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Semiconductor Front-End Process Episode 1: The Birth of Computers, Transistors, and Semiconductors

November 22, 2022

There is no denying that semiconductors are increasingly becoming one of the biggest industries in the technology market—or any market in general, for that matter. Global media, companies and governments all pay attention to where the next semiconductor fab might be built. As the demand for smart devices multiplies with each new innovation in the tech sector, the significance of chips becomes more transparent to the public.

But how familiar people are about the history and rise of semiconductors is a different matter. To provide more context on these indispensable materials that power everything from household appliances to mobile phones, this series will trace back the origins of semiconductors and explain why they became such a significant part of everyday life as we know it.

Starting with 'Computers and Transistors,' a total of six chapters including 'Process

The Advent of Computers

As people continuously look for ways to simplify their day-to-day activities at home, work, and wherever they need to go, the need for technological devices has always been on the minds of innovative thinkers. Starting with simple machines that only knew how to make basic calculations, people eventually progressed to developing more advanced and accurate machines that would become of more practical use.

Inventing such a machine required tremendous contributions from various people. A major experiment that came out from one of these individuals was Charles Babbage's Analytical Engine in 1871. Users could insert a thin plate called a punched card into the machine and perform a numerical calculation. When inserted into the machine, the inner analysis engine repeats various arithmetic operations according to specific commands and a result value is printed out from another part of the machine.

Although the Analytical Engine was never manufactured, it stands as an interesting case study. First, the Analytical Engine has all the elements of a computer. The punched card and the part of the engine where the result value is printed out is the same concept as the computer memory. So, the Analytical Engine is essentially the primitive CPU* (Central Processing Unit).

***CPU**: *Abbreviation for Central Processing Unit. A device that acts as the computer's brain.*

Simply put, the Analytical Engine was a computer that operated on steam and consisted of a memory and CPU unit made from pieces of metal and wood. Consequently, we can assume that people in the past knew how computers structurally functioned. It's also clear that computers and 'electronic circuits' are completely different concepts. Therefore, there's a need to know why electronic

Electronic circuits have advantages over other devices based on steam, manpower, or hydraulic power, because the control of signals is fast and efficient. Looking at steam, reaction rates are slow, as steam needs to physically reach a specific location. Furthermore, since steam is transmitted at a high pressure, the pipes need to be thick and, overall, it lacks efficiency. Now, let's suppose there's a device that opens and closes its door automatically when a rope is pulled. If steam is used as the energy source here, the operator will have to open the boiler valve and wait for the high-pressure steam to push the door in order for it to be closed. But when electricity is the energy source, a button and a motor is all that is required. The size of the entire device becomes smaller, while energy efficiency and reaction speed both increase.

