Research Progress of Chip Types and Their Applications

Zhixin Chen [1], Mingjun Huang [2], Haoyuan Kang [3, *]

[1] School of Materials Science and Engineering, Shanghai University, Shanghai 200120, China

[2] Guangzhou New Channel - Zengcheng Experimental School, Guangzhou 510000, China

[3] School of Microelectronics, South China University of Technology, Guangzhou 511442, China

* Corresponding Author Email: 202164050079@mail.scut.edu.cn

Abstract. Chip plays a vital role in human life. In recent years, the development of chips has sped up, and various innovations and breakthroughs have been emerging. This paper aims to discuss the research status of the types and application scenarios of chips, and introduce their classification, advantages and disadvantages, application scenarios and future prospect. The types of chips can be classified according to the processing signal, function, manufacturing process and application scenario. They have abundant advantages, so they are used in plentiful fields like automotive industry, medical rehabilitation, and Internet of Things, while there still exist several disadvantages. In the future, countries should vigorously support the development of chips, and researchers should pay attention to the shortcomings and conduct research on these weak points. This paper focuses on the characteristics and applications of chips, and expects that more people in society will pay attention to this field, laying the foundation for future development.

Keywords: Chip; chip classification; application; classification.

1. Introduction

In the past few decades, semiconductor technology has been rapidly developed, with chip integration improving. The performance of chips keep enhancing, and their product size is shrinking, which has brought great convenience to people's life. Driven by the scientific and technological revolution, the demand for data processing and transmission continues to grow, and consequently people's demand for more efficient and intelligent electronic devices is becoming more and more urgent. Meanwhile, the rise of emerging technologies such as artificial intelligence, cloud computing, and the Internet of Things also puts higher requirements on chips. Nowadays, in various fields, chips play an indispensable role to meet the needs to process massive data and realize complex algorithms.

Since chips prove vital in human life and they have been rapidly developing and innovating in recent years, it is important to have a comprehensive understanding of the types of chips and their applications in various fields. The existing reviews are basically about the application of specific chips in a certain aspect, and there is no comprehensive introduction to the classification and application scenarios of chips. In addition, the manufacturing and application of chips in various fields are facing many problems, so it is necessary to discuss and summarize the types of chips and the research status in different scenarios.

This paper first introduces the classification method of chips. For example, it is divided into digital chips and analog chips according to different processing signals. Secondly, this paper discusses the advantages and disadvantages of chips with analysis and puts forward the method to improve the shortcomings. As to people, the application of chips in daily life is the most important, so the paper introduces the application scenarios of the chip in the three fields of automotive industry, medical rehabilitation and Internet of things. Finally, with the rapid development of artificial intelligence, chips will develop more perfectly. In this paper, the research of chips is aimed at laying the foundation for exploring the new chapter of human science and technology development.

