

# 嵌入式系统设计 Embedded System

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## 摘要：

随着计算机技术和微电子技术的迅速发展，嵌入式系统应用领域越来越广泛。嵌入式系统对我们来说，已是不可或缺的一部分。嵌入式系统一般指非 PC 系统，有计算机功能但又不称之为计算机的设备或器材。嵌入式系统主要由嵌入式微处理器、外围硬件设备、嵌入式操作系统以及用户的应用程序等 4 个部分组成。当前 ARM 嵌入式系统应用市场份额约占 75%，从嵌入式系统的基本概念入手，以 ARM 嵌入式系统为例，分别从它的定义，微处理器，开发工具及调试方法来介绍 ARM 嵌入式系统基础知识。接着，讨论 ARM 嵌入式系统的实时性要求，介绍目前市场上的实时多任务操作系统（RTOS），最后，概括嵌入式系统开发与应用领域及其发展前景。

**关键词：**嵌入式系统；ARM 嵌入式系统；微处理器

## **Abstract:**

With the rapid development of computer technology and microelectronics, the application field of embedded system is more and more extensive. Embedded system is an indispensable part for us. Embedded system generally refers to a non-pc system, which has computer functions but is not called a computer equipment or equipment. Embedded system mainly consists of embedded microprocessor, peripheral hardware device, embedded operating system and user's application program. At present, the market share of ARM embedded system application is about 75%. Starting from the basic concept of embedded system, this paper takes ARM embedded system as an example to introduce the basic knowledge of ARM embedded system from its definition, microprocessor, development tools and debugging methods. Then, it discusses the real-time requirements of ARM embedded system, introduces the real-time multi-task operating system (RTOS) in the market, and finally summarizes the development and application field of embedded system and its development prospect.

**Keywords:** Embedded system; ARM Embedded system; The microprocessor

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# 1. My way of Embedded(我的嵌入式)

## 1.1 Analyze(分析)

With the rapid development of electronic technology, especially large-scale integration technology, Embedded Microcontroller MMC technology appears. It is applied to the field of modern industrial control, which brings a new technological revolution and the birth of Embedded Systems. At present, embedded system occupies a very important proportion in the whole semiconductor market. Embedded system has been playing an irreplaceable role in PC technology, network technology, communication, consumer electronics, industrial control, transportation, aerospace, national defense and other fields. Embedded system-based consumer products are also becoming a new trend, such as wireless communication equipment, digital entertainment products, digital cameras and so on.

In my understanding, embedded is a high-tech technology based on computer science. It takes computer technology as the core, combines the needs of users with microprocessors, and realizes the specific functions of hardware carrier by means of embedded computer. Embedded in our daily life is everywhere, such as mobile phones, washing machines, POS machines and other commonly used machines with specific functions. Without these machines, our world would be much more complicated and life would be much less fun. In short, up to now, embedded has been integrated into our human life, is an indispensable part of the human world, we software engineering students need it, it also needs us, embedded for our software engineering students, is a ladder to contact the world, but also a way to explore the world.

## 1.2 Get(获取)

In embedded learning, the most important thing is the method and channel to acquire knowledge. At first, my partner and I discussed the general structure of our paper in private, then discussed the content of the paper in all aspects, and finally thought about how to acquire the knowledge we need. First, it is through consulting relevant books and materials, self-study embedded. The 2nd, seek teacher, look for senior students to consult through looking for a teacher. Third, through the school library to consult the relevant papers, and some of the notes of predecessors and so on. The most important way is to consult relevant papers, which allows us to

get started quickly and find the knowledge we need quickly. It is of great help to our learning and is also the most commonly used method of knowledge acquisition.

