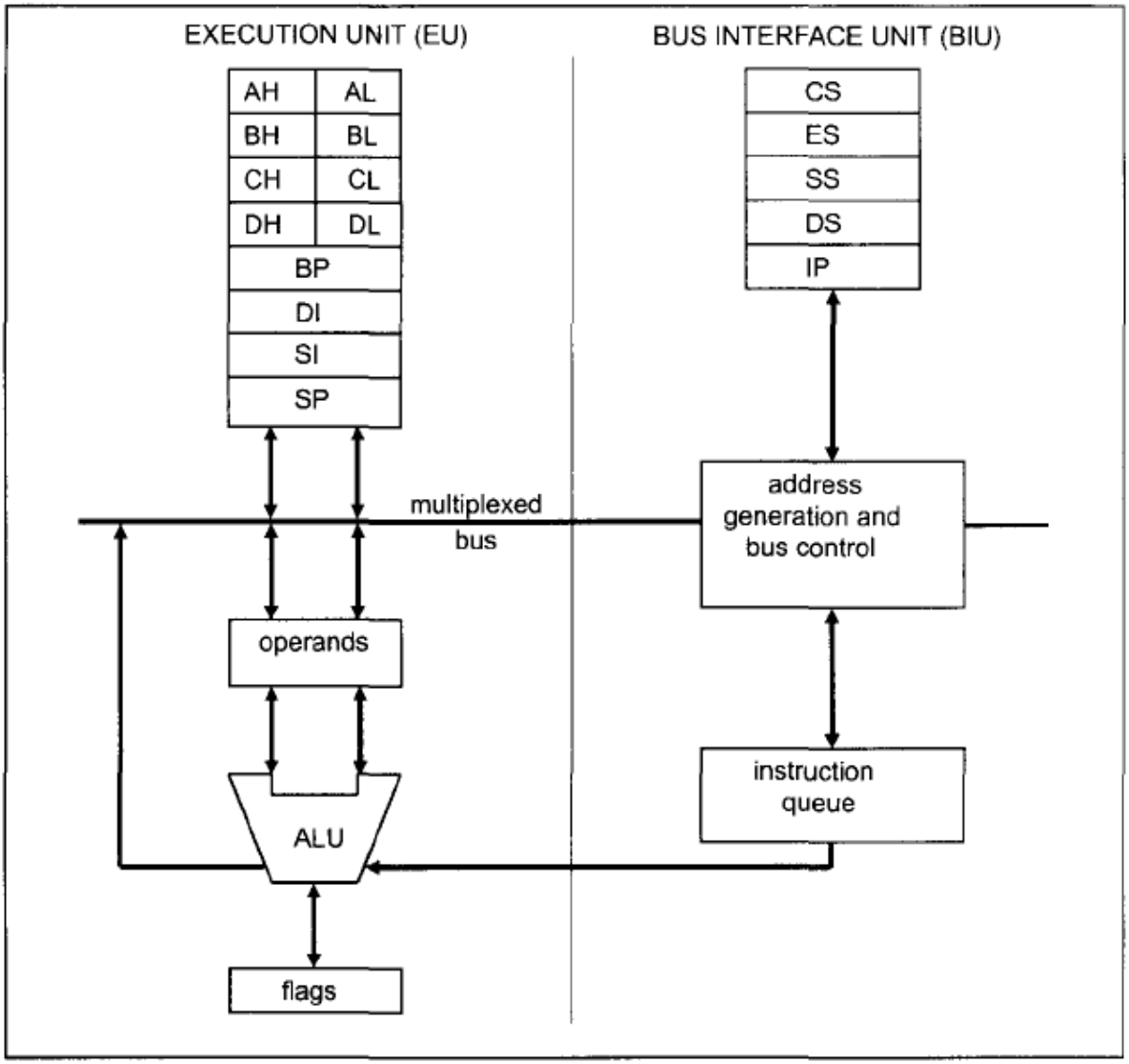

Figure (1.1) Internal block diagram of the 8088/86 CPU

Pipelining

There are two ways to make the CPU process information faster: increase the working frequency or change the internal architecture of the CPU.

The first option is technology dependent, meaning that the designer must use whatever technology is available at the time, with consideration for cost. The technology and materials used in making ICs (integrated circuits) determine the working frequency, power consumption, and the number of transistors packed into a single-chip microprocessor.