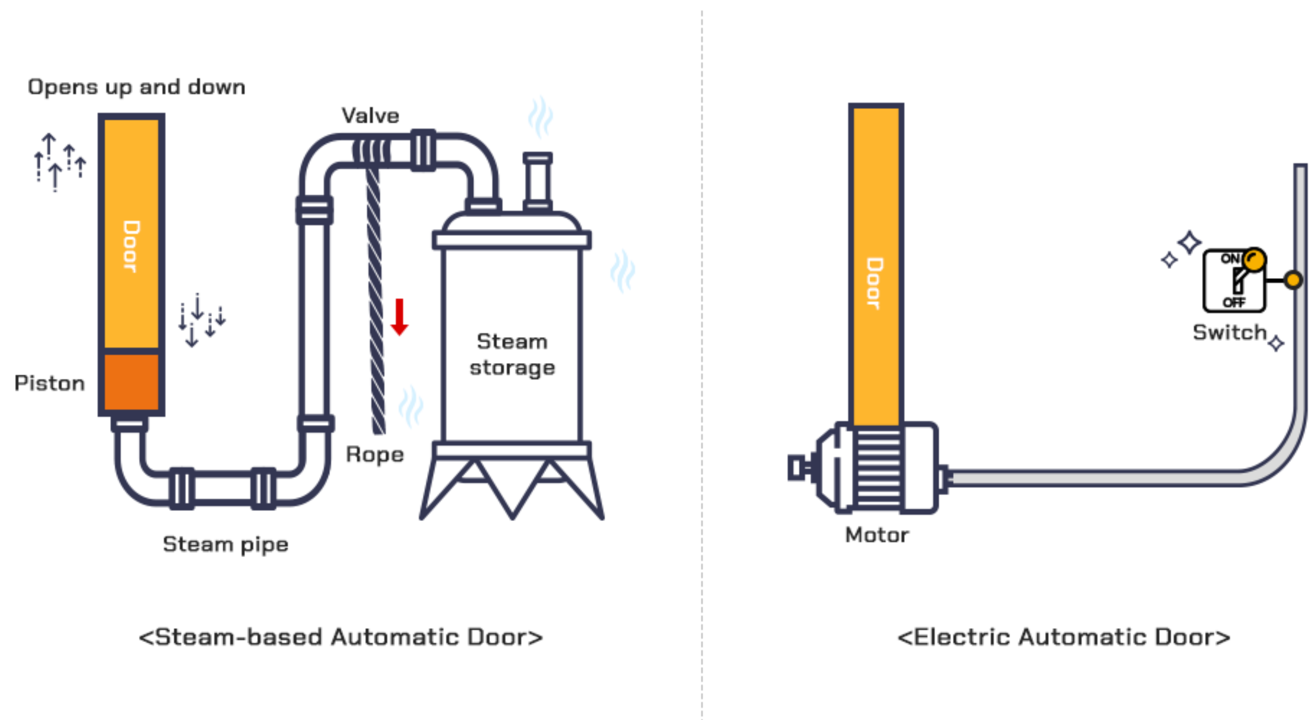

Figure 1. A steam-based automatic door (left) and an electric automatic door (right)

Analytical Engine that used gears and steam, the ENIAC operated through the combination of a type of light bulb called the vacuum tube and various electronic circuits. By looking at the components of the ENIAC that resemble light bulbs, it's quite clear that its energy source was electricity.

Figure 2. ENIAC (Source: View Original Document)

The ENIAC was a huge computer that almost took up a whole room and used up to 170 kW of electricity, equivalent to operating 170 microwave ovens. Nevertheless, it was able to accomplish numerous tasks that were needed back then. Its operation speed was still a lot faster as it used more than 170,000 vacuum tubes instead of

However, we know that the ENIAC's performance was not even a match for the portable calculators of the 1990s. Efficiency was a major issue, and it wasn't possible to supply these commodities on a large scale due to their size. This is why the world needed another innovation called the transistor.

The Emergence of Transistors

As aforementioned, the ENIAC was built using a vacuum tube similar to a light bulb. But it's important to know why these devices were needed in the first place. People knew that the ability to control signals would lead to the creation of some type of computing device, such as the automatic steam door that we looked at above.

Thus, a computer is basically a device that adds a lot of inputs and outputs to an automatic steam door along with various logical structures that are added by connecting thousands of pipes in the interior. Automatic steam doors can only do simple tasks such as opening and closing the door. But a computer can be built when it's possible to carry out more complex tasks such as simultaneously opening two doors with a single rope or making a safety door that does not close when a person is under the door. Ropes and steam pipes basically play the role of basic devices corresponding to a vacuum tube.

Figure 3. An automatic steam door that opens multiple doors with one operation (left), and an automatic door that opens only when two operators agree to open the door (right)

So, how can the performance of a steam computer be enhanced while adding extra functions to it? The number of steam tubes could be increased to add more functions, or a boiler with a higher pressure and temperature could be installed to increase the speed at which the steam rises. The problem with these solutions is that they are not easy.

Steam engines are very large by themselves, so adding a tube from the boiler to another area creates an even bigger burden on space. It requires too much energy, and the risks of explosion or other malfunctions also increase when trying to enhance the performance of the boiler. Vacuum tubes were merely the best devices available to engineers at the time. As they operate on electricity, there are no risks of explosions like with a high-pressure boiler. And the operating speed was clearly faster than the steam engine. Of course, there were frequent accidents such as individual vacuum tubes malfunctioning due to too much power being used. To make a better computer, it was necessary to find more advanced components.