2. Chips

2.1. Classification of Chips

There are many classifications of chips, which can be divided into two types: analog chips and digital chips, depending on the different signal processing methods. Simply put, analog chips use the amplifying effect of transistors, while digital chips use the switching effect of it. Specifically, analog chips are used to generate, amplify, and process various analog signals, including a wide variety of types such as Analog-to-Digital Converter (ADC) chips, amplifier chips, power management chips, Phase-Locked Loop (PLL) chips, and so on. The difficulty in designing analog chips lies in the numerous non-ideal effects, requiring solid basic knowledge and rich experience, such as small-signal analysis, time-domain and frequency-domain analysis, etc. [1]. In contrast, digital chips are used to generate, amplify, and process various digital signals, generally performing logical operations. Central Processing Units (CPUs), memory chips and Digital Signal Processor (DSP) chips all belong to the category of digital chips. The difficulty in designing digital chips lies in their large scale and complex process requirements, thus it usually requires multiple teams to work together in development [2]. According to their usage functions, chips can be mainly classified into CPUs, GPUs, Field-Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), Application-Specific Integrated Circuits (ASICs), and so on. CPUs are the computing and control core of computer systems, serving as the final execution unit for information processing and program running. GPUs are microprocessors designed specifically for performing image and graphics-related calculations on personal computers, workstations, game consoles, and some mobile devices such as tablets and smartphones. FPGAs are a type of semi-custom circuit that emerged in the field of ASICs, which can be programmed an infinite number of times. They have low latency and offer the highest real-time performance and flexibility by utilizing pipeline parallelism and data parallelism [3]. DSPs are chips capable of implementing digital signal processing techniques, with dedicated hardware multipliers, wide use of pipeline operations and special DSP instructions that can be used to quickly implement various digital signal processing algorithms [4]. ASICs are designed and manufactured to meet the specific requirements of certain users and electronic systems. Compared with general integrated circuits, ASICs are smaller and lighter, consuming less power. They have higher reliability and performance, with stronger confidentiality and lower cost [5]. Nowadays, chip manufacturing technology has become a focus of people's attention, and the more advanced the process, the higher the performance level of chip. Therefore, chips can also be classified according to their manufacturing processes, which is a common classification method. For example, we often hear about 5 nm, 7 nm, 14 nm chips, etc. These numbers refer to the manufacturing process. Currently, the most advanced process technology can reach 5nm, and the next step is 3nm. Generally speaking, the more advanced the manufacturing process, the higher the transistor integration density. The smaller the core area, the lower the cost, and the performance will be stronger accordingly.

In addition, chips can also be classified according to different application scenarios, such as commercial-grade, industrial-grade, automotive-grade, and military-grade chips. Commercial-grade chips are used in ordinary consumer electronic products like smartphones, tablets and televisions. These chips are characterized by relatively low prices and requirements for reliability and anti-interference, but they should have high cost-effectiveness and power control characteristics. Industrial-grade chips are used in industrial automation, monitoring and control, such as Programmable Logic Controllers (PLCs) and Distributed Control Systems (DCS). With higher requirements for reliability and anti-interference, they need to have stable and reliable performance, and be able to adapt to complex industrial environments. Automotive-grade chips are used in automotive electronic systems, including vehicle control, in-car entertainment, and driver assistance. Automotive-grade chips need to have extremely high reliability, anti-interference, low power consumption, and adapt to the special requirements of in-car environments, such as high/low temperature resistance, dust-proof and waterproofing. Military-grade chips are used in military applications and need to have extremely high reliability, anti-interference, and high/low temperature

resistance. Military-grade chips are supposed to undergo strict testing and certification to ensure that they can work normally in extreme environments, and they need to have features such as encryption and protection against attacks.

2.2. Advantages and Disadvantages of Chips

As a modern electronic technology, chips have many advantages, the most significant of which is miniaturization. Modern electronic devices require integration of a large number of electronic components, and chips can integrate these components into a very small space, greatly reducing the size of electronic devices. For example, modern smartphones, tablets, computers and other electronic devices are based on chip technology. Chips also have features such as high performance, low power consumption, and programmability, which can quickly and accurately process large amounts of data and achieve different functions and applications as needed. Emerging technologies such as Artificial Intelligence (AI), machine learning, and virtual reality all require high-performance chips to support them.

However, chips also have some disadvantages. Firstly, the manufacturing cost of chips is high, requiring advanced manufacturing processes and equipment, which makes the manufacturing cost expensive. For example, Apple's A-series chips require the use of special 7nm or 5nm processes, which are complex and quite expensive. Secondly, the design and manufacture of chips require highly specialized skills and knowledge, which can be difficult for ordinary people. Therefore, chip design and manufacture are usually carried out by professional companies or teams. In addition, the market demand for chips changes very quickly, requiring constant updating and improvement, and otherwise they will be eliminated from the market. For example, the demand for AI chips has skyrocketed in recent years, so many companies have started developing and launching their own AI chips to meet market demand. Chips may also have security vulnerabilities, which can lead to serious consequences if they are attacked by hackers. Finally, chip manufacturing requires a lot of energy and chemicals, which may cause pollution to the environment.

