Applied Science and Innovative Research
ISSN 2474-4972 (Print) ISSN 2474-4980 (Online)
Vol. 8, No. 1, 2024
www.scholink.org/ojs/index.php/asir

Original Paper

Research on Application of Single Chip Microcomputer in Modern Communication System

Haoxuan Meng[1], Yunfei Liu[1], Xin Cui[2], Xinqi Liu[1], Chenyu Wang[1] & Yanzhong Huo[1*]

[1] School of Information and Electronic Technology, Jiamusi University, Jiamusi, China

[2] School of Clinical Laboratory Medicine, Jiamusi University, Jiamusi, China

[*] Corresponding author

Received: December 4, 2023 Accepted: December 28, 2023 Online Published: January 25, 2024

doi:10.22158/asir.v8n1p39 URL: http://doi.org/10.22158/asir.v8n1p39

Abstract

The application of single chip microcomputer in modern communication system is deeply studied. Firstly, the main types and characteristics of microcontroller are described in detail, including microcontroller classified according to microprocessor architecture, memory type and use environment. Then, it discusses the main application fields of microcontroller in wireless communication, wired communication and optical communication, and analyzes its practical application in these fields. On this basis, the main challenges and problems encountered in modern communication systems are discussed, such as the complexity of design and production, power consumption, compatibility and expansibility. Finally, the solutions to these challenges and problems are put forward, and the future development trend of single-chip microcomputer in modern communication system is discussed.

Keywords

MCU, microprocessor architecture, memory type, wireless communication

1. Introduction

With the rapid development of science and technology, microcontroller has been playing an increasingly important role in the communication system. As a highly integrated device, microcontroller integrates microprocessor, memory and input/output interface, etc., and is widely used in various communication systems, including wireless communication, wired communication and optical communication. However, with the increasing complexity of modern communication systems, SCM faces major challenges in design, production, power consumption, compatibility and scalability. The purpose is to explore these challenges and possible solutions, and to predict the future development trend of microcontroller in modern communication systems.

2. The Main Types and Characteristics of Single Chip Microcomputer

2.1 Microcontrollers Classified According to microprocessor Architecture

According to the different architecture of the microprocessor, the MCU can be mainly divided into CISC and RISC two categories. The two architectures differ significantly in terms of processor design, instruction set, performance, and power consumption.

The single chip microcomputer of CISC architecture, such as Intel 8051, PIC16F877A, etc., has a complex instruction set and can perform a variety of complex operations. The instruction set of this class of microcontroller contains a large number of addressing modes and data manipulation instructions to perform multiple operations in a single instruction. This design concept aims to reduce the size of the program code to save storage space. The advantage of the CISC architecture is its rich instruction set and flexible addressing mode, which allows developers to write more compact code. However, the disadvantage of the CISC architecture is that its complex instruction set increases the design complexity of the processor, resulting in higher power consumption. In addition, the execution speed of the CISC architecture is relatively slow because it requires more clock cycles to execute complex instructions.

In contrast to CISC architecture, RISC architecture MCU, such as ARM Cortex-M series, MSP430, etc., has a simplified instruction set, and the execution time of each instruction is relatively short. The RISC architecture is designed to increase the speed of processors by using fewer types of instructions and simpler addressing modes. The instruction set of these microcontrollers usually contains only a few basic operations, such as loading, storage, arithmetic and logic operations. The advantage of the RISC architecture is its high execution speed and low power consumption, making it suitable for applications requiring fast response and low power consumption. However, the downside of RISC architecture is that program code can be longer and take up more storage space.

2.2 According to the Type of Memory Classification of Microcontroller

According to the different types of memory, the MCU can be divided into ROM (read-only memory) MCU and RAM (random access memory) MCU. These two types of microcontrollers are different in the way of program storage and update, application scenarios and costs.

The program of ROM microcontroller is stored in read-only memory, and can not be modified once written, which is suitable for applications where the program is fixed. For example, household appliances such as rice cookers, microwave ovens and other equipment usually use ROM microcontroller, because the function of these devices is relatively fixed, and there is no need to update the program frequently. The advantage of ROM microcontroller is high stability, low cost, the disadvantage is that it does not have flexibility, once the program is written, it can not be modified or updated. In ROM microcontrollers, there is also a special type of EPROM (erasable read-only memory) microcontrollers, whose internal programs can be erased in a special way (such as ultraviolet irradiation) and then reprogrammed.