### 1.3 Adjust(调整)

Finally, the paper is adjusted to meet the relevant requirements of the large assignment, check whether the relevant terms are objective, and make our summary of embedded. Embedded controller applications are everywhere, such as mobile phones, intelligent electrical appliances, CNC machine tools, and so on have its trace. Embedded controller because of its small size, high reliability, strong function, flexible, convenient and many other advantages, its application has been deep into the industry and agriculture, education, national defense, scientific research and daily life and other fields, in all walks of life technological upgrading, product upgrading, accelerate the automation process and increase productivity has played a very important role. Therefore, it can be said that embedded intelligent chip is the "digital gene" that makes up the future world. As predicted by academician Shen Xubang, a senior embedded system expert in China, "in the next decade, there will be embedded intelligent chips with the size of needles and more than 100 million computing power", which will provide us with infinite space for creation. Therefore, our software engineering students should also keep pace with The Times, keep up with the pace of The Times, learn embedded[1]

## 2. Embedded(嵌入式)

### 2.1 Embedded history of development(嵌入式发展历史)

Although embedded system has been really popular in recent years, in fact, the concept of embedded system has existed for a long time. From the appearance of MCU in 1970s to the wide application of various embedded microprocessors and microcontrollers, embedded system has a history of nearly 30 years. Throughout the development process of embedded system, it has roughly experienced the following four stages:

#### No Operating System Phase

The initial application of embedded system is based on single-chip computer, mostly in the

form of programmable controller. It has the functions of monitoring, servo, equipment indication and so on. It is usually used in various kinds of industrial control, aircraft, missile and other weapons and equipment. Generally, there is no support of operating system. It can only control the system directly by assembly language, and then clear the memory after operation. Although these devices have preliminary characteristics of embedded applications, they only use 8bit CPU chips to execute some single-threaded programs, so strictly speaking, there is no "system" concept.

At this stage, the main characteristics of embedded system are: the structure and function of the system are relatively single, the processing efficiency is low, the storage capacity is small, and there is almost no user interface. Because of its simplicity and low cost, this embedded system has been widely used in the field of industrial control, but it cannot meet the needs of information appliances which have higher requirements for execution efficiency and storage capacity.

#### Simple Operating System Stage

O design microcontroller, and at one stroke become a new emerging force in the field of embedded systems. At the same time, programmers of embedded systems have begun to develop embedded application software based on some simple "operating systems", which greatly shortens the development cycle and improves the development efficiency. Chinese style

The main characteristics of embedded system in this stage are: a large number of high reliable and low power embedded CPUs (such as PowerPC) appeared, and various simple embedded operating systems began to appear and developed rapidly. At this time, although the embedded operating system is relatively simple, it has a certain compatibility and expansibility. The kernel is exquisite and efficient. It is mainly used to control the system load and monitor the operation of the application program.

#### Real-time Operating System Phase

In the 1990s, driven by the huge demands of distributed control, flexible manufacturing, digital communication and information appliances, embedded system developed rapidly, while DSP products oriented to real-time signal processing algorithm developed towards the direction of high speed, high precision and low power consumption. With the improvement of real-time requirements of hardware, the software scale of embedded system is also constantly expanding, and the real-time multi-task operating system (RTOS) is gradually formed and becomes the mainstream of embedded system. The main characteristics of the embedded system at this stage are: the real-time performance of the operating system has been greatly improved, and it has been able to run on various types of microprocessors, with a high degree of modularity and extensibility. At this time, the embedded operating system has file and directory management, device management, multi-task, network, graphical user interface (GUI) and other functions, and provides a lot of application program interface (API), so that the development of application software

becomes more simple.

#### Internet oriented phase

The 21st century will undoubtedly be a network era, and the voice of applying embedded system to various network environments will naturally become higher and higher. At present, most embedded systems are isolated from the Internet. With the further development of the Internet and the increasingly close combination of Internet technology with information appliances and industrial control technology, the combination of embedded devices and the Internet is the real future of embedded technology.

The arrival of the information age and the digital age has brought great opportunities for the development of embedded systems, but also posed new challenges to the manufacturers of embedded systems. At present, the combination of embedded technology and Internet technology is promoting the rapid development of embedded technology. The research and application of embedded systems have brought about the following remarkable changes: ()

With the emergence of new microprocessors, the design of embedded operating system structure is more convenient to transplant, and it can support more microprocessors in a short time. Chinese style

The development of embedded system has become a system engineering. Developers should not only provide embedded software and hardware system itself, but also provide powerful hardware development tools and software support packages. 8594 Chinese style

With the rapid development of various embedded Linux operating systems, because of its open source code, small system kernel, high execution efficiency and complete network structure, it is very suitable for the needs of embedded systems such as information appliances. At present, it has formed a strong competitive situation with embedded operating systems such as Windows\_CE, Palm\_OS. Chinese style