3. Chip Application Scenarios

As a kind of integrated circuit, chip has become an important part of modern technology, and its application scenarios are diverse and wide. With the continuous progress of technology, the functions and performance of chips keep improving, bringing more innovation and convenience to various industries. This chapter will focus on the application scenarios of chips in the three fields of automotive industry, medical rehabilitation, and the Internet of Thing.

3.1. Automotive Industry

The automotive electronic devices are mainly divided into two categories, namely, the vehicle electronic control system and the on-board electronic device. Among them, the vehicle electronic control system is the core control system of the vehicle, which integrates and manages various electronic and electrical equipment to achieve accurate control. The on-board electronic device is installed inside the car and connected with the vehicle electronic control system to achieve specific functions. According to the classification of chips, automotive chips can be segmented into four categories: computing, storage, sensing and energy chips.

3.1.1 Computing

Automotive computing chips are divided into Microcontroller Unit (MCU) and System on Chip (SoC). MCU is consisted of central processing unit, memory, input or output interface and other peripheral components. Through processing and controlling various input signals, it implements the corresponding algorithm and processes real-time data, which is widely used in engine management and body electronic control.

SoC is a system that combines integrated circuits with specific functions on a single chip, which contains a complete hardware system and its embedded software. Compared with MCU, SOC

improves the performance and efficiency of complex systems, with a wider range of applications, including intelligent driving, security protection, and infotainment. The composition of MCU and SoC is shown in Fig. 1 [6].

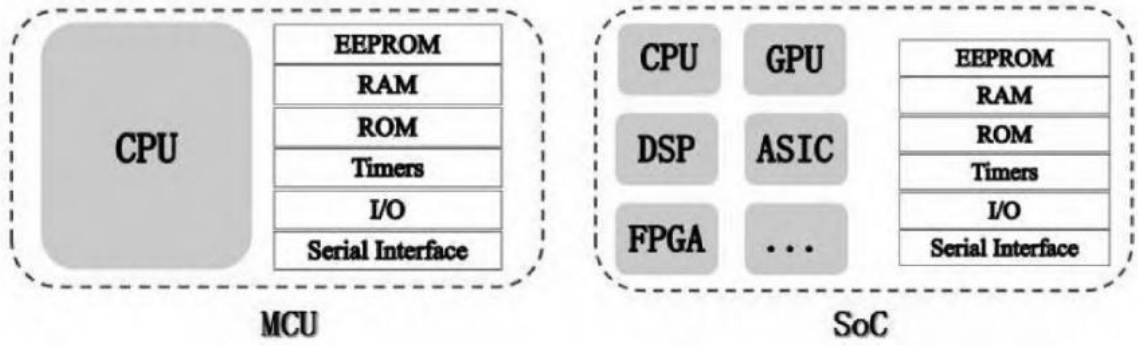

Fig. 1 Structure of MCU and SoC.
https://kns.cnki.net/KXReader/Detail?invoice=cTEXyOrgrRSqpZjWeR7u1Eld9PUkY4sdhXLVwpAVEAHxQ%2Fc9i46%2F%2BzbHv%2B5Dj0DWVmn%2B5Ha7G63tapRi8OL1r9nOEs1vsS64bwuOcewOylXdVBQL%2FsjuVCOWV21CeUc%2F1kn0P3APOEzDWzSWIW%2FMsTMo0mCt3btB8JZyivkqSRg%3D&DBCODE=CJFD&FileName=DZZN202203017&TABLEName=cjfdlast2022&nonce=4B6D1A18CAB64EB9AA55960AE2F4C823&TIMESTAMP=1690776218163&uid=

3.1.2 Storage

Memory chips are integrated circuits used to store and read data. In automobiles, Dynamic Random Access Memory (DRAM) and Electrically Erasable Programmable Read-Only Memory (EEPROM) chips are mainly used. DRAM is a volatile memory known for its high access speed and rich storage capacity, but the data stored by DRAM is temporary and will be lost when the power is off, so backup and recovery mechanisms are required in the automotive system.

