The History of the Component of the Logic Gates

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Abstract: This passage will provide a insight into the history of the development of the logic gates alongside with some applications of it. From the invention of relays in 1830s to transistor, which we are still using today as the component of the logic gates. From the analysis of the history, it is to be concluded that the components of the logic gates are getting smaller and faster, and the logic gate itself is getting more complex. It turns out to be that people will need to find a new device as the component of the logic gates in order to start another revolution in our computing power.

1. Introduction

The logic gates are one of the most important bedrock of modern computer science, and had, undoubtedly, contributed to the progress toward making artificial intelligence. Nevertheless, this essay will be discussing how the logic gates had become such a powerful tool in today's society, and in which aspects they impact.

As the name suggests, the logic gates are composed of multiple individual gates. To make a logic gates, those individual gates need to be "logical". In other words, able to make a decision. When thinking about some of the most complex decision questions, people found out that any questions can be reduced and simplified into one or multiple "yes" or "no" questions.

Let's say, for example, I asked the logic gates for which restaurant to go to have lunch today. This complex problem can be broken down into several simple "yes" or "no" questions to examine whether a restaurant is the best choice: is this restaurant close to my current location? Is this restaurant affordable for me? Are the ratings of this restaurant high? Is the food in the restaurant safe? Will I like the food style served in this restaurant? Some questions in this series of questions can be broken down into several secondary questions, for example, regarding the food safety, the logic gates ask furthermore: are the workers healthy? Is the sanitation good? etc. This example demonstrates that any seemed-to-be complex questions can be broken down into many "yes" or "no" questions, which, is processable for the logic gates.

Since the answer to those simple "yes" or "no" questions are either yes or no, there are only two choices that could be made here. To keep in a count of the choices made by the individual gates and to pass it onto the next gate, we need a number system. Here's where the theory of binary comes in. In the binary system, there are only two numbers: 0 and 1, which can be assigned accordingly to the choice of, for example, no and yes. After answering the question of whether it's yes or no, the gate can simply pass its answer to the next gate in form of binary numbers.

2. The Earliest Components of the Logic Gate

When it comes to the actual physical things that made up the logical gates, it's very simple, too, like the "yes" or "no" questions. However, it's the simplest things that people would always want to improve.

One of the earliest physical components of the logic circuits is the relay. It was invented by American Joseph Henry in 1835 and utilized the electrical magnets and metal plates as its main functional parts.

In 1831, Michael Faraday discovered electromagnetic induction, which made the conducting wire, when placed correctly in a magnetic field, can create a current. This phenomenon proves that electricity and magnetism can convert between each other. It is base on these phenomena that Henry, a scientist who is also dedicated in the field of electric magnetism, created the first relay as an entertaining device to amaze his students. The relay, specifically, uses the phenomenon of electricity generating magnetism.

The structures of different types of relays vary to suit their purposes, but the individual relay is never a very complex structure since the relay only needs to represent two states: opened or closed. The relay built for telephone switching shown in Figure 1, for example, embodies simple structure. This device is only composed of three metal plates, an iron armature with an insulated pin, an electromagnet, and some wires. As the wrapped wire applies voltage onto the electromagnet, the electromagnet will generate a magnetic force that will attract the metal armature and thus causing the insulated pin to push the metal plate in the middle to contact with the metal plate at the top. By this an electric circuit is closed between the middle plate and the upper plate, and sends a signal. If the relay is to be closed, simply cancel the voltage added onto the wrapped wire, so that the metal armature will no longer be attracted.