With the maturity of Internet technology and the improvement of bandwidth, the requirement of networking and informationization is becoming more and more prominent. In the past, the functions of single-function equipment such as telephone, mobile phone, refrigerator and microwave oven are no longer single, and the structure becomes more complex. Network interconnection has become an inevitable trend. Streamlining the system core, optimizing key algorithms, reducing power consumption and hardware and software costs. Provide more friendly multimedia human-computer interaction interface[2]



## 2.2 Embedded system(嵌入式系统)

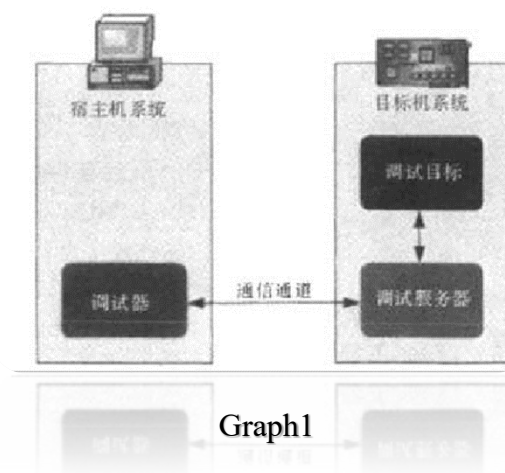
To implement embedded, we need computers. Embedded computer implementation refers to the physical implementation of computer "which includes the physical structure of the processor and main memory components" device "signal transmission device module integration and speed of the partition of plug-in base plate and connecting" special device design "power, cooling, assembly technology and related manufacturing technology and process, etc. An embedded system is actually a type of computer to realize "it has specificity, real-time, reliability and energy saving characteristics such as low consumption" applications increasingly widespread, project is associated with computer to realize computer system structure and principle "is the system hardware and software system structure and interface" principle is the implementation of the logic system structure. In this paper, we take ARM embedded system as an example to illustrate, which will be elaborated in detail in the fourth section, without too much discussion here.

## 2.3 Embedded technology(嵌入式技术)

### Cross-compile and link

After complete embedded software code, compile and link will be necessary to generate executable code, due to the development process are mostly in the use of Intel x86 series of general-purpose computer CPU, and the target environment processor chip is much as ARM, MIPS, PowerPC, DragonBall series such as microprocessor, which requires to cross in good cross development environment to compile and link. At present, the embedded integrated development environment supports cross-compilation and cross-linking, such as WindRiver, Tomado and GNU tool chain. After cross-compilation and cross-linking, embedded software usually generates two types of executable files: executable files for debugging and executable files for curing.

After the embedded software is compiled and linked, it will enter the debugging stage. Debugging is an essential link in the software development process. The cross-debugging in the embedded software development process is different from the debugging in the general software development process: In general software development, the debugger and the debugging of program is often run on the same machine, the debugger running alone, it provided by operating system debugging interface to control the process of being debugged, and in embedded software



development, debugging is in between the host and target machine cross debugging, the debugger is still running on the host machine's general operating system, but the process of being debugged is running on the embedded operating system based on a specific hardware platform, the debugger and the debuggee via a serial port or network communication, the debugger can control, access the debuggee, Reads the current state of the debugged process and can change the running state of the debugged process. Cross-debugging, also known as remote debugging, is a debugging method that allows the debugger to control the running mode of the debugged process on the target machine in a certain way, and has various debugging functions such as viewing and modifying memory units, registers and variable values in the debugged process on the target machine. In general, the structure of the remote debugging process is shown in the graph1[3]