EEPROM is an erasable programmable read-only memory. Unlike traditional read-only memory, EEPROM can modify the stored data through electronic erasure and programming operations. Therefore, EEPROM is suitable for storing data that needs to be updated frequently. Since the data stored is non-volatile, even in the case of power failure, the stored data will not be lost.

Both DRAM and EEPROM have their own application scenarios in automobiles. DRAM is suitable for scenarios where large amounts of data need to be stored and processed quickly and temporarily, such as sensor data processing and graphics rendering. EEPROM is suitable for storing persistent and erasable data such as vehicle configuration, logs and diagnostic information. It should be noted that the vehicle memory chip needs to meet the strict requirements of the automotive-grade chips, including environmental requirements, operation stability requirements, reliability and consistency requirements, etc., to ensure the safety and reliability of data [7].

3.1.3 Sensing

Sensing chip is a key technological innovation in modern automobile. It can sense and understand the surrounding traffic environment, playing an important role in the intelligent safety system, intelligent parking system and driver assistance system. Specifically, the sensing chip obtains all kinds of information in real-time environment through data interaction with various sensors, so as to realize the functions of data acquisition, processing, fusion and decision control. A wide variety of automotive sensors, including cameras, radar, ultrasonic sensors, infrared sensors, etc., can provide images, sound, distance, speed and other types of data. The sensor chip processes and analyzes these data, and extracts useful information from them through data processing algorithms and object recognition algorithms. After that, the chip can use data fusion algorithms to integrate the data and provide accurate and reliable environmental perception results. On this basis, the vehicle can better understand and adapt to the surrounding environment, making safe and efficient decisions according to preset rules and algorithms.

3.1.4 Energy

The energy chip is a circuit that integrates multiple power management functions, which is used to manage and control various parameters of the power system. Among them, power semiconductor devices are the key components to achieve energy conversion and power control, which are used in the modules of energy chips. Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) and Insulated Gate Bipolar Transistor (IGBT) are the most widely used power semiconductors.

The MOSFET controls the current between the drain and source through an electric field between the gate and the semiconductor. When the gate voltage is positive, an electronic air gap is created that allows current to flow from the source to the drain. When the gate voltage is negative, the electronic air gap is blocked and the MOSFET enters the off state. MOSFET has the characteristics of low switching loss, high efficiency and fast switching speed, which is often used in motor drive systems to regulate the speed and torque of motor by controlling the current flow.

The structure of the IGBT consists of an NPN bipolar transistor and a P-type MOSFET, which has three electrodes, respectively, Emitter, Collector and Gate. IGBT can withstand high voltage and high current, and it has low switching loss and high switching speed, thus making it the core technical component of electric vehicles and charging piles.

3.2. Medical Rehabilitation

With the advancement of AI technology, wearable smart device has become an important tool in clinical diagnosis, treatment and rehabilitation evaluation, whose key is smart chips. These devices put smart chips in wristwatches, belts, shoes and other personal items, using sensors to monitor patients' physiological parameters. They evaluate and analyze patients' conditions with the support of AI algorithms such as time series analysis and voice recognition, and help medical staff make rehabilitation plans for them. It has broad application prospects in promoting rehabilitation treatment, improving rehabilitation effect and improving patients' quality of life.

Among smart chips, SpiNNaker is a brain-like computing system developed by the University of Manchester in the United Kingdom, whose core idea is to connect a large number of processor cores to form a computational structure similar to the neural network. The system uses a parallel processing architecture and consists of a number of customized chips loaded with multiple low-power ARM processors, each of which can simulate the behavior of neurons by connecting to each other to transmit and process information. This design enables SpiNNaker to handle large-scale parallel computing tasks with low power consumption and high computing efficiency.

A SpiNNaker node (CMP, Chip Multi-Processor) contains 18 ARM968 processor cores, 128MB SDRAM storage, router cores, etc., as shown in Fig. 2a. The ARM processor core has a clock rate of 200MHz and is capable of simulating 1,000 neurons. The router core of CMP contains 6 ports, and 48 CMP form a computing motherboard in a hexagonal network topology, as shown in Fig. 2b. The SpiNNaker system has 10 cabinets, each of which has five built-in racks, and each rack has 24 compute boards. As a result, the whole SpiNNaker system can simulate about 1 billion neurons [8].