In 1947, the transistor was invented. Transistors were innovative devices that could regulate the flow of large currents with very small currents. Scientists found that by using two types of semiconductor materials, as shown below, it was quite easy to

Junction Transistor), which is widely used to this day, was also invented. At this juncture, semiconductors also began to be known by the public.

**BJT*: The Bipolar Junction Transistor, within a semiconductor is a transistor made by using a PN junction, or the boundary between two domains of a P-type semiconductor and an N-type semiconductor.*

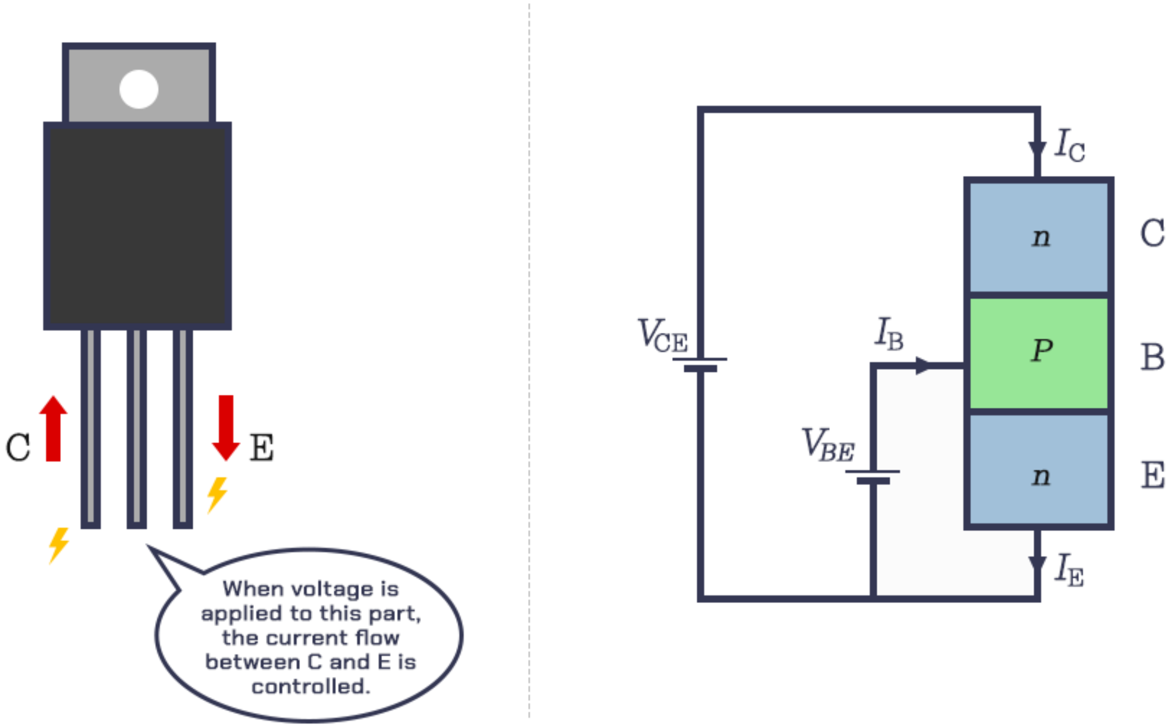

Figure 4. The structure of the transistor. Both N-type and P-type semiconductors are used. (Source of the right image: *The Understanding of the Semiconductor Manufacturing Technology*, p. 143, Table 4-6)

Semiconductors for everyone: MOSFET's Revolution and Its Manufacturing Technology

semiconductor layers on a silicon disk and then placed metal on top of it to [illegible] flat transistor. Although the operating principle of this transistor was slightly different, its usage was not too distinct from the transistors introduced above. But what made this transistor stand out was its productivity.