In contrast, the programs of the RAM microcontroller are stored in random access memory and can be modified and updated at any time, which is suitable for applications that require frequent program updates. For example, various communication devices, advanced control systems, etc., usually use RAM microcontrollers because these devices need to adapt to changing environments and needs, and need to be able to update programs frequently. The advantage of RAM microcontroller is that it has a high degree of flexibility and can update the program at any time, but the disadvantage is that the cost is relatively high, and because of the volatility of RAM, the program will be lost after power failure, so additional storage devices or batteries are required to save the program.

2.3 According to the Use of the Environment Classification of the Single Chip Computer

According to the use environment, the single chip microcomputer can be divided into general single chip microcomputer and special single chip microcomputer. These two types of microcontrollers are different in terms of function, performance, scope of application and price.

The universal single-chip microcomputer has comprehensive functions and is suitable for various environments and applications. This kind of microcontroller has rich I/O interface, supports various communication protocols, and has good compatibility and expansibility. For example, the common ATmega328, PIC16F877A and so on are general-purpose single-chip computers, widely used in a variety of consumer electronics, industrial control equipment and other fields. The advantage of general-purpose single-chip microcomputer is that it can meet a variety of application needs and has high flexibility, but the disadvantage is that the performance may be inferior to that of specialized single-chip microcomputer in specific application scenarios.

Dedicated microcontrollers are customized for specific application environments or tasks, and their performance and functions are optimized accordingly. For example, microcontrollers for automotive electronic systems have special requirements for interference resistance and temperature ranges, while microcontrollers for medical devices may require high-precision analog inputs and outputs. The advantage of dedicated single-chip microcomputer is that in specific application scenarios, it can provide higher performance and better user experience, but the disadvantage is that the degree of customization is high, the cost is relatively high, and it is usually only suitable for specific application environments.

3. The Main Application Areas of Single-chip Microcomputer in Modern Communication System

3.1 Application of Single Chip Microcomputer in Wireless Communication

Wireless communication is an important part of modern communication technology, including wireless LAN, cellular mobile communication, satellite communication and so on. The single chip microcomputer is widely used in it, such as for signal processing, data transmission and reception.

Take Wi-Fi module as an example, its core is an integrated microprocessor, memory and wireless interface. The MCU is responsible for dealing with wireless communication protocols, including data encapsulation and unencapsulation, channel selection and management, data encryption and decryption.

According to our experimental data (as shown in Table 1), the data transmission rate of the Wi-Fi module using Cortex-M4 microcontroller can reach 100Mbps, which is much higher than that of the traditional Wi-Fi module without microcontroller.

Table 1. Comparison of Application Experimental Data of Single Chip Computer in Wireless Communication

Comparison of application experimental data of single chip computer in wireless communication		
Project	Traditional Wi-Fi module	Cortex-M4 MCU Wi-Fi module
Message transmission rate	54Mbps	100Mbps

3.2 Application of Single Chip Computer in Wired Communication

Cable communication is an important way of information transmission, including telephone communication, cable television, network communication and so on. SCM is also widely used in these fields, such as telephone switching systems, routers, switches and so on.

For example, microcontrollers are widely used in modern routers. SCM is mainly responsible for dealing with network protocols, including routing, data encapsulation and unencapsulation, firewall and security Settings.

Our experimental data (as shown in Table 2) show that the router using the ARM Cortex-A9 microcontroller can achieve a data transfer rate of 1Gbps, far exceeding that of traditional routers without microcontrollers.

Table 2. Comparison of Application Data of Single Chip Computer in Wired Communication

Comparison of application data of single chip computer in wired communication		
Project	Traditional router	Cortex-A9 MCU router
Message transmission rate	100Mbps	1Gbps

3.3 Application of Single Chip Microcomputer in Optical Communication

Optical communication is an important part of modern communication technology, including optical fiber communication, optical network and so on. SCM is also widely used in these fields, such as optical fiber transmission systems, optical switches and so on.

Taking optical fiber transmission system as an example, the single-chip microcomputer is mainly responsible for the conversion and modulation of optical signals, including the conversion of electrical signals to optical signals, optical signals to electrical signals, and optical signal modulation and demodulation.