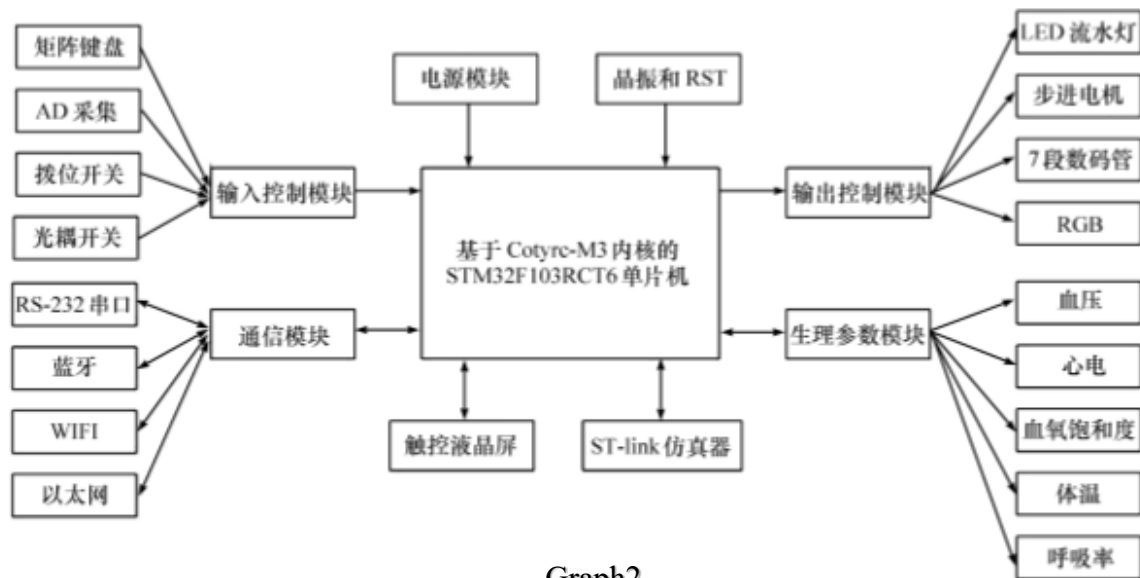
### 3. Embedded application(嵌入式应用)

#### 3.1 Medical electronic embedded(医疗电子嵌入式)

Medical embedded system is a characteristic course, which is a comprehensive course integrating theoretical learning and curriculum practice. And it is also an application representative of embedded system development and design. This course is based on the principles of embedded system development technology to train students with solid professional knowledge and theories. The supporting medical embedded system experiment course enables students to transform the theory they have learned in class into reality, which is of great significance for cultivating students' embedded development ability and cultivating good consciousness of innovative design. This course requires students to understand and apply the key technical components of blood pressure meter, monitor, biochemical analyzer and other common medical devices on the basis of learning traditional embedded system courses, so as to lay a foundation for students' future internship and employment. Function of this section has developed a set of perfect medical electronics embedded experimental platform, the platform adopts the popular market at present is based on the kernel architecture (M3 STM32 embedded single chip microcomputer as main control chip, with many kinds of general embedded system technology module, at the same time joined the biomedical engineering professional characteristics of physiological parameter module. The experimental platform can effectively help students master the basic principles of embedded system in the process of learning, and have a preliminary understanding of the development of medical

instruments.

STM32 embedded single-chip microcomputer of STM semiconductor company is adopted in this experimental platform. As a microcontroller commonly used in industrial fields, STM32 chip has the advantages of high performance, low cost and low power consumption, and has strong practicability in experimental teaching. The platform is externally equipped with touch LCD screen, 7-segment digital tube, flowing water lamp, buzzer, RGB, keyboard, stepper motor,



Graph2

bluetooth, WIFI and other universal experimental modules. Meanwhile, it is equipped with physiological parameter modules such as blood pressure, ecg, blood oxygen saturation and body temperature, as shown in graph2

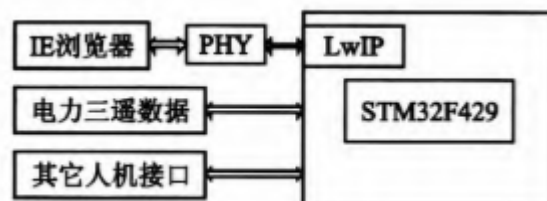
Since this paper mainly introduces the development of embedded system, the application of embedded system is not studied in depth in this chapter. You just need to know how to apply it[4]

### 3.2 Automated service(自动化服务)

This section is designed to solve the problem of countries around the intelligent level of uneven distribution network, in order to maintain distribution network terminals, at present, the terminal manufacturers generally used methods for each function of the terminal to develop a maintenance software version, even if the same type of terminal will exist a lot maintenance software version, for the maintenance of the late great effort. In view of the above distribution network terminals have a variety of maintenance software versions, maintenance difficulties, general distribution network terminals have the characteristics of the network port, this paper based on embedded

WebServer technology design and implementation of Internet explorer as a general maintenance software system, so as to achieve unified maintenance software, maintenance is simple.