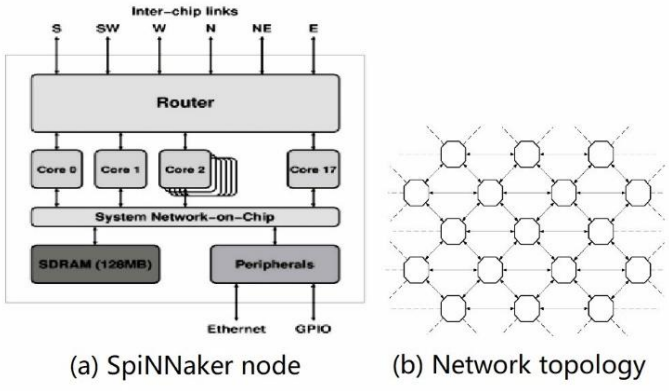

Fig. 2 SpiNNaker Architecture. (Photo/Picture credit: Original)

3.3. Internet of Thing

The Internet of Things (IoT) refers to the technology and concept of connecting objects such as various physical devices, sensors, and mechanical devices through an interconnected network to achieve data exchange, information transfer and remote control. IoT builds an extensive communication network that enables various devices to connect to each other and communicate with the Internet. They utilize embedded sensors and communication modules to collect data, storing, analyzing and applying it through cloud computing and analytics processing platforms. Through data exchange and analysis, IoT can provide people with a more convenient, efficient and intelligent way of life, bringing broad application prospects to many fields, including smart agriculture, intelligent transportation, intelligent energy and so on. Considering that Bluetooth and Wi-Fi are two widely used connection technologies in IoT, this chapter will focus on Bluetooth chips and Wi-Fi chips [9].

3.3.1 Bluetooth chip

Bluetooth technology is a technical standard for short-range wireless communication that allows devices to exchange data over the 2.4 GHz band. It is widely used in wireless communication between various devices, establishing a many-to-many connection, so that these devices can connect with each other and carry out data transmission, audio transmission, file sharing, etc. Bluetooth chip refers to the chip with built-in Bluetooth function, which is used to realize the hardware support of Bluetooth communication. It is usually composed of RF modules, DSP, modems and control circuits, etc., whose main function is to convert data into signals suitable for Bluetooth communication and carry out modulation, demodulation and processing to achieve wireless communication between devices. This low-power wireless connection is suitable for a variety of application scenarios, such as smart home, smart health monitoring, smart industry, etc. In addition, Bluetooth chips provide a secure communication mechanism that encrypts and authenticates data, preventing data leaks and unauthorized access.

3.3.2 Wi-Fi chip

Wi-Fi (Wireless Fidelity) is a kind of short-range wireless network transmission technology. In recent years, with the rise of mobile devices represented by smart phones, laptops and tablets, the shipment of terminal devices with Wi-Fi function has been increasing, and Wi-Fi has become one of the mainstream IoT connection methods at present.

Wi-Fi chips are used for wireless communication, which contains various circuits and functions required for Wi-Fi modules, supporting different Wi-Fi standards and security protocols. It is usually composed of RF transceivers, baseband processors, power amplifiers, filters, and so on. In IoT, the crucial Wi-Fi chips provide high-speed wireless data transmission capabilities and support a wide range of device connections, thus enabling a variety of IoT devices to securely interconnect and transfer data in high speed through wireless networks. Additionally, their low-power characteristic enables IoT devices to save energy, which is important for some applications that need to run for a long time, such as smart sensors, smart monitoring devices, and so on.

4. Future Development

With the rapid development of AI technology, people are paying more and more attention to the development trend of chips. In the future, chips will become the basic support for AI technology and play a crucial role in its development.