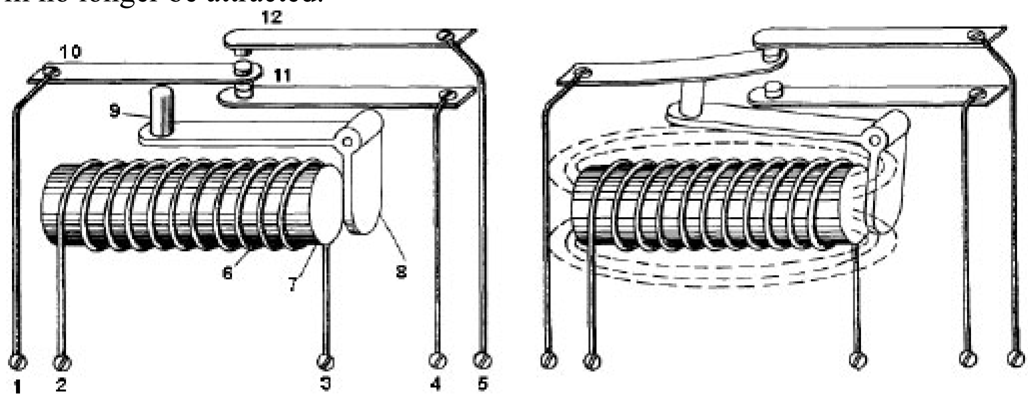

Fig.1 A Typical Relay Buildup Used in Telephone Switching

The relay is a magnificent invention, it had directly invoked the technology of telegram, facilitating the human message transaction to a level that never before. However, there are some significant drawbacks to it too. For example, the relay is big. To build a computer that can do some simple math solely based on logical circuits made with many relays, will take an entire room for it. Another disadvantage is that the relay is based on mechanical structures----the metal plate in the middle have to mechanically move and hit the electric magnet to send out the decision.

These drawbacks had set a limit on computer science. To build a logic circuit out of the relays means that the processor must be very large and slow. If modern computers need to be smaller and faster, a new component of the logical circuit must be discovered and utilized.

3. More Modern Components and Beyond

In 1906, American inventor Lee de Forest invented the electronic tube. This device had made the first step toward a more portable computational device. The electronic tube is much smaller than the relay and doesn't rely on mechanical parts. The electronic tube was soon put to use in the fields of communication, plane, rockets, etc. In fact, this epoch-making invention had earned Forest a Medal of Honor from the IRE, for "his invention of that outstandingly significant device: the three-electrode vacuum tube" (Brittain, 2005).[1]

Yet as time passed, people discovered some of the disadvantages of the electronic tube. Apart from still being too big for modern computers, it is too noisy, too short-lived, and too complicated to manufacture. Figure 2 is a picture of the first ever programmable computer, ENIAC, finished in the February of 1946. Its creation signified an important step to computers based on electronic parts, with its "line of descendants include most computers in use today: laptops, PCs, workstations, as well as supercomputers." (Eigenmann & Cybenko, 1996) [2]The machine, though made up of electronic tubes (17468 of them), still takes the size of a room, weights 31 tons, and costs 480 thousand US dollar. Yet this computer was built with an aim and capability just to calculate the projectile of the new artillery. If using only the electronic tubes, people could never watch movies, play video games, and work on complex 3-D models in a small, portable device as like today.[3]