This system USES STM32F429 as CPU chip and LAN8742 as Ethernet PHY chip. Telemetry, telecontrol, telecontrol and other telecontrol data and other human-computer interface parts adopt the general design scheme of power terminal. TCP/IP protocol is implemented by transplanting LwIP protocol stack. Browser web files are designed in HTML language, and then converted into static data stored in the terminal. For the data in the web page that needs to be refreshed in real time, dynamic frame grouping is adopted and



Graph3

transmitted to the browser for display in real time. The overall architecture of the system is shown in graph3.

Only the overall structure of the introduction, do not do specific details[5]

## 4. ARM Embedded System(ARM 嵌入式系统)

### 4.1 ARM Embedded System design(ARM 嵌入式系统设计)

Since the emergence of the single chip microcomputer application of all kinds of embedded microcontroller processor, embedded systems have been forty years of development, and with the continuous development of science and technology in recent years, various of new technology and equipment, embedded system itself is constantly optimized, the superiority of people for embedded systems is more and more recognition, embedded systems have been widely applied to various kinds of high precision equipment. ARM processor is currently recognized as the industry's leading 32-bit embedded RISC processor, so this section will take ARM embedded system as the core, introduce embedded system development and design.

#### ARM microprocessor, embedded system analysis

Embedded microprocessor plays a key role in embedded system. Among them, ARM microprocessor belongs to 32-bit compact instruction set computer microprocessor. This kind of microprocessor has good performance and low cost, so it has a good application system adaptability and can reduce the operation cost of the factory in the actual application. Embedded

system, refers to the embedded computer system, the structure includes: software (system application software, operating system), hardware (system equipment, processor) two parts. The system characteristics of this computer are: low energy consumption, high integration, program development needs to be developed in a specific environment, the system can not develop the program on its own, all system applications are fixed (solidified) in the chip. The performance of the system is stable and can be used for a long time. Therefore, schools and factories need to use embedded systems in specific situations when they apply them.

#### Advantages of ARM processor

For a large number of 32-bit embedded applications emerging today, in my opinion, the advantages of ARM processor mainly include the following aspects:

High performance, low power consumption, low price

Rich selection of chips

Extensive third-party support

Complete product line and development plan

#### Selection of the ARM

ARM processors include ARM9, ARM9E, ARM10, Intel StrongARM and other series, each series has its own characteristics, so in the system development process we must first according to the system requirements and user needs for ARM selection. ARM processor consists of a series of kernel structure, so as to adapt to the needs of different users, for example, users need to use the WinCE or standard Linux operating system, such as when we are in the system design is about to consider to choose storage capacity in more than 20 t with the function of MMU ARM chips, in fact there are many kinds of AARM chip with MMU functions, and current software is similar to uCLinux, don't need the support of MMU functions can complete the desired operation.

#### Bootloader development

Bootloader is a chip boot program written by assembly language. This program immobilized storage device, the main function is to start storage media embedded software. The relationship between Bootloader and ARM chip is that Bootloader can be designed to run in RAM or independently of ARM. Currently, CPU support is the prerequisite for running in ARM. Bootloader development first requires that the processor be initialized, that is, some configuration registers in the processor be initialized using Bootloader. The next step is to initialize some necessary hardware, including FlashROM and interrupt controller, and some download system image from the host to the hardware board also completed by its initialization interface equipment, the whole process is relatively complex, initialization and download the image download in Ethernet as the transmission intermediary work, Bootloader will be responsible for the initialization of related hardware.

### Development and design of embedded system

System requirements analysis: the most important feature of embedded system is to face specific users, so the user's system requirements is the first consideration of embedded system development and design. Therefore, in the specific design work, users' project needs should be combined to determine the design objective, according to which each part of the system function, performance, production cost and some specific parameters should be further determined, and the feasibility analysis of these data can provide reference for the specific development work.

Architecture design: the architecture design of the system is the framework design of the embedded system, which is the basis of the whole system design.

Hardware - software collaborative design: if the architecture is a general design, the design of the thick line, the hardware - software collaborative design is detailed design of hardware and software, specific design, the design of specific to each component specifications and structure, mainly including is the large peripheral equipment, circuit boards, etc. All the parts of the hardware and system software. Of course, in the design of specific components, in addition to each individual component, but also consider the hardware - software collaborative design, to ensure the coordination of the whole system.