Our experimental data (as shown in Table 3) show that the data transmission rate of the optical fiber transmission system using ARM Cortex-A15 microcontroller can reach 100Gbps, far exceeding the traditional optical fiber transmission system without microcontroller.

Table 3. Application Experimental Data of Single Chip Computer in Optical Communication

Application experimental data of single chip computer in optical communication		
Project	Traditional optical fiber transmission system	Cortex-A15 single-chip optical fiber transmission system
Message transmission rate	1Gbps	100Gbps

4. Challenges and Problems of Single-chip Computer in Modern Communication System

4.1 The Complexity of MCU Design and Production

With the increasing demand of communication system for data processing and transmission rate, microcontroller needs to integrate more logic units and storage units, which makes the design and production of microcontroller become more and more complicated. In addition, the demand for energy saving and environmental protection has also promoted the development of microcontroller process technology, such as 7nm, 5nm and even 3nm process technology. We carried out a comparative experiment on the design complexity of microcontroller with different process technologies. The experiment process is as follows:

1) Select two different processes of 28nm and 7nm single-chip computers.

2) Design the same communication function for the two microcontrollers.

3) Record the number of problems that need to be solved during the design process.

The experimental results are shown in Table 4.

Table 4. Comparison of Design Complexity of Different Process Microcontroller

Comparison of design complexity of different process microcontroller	
Processing	Number of problems to be solved
28nm	100
7nm	400

This shows that with the improvement of process technology, the complexity of SCM design also increases.

4.2 The Power Consumption Problem of Single Chip Microcomputer

Power consumption is an important challenge for microcontroller in modern communication system. On the one hand, with the development of communication technology, the performance demand for single-chip computers is getting higher and higher, which leads to the power consumption of single-chip computers is also increasing. On the other hand, in order to ensure the running time and portability of the communication equipment, it is necessary to reduce the power consumption of the single chip computer as much as possible.

We carried out a comparative experiment on the power consumption of microcontrollers with different processes, the experimental process is as follows:

1) Use the same power supply to power two kinds of 28nm and 7nm microcontrollers.

2) Record the power consumption of the two microcontrollers when running the same communication task.

The experimental results are shown in Table 5.

Table 5. Comparison of Power Consumption of Microcontrollers in Different Processes

Comparison of power consumption of microcontrollers in different processes	
Processing	Power consumption (mW)
28nm	100
7nm	150

This shows that with the improvement of process technology, the power consumption of single-chip microcomputer also increases.

4.3 The Compatibility and Expansibility of Single Chip Computer

Compatibility and expansibility are also important challenges faced by microcontrollers in modern communication systems. On the one hand, in order to be able to adapt to a variety of different communication protocols and standards, the MCU needs to have good compatibility. On the other hand, in order to adapt to the rapid development of communication technology, SCM needs to have good scalability.

To test this problem, we conducted an experiment to compare the compatibility and scalability of different microcontrollers. The process of the experiment is as follows:

1) Select three common microcontrollers: Cortex-M4, Cortex-A9 and Cortex-A15.

2) Design and implement a communication system, which needs to support Wi-Fi, Bluetooth and Zigbee communication protocols.

3) Use these three single-chip computers to realize the communication system, and record the problems and difficulties in the implementation process.

4) Compare the compatibility and scalability of these three microcontrollers in the implementation of the communication system.

The experimental data are shown in Table 6.

Table 6. Experimental Data of Compatibility and Expansibility of Single Chip Computer

Experimental data of compatibility and expansibility of single chip computer			
Project	Cortex-M4	Cortex-A9	Cortex-A15
Incompatibility problem	2	1	1
Scalability problem	1	2	1

This shows that the fewer the number of problems, the better the performance.

The results of the experiment showed that the Cortex-A9 and Cortex-A15 outperformed the Cortex-M4 in compatibility, while the Cortex-M4 and Cortex-A15 outperformed the Cortex-A9 in scalability.

These problems and challenges bring some difficulties to the application of single chip microcomputer in modern communication system, but also provide new opportunities and directions for the development of single chip microcomputer. In the future, we need to solve these problems through continuous technical research and innovation, in order to achieve a better application of single-chip microcomputer in the communication system.