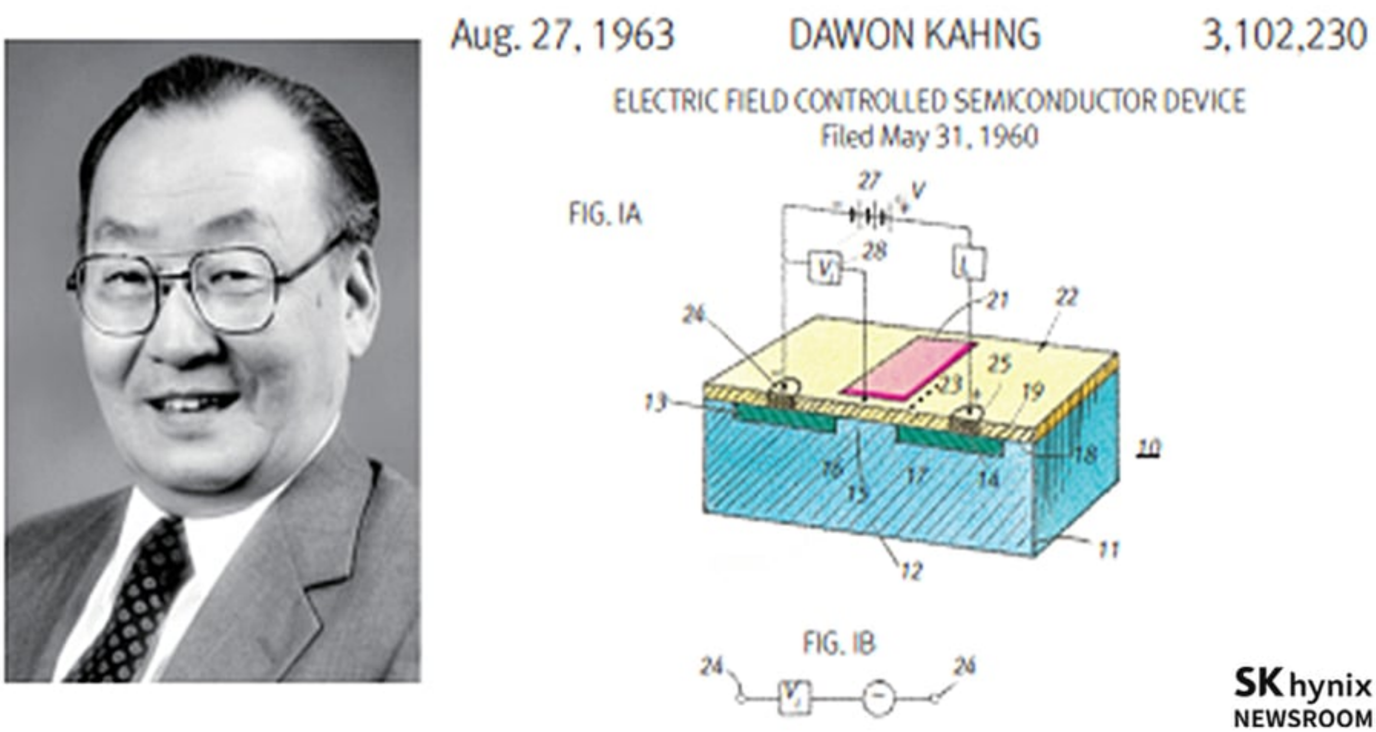

Figure 5. Dr. Dawon Kahng's MOSFET model structure (Source: Hanol Publishing Co., Ltd.)

Due to their flatness, numerous MOSFETs could be made on a silicon wafer simultaneously. If the outline could be made smaller, it was possible to make ten times more MOSFETs on wafers of the same size. Additionally, a set of already-connected MOSFETs could be manufactured simultaneously as well. Let's say a CPU needs to be built using a BJT. No matter how efficient the BJT's production process is, it's necessary to solder hundreds of millions of BJTs together and attach them to the circuit board, as CPUs were made by connecting BJTs. As for MOSFETs, hundreds of

Eventually, the whole point of semiconductor factories is to make MOSFETs more affordable. The succeeding chapters will explain how terms like exposure, etching, deposition, and other processes of making semiconductors contributed to producing affordable MOSFETs.

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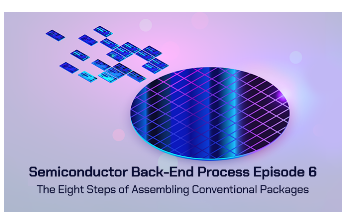

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