System integration: specific hardware and software design is completed, is the need for system integration, the system hardware, software, and the execution unit together, we get the prototype of a system, this system could be related to the goal we expected after assembly system on the function and composition of a certain discrepancy, so after the system integration to debug, through debugging, we can found the shortage of the system, optimization and adjustment, finally forms the expected function system.

Complete testing and forming products: the system test is the last link of the system design, concrete is to get the design and debugging good testing system in the actual operation environment, system test process is relatively complex, through a series of testing process, ensure system can meet the needs of practical application, can form a systematic products, development process, through above procedural basic guarantee can running effect of the embedded system, if there any problems in use process should look for professional personnel for maintenance[6]

## 4.2 Embedded LINUX terminal based on ARM(基于 ARM 的 LINUX 终端)

With the rapid development of network and electronic information technology, the hot

technologies represented by embedded technology, artificial intelligence technology and communication technology are developing rapidly. After China put forward the "Internet +" innovation mode, embedded technology and its operating system have attracted more and more attention. Linux accounts for a large proportion of different embedded operating systems. At present, people have higher and higher requirements on the performance of embedded Linux terminal system, and the embedded Linux terminal system itself cannot meet the special requirements of the field, so it needs to be optimized. The traditional performance optimization method of embedded Linux terminal system is realized by software, ignoring the hardware optimization, and the optimization result is not good. This section combines hardware and software to introduce an arm-based embedded Linux terminal system optimization method.

#### Real-time performance optimization of embedded Linux terminal system based on ARM

ARM 920t is the core of ARM development board, which can be programmed in two states :ARM state and Thumb state. ARM state is used to execute 32-bit ARM instruction and Thumb state is used to execute 26-bit Thumb instruction. The transition of the two states is independent of processor and register state. In ARM, the memory address belonging to the kernel/system space is from 0xFFFFFFFF ~ 0xc0000000, while the memory address belonging to the process is from 0xc0000000 ~ 0x00000000. There is a lot of Shared memory between stacks. Figure 1 describes the memory allocation diagram of embedded Linux terminal system based on ARM. When using ARM to optimize the memory of embedded Linux terminal system, the memory optimization of hardware is realized on the basis of mastering the design objectives of the system, and unnecessary hardware functions can be ignored.

#### Software optimization

The memory allocation problem of embedded Linux terminal system is transformed into 0-1 knapsack problem, and the memory optimization of embedded Linux terminal system is realized through dynamic programming. The 0-1 knapsack problem is described as follows: suppose the existing knapsack space is  $V$ , the item type is  $n$ , and each item  $I$  has a certain weight  $m_i$  and the interest  $q_i$  of packing. If there is enough space left in the backpack, all kinds of items can be loaded into the backpack. In the process of packing, it is stipulated that all items of class 1 should be put into the backpack or none at all. 0-1 knapsack problem refers to how to pick out several items from these  $n$  categories and put them into knapsack, so as to maximize profit.

There's a lot more to embedded system development for LINUX, but we haven't been able to apply this knowledge well, so we've only discussed the software optimization part[7]

## 5. RTOS(实时多任务操作系统)

Real-time multi-task operating system (RTOS) is the foundation and development platform of embedded application software. At present, commercial RTOS can support dozens of embedded processors from 8BIT 8051 to 32BIT PowerPC and DSP. Famous companies that provide high-quality source code for RTOS are mainly concentrated in the United States. At present, most embedded software development in China is still directly written based on processors, and commercial RTOS is not adopted, so system software and application software cannot be processed separately. An RTOS is a piece of software embedded in the target code on which the

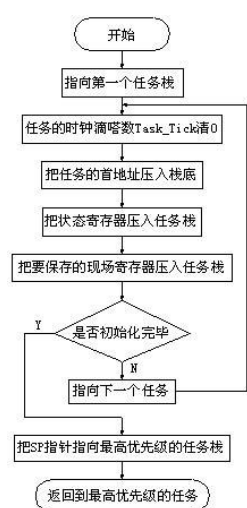
user's other applications are built. Not only that, RTOS is also a real-time kernel with high reliability and credibility, which wraps up CPU time, interrupt, I/O, timer and other resources, leaving users with a standard API, and reasonably allocate CPU time among different tasks according to the priority of each task.