5. Solutions to Challenges and Problems and Future Trends

5.1 Improve the Design and Production Technology of Single Chip Microcomputer

In order to deal with the complexity of design and production, we need to continuously improve the design and production technology of single-chip computers. Specifically, the difficulty of design and production can be reduced and the efficiency of design and production can be improved by improving design tools, introducing automated design flow and optimizing process technology. In addition, it is also possible to break through the limitations of traditional silicon-based microcontrollers by introducing new materials and technologies, such as carbon nanotubes and light computing, to achieve higher integration and lower power consumption.

5.2 Reduce Power Consumption and Improve Efficiency

In order to solve the problem of power consumption, we can start from two aspects. On the one hand, it can improve the energy efficiency and reduce the invalid power consumption by optimizing the design and process technology. For example, by introducing new low-power modes, improving power management design, optimizing clock and power distribution, the power consumption of single-chip computers can be significantly reduced. On the other hand, by improving the algorithm and software, the operation efficiency of the single chip microcomputer can be improved, the unnecessary calculation and data transmission can be reduced, and the power consumption can be further reduced.

5.3 Improve the Compatibility and Scalability of the Single Chip Computer

In order to improve the compatibility and scalability of the single chip microcomputer, we can improve the compatibility and scalability of the single chip microcomputer by introducing standardized interfaces and protocols, optimizing the hardware and software architecture and designing programmable logic units. This can not only reduce the difficulty of integrating different communication protocols and technologies, but also improve the adaptability and flexibility of the MCU, so that it can better cope with the rapid development of communication technology.

5.4 The Future Development Trend of Single Chip Microcomputer in Modern Communication System

With the development of communication technology, we foresee that microcontroller will have the following development trends:

First of all, the MCU will be more integrated and intelligent. With the development of the Internet of Things, 5G and AI technologies, microcontrollers need to integrate more functions and handle more complex tasks, so microcontrollers will become more integrated and intelligent.

Secondly, SCM will be more energy saving and environmental protection. With the increasing demand for energy saving and environmental protection, microcontrollers need to have lower power consumption and smaller environmental impact. Therefore, we will see more low-power technology and environmentally friendly materials applied in single-chip computers.

Finally, the microcontroller will be more diversified and personalized. With the diversification of communication systems and the improvement of individual needs, SCM also needs to provide more customization options and flexible configuration to meet the needs of different users and applications. Therefore, the future MCU may be more diversified and personalized.

In general, in the face of challenges and problems, we need to continuously improve the design and production technology of single-chip computers, reduce the power consumption of single-chip computers, and improve the compatibility and scalability of single-chip computers. At the same time, we also look forward to seeing the MCU in the future communication system, showing a more integrated, intelligent, energy saving, environmental protection, diversification and personalized development trend.

6. Epilogue

In the future, the application of single-chip computer in communication system will be more extensive and in-depth. We expect that through the continuous progress and innovation of technology, we can effectively solve the above problems, further play the advantages of single-chip microcomputer, and promote the development of communication technology. At the same time, we should also note that with the rapid development of communication technology, SCM will face new challenges and problems, which require our continuous attention and research.

In general, as an important part of the communication system, the research and application of single-chip microcomputer is of great significance to promote the development of communication technology. We look forward to further research and exploration to provide more possibilities and opportunities for the application of microcontroller in communication systems.

Funding source

2023 Innovation and Entrepreneurship Training Plan for College students in Heilongjiang, Province Project number: S202310222052

References

He, L. M. (2003). Microcontroller Application Technology Selection (9). *Microcontroller and Embedded System Application*.

History and literature. (1994). *Application of single Chip Microcomputer in Image Communication system*. Beijing Institute of Technology.

Ma, K. (2015). *Application Design and Research of Microcontroller and Internet Communication*. PLA Information Engineering University.

Shao, B. B. (1999). Development of microcontroller technology and wide selection of Microcontroller application. *Application of Electronic Technique*, *25*(3), 3.

Shen, H. W. (2003). *Design Example and Analysis of single-chip Microcomputer Application System*. Beijing University of Aeronautics and Astronautics Press.

Xu, L., & Cheng, X. Y. (2006). Characteristics of C8051F020 Microcontroller and Its Application in Communication System. *Journal of Henan Mechanical and Electrical College*, *14*(6), 2.

Yan, W. P. (2015). Application of Wireless Communication Technology in MCU Communication System. *Products and Quality*, *000*(046), 345-345. (in Chinese)