In the future, the size of chips will be smaller and smaller, which makes the circuit inside chips more complex, improving their performance and efficiency. At the same time, miniaturized chips can also be more easily embedded in various devices and become much more intelligent. In addition, the energy consumption of future chips will be lower and the performance will be more efficient. This will lead to more computing power, which will better support the development of AI technology. In the future, chips will have more diverse functions, such as speech recognition, automatic driving, and so on, making the field of AI applications more extensive

Integrated circuits are the foundation of modern information industry, but the Moore's law that guides its development is suffering from great limitations, resulting in little development space for some technologies, so it is necessary to use new chips to make it develop continuously. Countries need to keep developing chips, tap technical talents, enact regulations to give technical personnel the greatest benefits, actively layout future plan, seize the commanding heights of the international chip strategy and create history.

For China, chip development still has a long way to go. With the vigorous development of the digital economy, the strategy of building an economic power and the related literature point out that China will reach 70 percent self-sufficiency by 2025. China has once again taken heart after a low period and embarked on the right track of development. However, there still exist many problems, such as backward technology, insufficient production capacity, lack of talents and long development prospects. The government should also rectify the development environment of the chip industry from different aspects, such as financial investment, taxation, high-tech research and development, intellectual property protection and further opening up the market to fully support the development of personnel related to the chip industry. Meanwhile, the state should also issue relevant policies and regulations, indicating the development prospects of the entire industry, protecting all aspects of technical personnel, breaking foreign monopolies and balancing the opportunities and risks faced by the development of new technologies. Through these measures, China is expected to equal or even surpass the world's highest level [10].

5. Conclusion

At present, as a core component of modern electronic technology, chips occupy a pivotal position in many fields, and various innovations and breakthroughs continue to come. In general, the types of chips can be classified according to the processing signal, function, manufacturing process, and application scenario. From the processing signal, it can be divided into digital chips and analog chips. From the functions, it can be divided into CPU, GPU, DSP, ASIC and so on. It can also be classified according to the manufacturing process. The more advanced the manufacturing process is, the higher the chip integration will be. According to different application scenarios, it can be divided into commercial-grade, industrial-grade, automotive-grade, and military-grade chips. In addition, the chip can be applied to automotive industry, medical rehabilitation and the Internet of things. In cars, chips are used for computing, storage, sensing and energy control. In medical rehabilitation, it can be applied to wearable devices and brain-like computer research. In IoT, it can be used as Bluetooth chip and Wi-Fi chip. Moreover, chip has so many advantages, including miniaturization, high performance, low power consumption and so on, however, whose shortcomings are worthy of attention, such as its high manufacturing cost, the fast-changing market demand and the amazing elimination rate. In the future, the development space of chips is still broad. With the development of science and technology, the size of chip will keep shrinking, and its structure will optimize, making it more widely used. The research results of this paper will lay a foundation for the future research of chip and contribute to the further development of this industry.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

[1] Camenzind H., Designing analog chips. Virtual book worm Publishing, 2005.

[2] Hodges D.A., Jackson H G., Analysis and design of digital integrated circuits. 1983.

[3] Field-programmable gate array technology. Springer Science & Business Media, 2012.

[4] Frantz G., Digital signal processor trends. IEEE micro, 2000, 20(6): 52-59.

[5] Kin J., Gupta M., Smith W.H.M., Application specific integrated circuits. 1997.

[6] Zhang S., Characteristics and Application Analysis of Automotive Chip. Electronics Quality, 2022, (03): 73-75. (In Chinese)

[7] Zhu J., Status of global automotive semiconductor industry and suggestions for development of the industry in China. China Integrated Circuit, 2021, 30(03): 11-17. (In Chinese)

[8] Zhang X., Cao Z., Liu Z., Development of Smart Chip and Applications in Health Care. China Integrated Circuit, 2021, 30(09): 16-22+36. (In Chinese)

[9] Research on the Development of IoT Connection Chips. China Industry & Information Technology, 2018, 2(06): 54-67. (In Chinese)

[10] Notice of The State Council on the issuance of Made in China 2025. Gazette of the State Council of the People's Republic of China, 2015, 16: 10-26.