RTOS is an efficient real-time multitasking kernel designed for optimal design of different processors. Excellent commercial RTOS can provide similar API interfaces for dozens of embedded processors such as MPU, MCU, DSP and SOC, which is the basis of independent application development of RTOS based on devices.

Therefore, the C language program based on RTOS has great portability. According to the estimation of experts, only 1-5% of the

content needs to be modified for excellent RTO program porting across processor platforms. On the basis of RTOS, a variety of hardware device drivers, expert library functions, industry library functions and product library functions can be written. Together with universal applications, RTOS can be used for product sales and promote the exchange of intellectual property rights within the industry. Therefore, RTOS is a software development platform.

RTOS is the software development platform of embedded system. RTOS is the most key part of the real-time multitasking kernel, its basic features include the kernel task management, timer management, memory management, resource management, event management, system management, news management, queue management, management, etc., these management function is through the kernel service function form to the user calls, namely the API of RTOS. The introduction of RTOS solves the problem of standardization of embedded software development. With the increasing proportion of software in embedded systems and the increasing





application programs, the organization and management of developers, application program interfaces and program files has become a big topic. The introduction of RTOS is equivalent to the introduction of a new management mode, which is an improvement for both developers and developers.

The program developed based on RTOS has a high portability, and more than 90% of the equipment is independent. Some mature general programs can be introduced into the society as expert library function products. The functionalization and productization of embedded software can promote industrial communication and specialization of social division of labor, reduce repetitive labor and improve the efficiency of knowledge innovation. The foundation of embedded industry is application-centered chip design and application-oriented software development. The significance of real-time multi-task operating system (RTOS) entering the embedded industry is no less than the contribution made by the mechanical industry in the history to adopt three views. It is a milestone for the standardization of embedded software and the acceleration of knowledge innovation.

## 6. Embedded development prospect(嵌入式前景)



Today, neural networks are used in many of the devices we use every day: in smartphones they support photo search, and in face recognition to help people unlock their phones with faces. They can tell you whether you are driving into or out of a congested area by reading the license plate. Them enough "smart", that can detect a person's body language - this is very useful for monitoring and control system, they have also been applied to the camera of AV systems, everyone

can recognize and let the system to provide personalized content services, involving applications include lane departure warning in the car, the driver condition monitoring, etc., in addition, through a large number of experiments and application prove that the neural network is better than the human good at detecting skin cancer --, the application of neural network is widely, and varied. Different from "traditional" cloud-based artificial intelligence (AI), these neural network computations based on field application devices can be called embedded AI. This is a rapidly developing market that also yearns for technological innovation, and it is also a market that many SoC design companies are exploring with innovative products. With Imagination's launch of Series2NX neural network accelerator (NNA) last September, the rules of the game in embedded AI acceleration are changing[8]

In the abstract of this paper, the application of embedded controller is almost everywhere: mobile phones, household appliances, cars... it is everywhere. Embedded controller because of its small size, high reliability, strong function, flexible, convenient and many other advantages, its application has been deep into the industry, agriculture, education, national defense, scientific research and daily life and other fields, in all walks of life technological upgrading, product upgrading, accelerate the automation process and increase productivity has played a very important role. Embedded computers far exceed all kinds of general-purpose computers in the number of applications. The external devices of a general-purpose computer contain 5-10 embedded microprocessors. Embedded computers are applied in manufacturing industry, process control, network, communication, instrument, instrument, automobile, ship, aviation, aerospace, military equipment, consumer products and other aspects. Embedded system industry is a dedicated computer industry, its purpose is to make everything more simple, more convenient, more universal, more applicable; The development of general-purpose computers has turned into functional computers and generally entered the society. The goal of the development of embedded computers is to use special computers to achieve "generalized computing". Therefore, it can be said that embedded intelligent chips are "digital genes" constituting the future world. As predicted by academician shen xubang, a senior embedded system expert in China, "in the next decade, embedded intelligent chips with the size of needles and more than 100 million computing power will be produced", which will provide us with infinite space for creation. In short, "embedded microcontrollers, or MCU's, are like a black hole that will attract many of today's technologies and achievements. As students of software engineering, we should seize the opportunity to learn embedded development technology and prepare for the future[9]

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