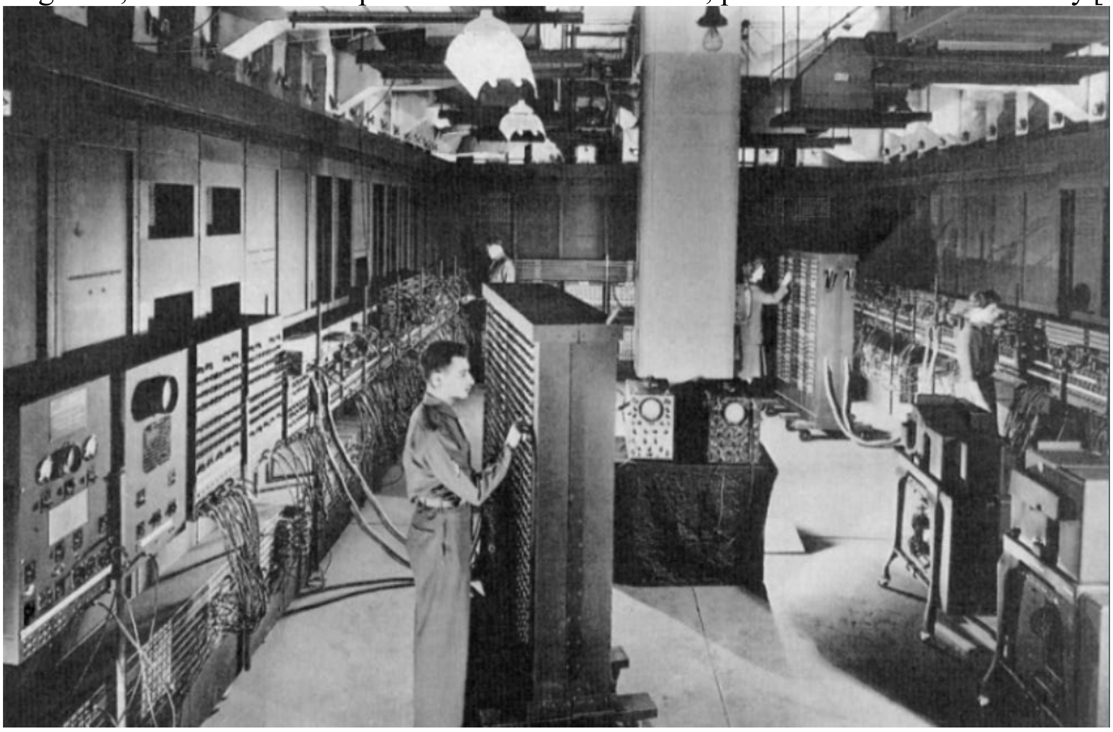

Fig.2 A Picture of Eniac

During World War II, another critical drawback became more and more prominent: the electronic tubes used in radar stations, mobile military apparatus, and other mobile military equipment are very prone to interference. It breaks easily while on the move and can be interfered with by the radar of the radar station. Thus, due to this strict wartime need, scientists started to find a substitute for the electronic tube.

In 1947, Shockley, Bardeen, and Brattain invented the transistor. It is no doubt a revolutionary invention: the transistor is small and less power-consuming. Its invention “gave rise to a rapid development of semiconductor devices and integrated circuits, electronic computing on the new element base.” (Borisov & Bergman, 2020) It still had some drawbacks like being noisy, not very applicable to many modern industries, and being hard to control when at a higher power level. Nevertheless, these drawbacks are eliminated with an improvement of the transistor in 1950[4].

Transistors are used extensively in today’s technological products, it is one of the pillars of modern computer science, probably the biggest one. As technologies improved over time, constant improvements to the transistors were made. They become more and more smaller, powerful, and cheaper following the Moore’s Law, as depicted in Figure 3. The inclined line in the figure indicates the prediction of Moore’s Law, in which states that the transistor on the microprocessor doubles every 18 to 24 months. It can be seen that for the past few decades, the microprocessors are closely following the Moore’s Law’s prediction.

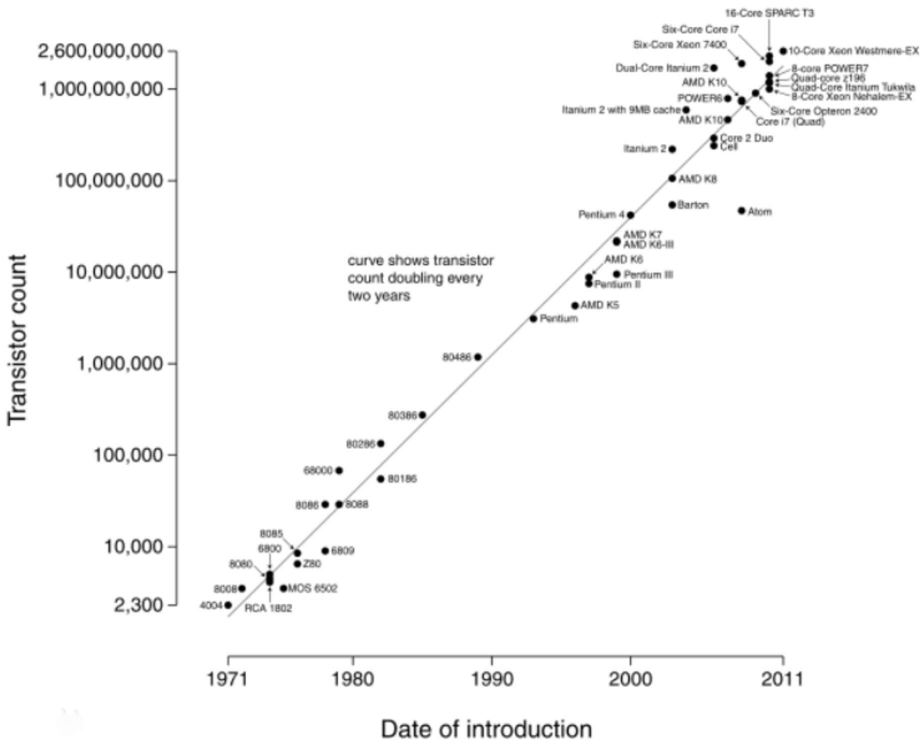

Fig.3 The Transistor Counts of Different Microprocessor of Different Times

However, these improvements are touching a limit: the transistor itself had a limit in size, and putting those very small transistors on a chip had also put a limit on the machinery used. These limitations had their impacts growing in time. During past years, as manufacturing technologies and productivity "have reached their practical limits, the industry has accelerated the introduction of smaller feature sizes." (Brown, 2000) People certainly need a new device that can carry computational devices onto another level. It is, however, a topic for cutting edge inventors and researchers.

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