DOI: 10.53469/jtpes.2024.04(03).09

Data Acquisition System based on Serial Port

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Abstract: ***Data collection refers to the automatic collection of non electrical or electrical signals from sensors or other devices with analog or digital units under test, and then sent to the upper computer for analysis and processing. In recent years, people have been constantly paying attention to the development and market situation of data collection and its applications. The attention of the general public has led to a qualitative leap in the development of data collection systems, which are widely used in various digital markets. This article introduces the relevant concepts and basic principles of data collection, and designs the hardware and software implementation method and process of a data collection system based on STM32F103. After signal collection, it is converted into signals through ADC0832 and supplied to the microcontroller for data collection. RS-485 standard is used to communicate with the PC.***

Keywords: STM32F103; Data collection; Serial communication; RS-485.

1. INTRODUCTION

1.1 Design background and significance

In today's widely used computer, data acquisition has very important applications in many fields. It is the bridge to realise the interaction between computer and external devices. The importance of data acquisition is more and more reflected in the industry, engineering, production plant and other sectors, especially in the high demand for real-time performance of information and harsh working environment. It is more and more important to analyse and process the detected data with the help of powerful data processing functions of computers, in which the transmission and interaction of signals are very important.

In order to improve the cost-effectiveness of the system, the microcontroller is generally used to collect the data, and then the data is transmitted to the computer for processing, through the serial communication to achieve the communication between the PC (host) and the microcontroller (host), and the development of the VC interface to real-time display and monitoring of the collected data. This design is based on the serial communication data acquisition system design includes the upper computer part and the lower computer part. The hardware part of the system is based on the microcontroller as the core, and also includes A/D analogue-to-digital converter module, display module and serial interface part. The data acquisition system based on serial communication is designed to achieve the acquisition and transmission of voltage analogue. This superior performance in the industry, engineering, production plant and other sectors, as well as in the information of real-time performance requirements of high and harsh working environment can also accurately collect the required information data.

1.2 Purpose of the design and main tasks

This design is based on serial communication data acquisition system, the system uses STM32F103 microcontroller as the core, the host computer to process the received digital quantity, in order to achieve the real-time monitoring and measurement of the voltage function.

The main tasks of this design are:

(1) ADC analogue-to-digital conversion converts the collected analogue quantities into digital quantities.

(2) The microcontroller receives the collected digital quantity.

(3) LCD liquid crystal display of the collected voltage value.

(4) The lower unit is connected to the upper unit via RS485 serial communication.

2. PROGRAMME VALIDATION

2.1 Programme formulation and design

In this paper, two schemes are proposed based on the different serial communication standards of the serial port signal acquisition system, scheme 1 is to use RS-422 communication standard and scheme 2 is to use RS-485 standard.

Option 1: The full name of the RS422 standard is "Balanced Voltage Digital Interface Circuit Electrical Characteristics", which is a four-wire interface; full-duplex; differential transmission; multi-point communication data transmission protocol. In fact, there is a signal ground; a total of 5 wires. It uses balanced transmission using unidirectional/non-reversible; with or without the enable end of the transmission line. Hardware composition on the RS-422 is equivalent to two groups of RS-485; that is, two half-duplex RS-485 constitutes a full-duplex RS-422. allows the connection of multiple receiver nodes on the same transmission line; up to 10 nodes. That is, a master device; the rest are slave devices; slave devices can not communicate with each other; so RS-422 supports point-to-multipoint bidirectional communication. Receiver input impedance is 4k; so the maximum load capacity of the sender is $10 \times 4k + 100\Omega$. RS-422 four-wire interface due to the use of separate sending and receiving channels; therefore, do not have to control the direction of the data; any necessary signal exchange between the devices can be achieved according to the software mode or hardware mode.

Option 2: RS485 is a standard that defines the electrical characteristics of drivers and receivers in a balanced digital multipoint system; the standard is defined by the Telecommunications Industry Association and the Electronic Industries Alliance. The use of the standard digital communication network can be in the long-distance conditions and electronic noise environment to effectively transmit signals. rs-485 makes it possible to connect the local network and the configuration of multi-branch communication links. rs485 is developed from the basis of rs-422; so rs-485 many of the electrical provisions and rs-422 is similar. Such as the use of balanced transmission, all need to be connected to the transmission line termination resistor, etc. RS-485 can be used two-wire and four-wire mode; four-wire connection with RS-422 can only achieve the same point-to-multiple communications that there can only be a master device and the rest of the slave device; but it is an improvement over the RS-422; regardless of whether the four-wire or two-wire connection can be connected to a maximum of 32 nodes on the bus; and the two-wire system is; RS-485 is the same; RS-485 many electrical provisions and RS-422 similar to. System is; RS-485 using half-duplex mode of operation can achieve true multi-point bidirectional communication; at this time there can only be a point at any time in the transmission state; therefore, the transmission circuit must be controlled by the enable signal.

2.2 Programme validation and selection

The RS-485 standard is chosen because it meets all the specifications of RS-422 and has the ability to suppress common mode interference and more receiver nodes than RS-422.

This data acquisition system design, the hardware part is based on the microcontroller as the core, also includes A/D analogue-to-digital converter module, display module and serial interface part. The lower computer of the system is responsible for data acquisition and answering the commands from the host computer. The system converts the collected data from analogue to digital through the analogue-to-digital converter and transmits the converted data to the host computer through the serial interface RS-485, which is responsible for accepting, processing and displaying the data and displaying the collected results on the LCD liquid crystal display.

The data acquisition system can acquire four analogue signals. The system converts the analogue voltage signals into digital signals, which are sent to the PC through the serial port of the microcontroller after TTL level conversion, and then the PC processes the acquired signals. STM32F103 is the core control chip of the system, which plays the role of collecting and controlling the display.

Analogue-to-digital conversion module: ADC0832 is used to convert analogue signals to digital signals to supply the microcontroller to collect data.

Display module: LCD 12864 liquid crystal display is used to display the collected values.

Communication module: RS-485 standard is used to achieve communication between microcontroller and PC.

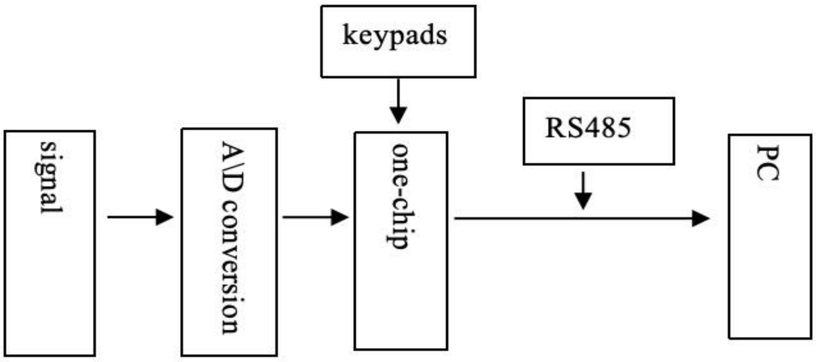

Figure 1: System Block Diagram

3. INTRODUCTION TO THE MAIN COMPONENTS

3.1 Microcontroller STM32F103

Microcontroller is a single chip microcomputer (Single Chip MicroComputer). It constitutes a computer's main functions, devices, such as CPU (computing, control), RAM (data storage), ROM (programme storage), input/output devices (eg: serial port, parallel output port, etc.), interrupt system, timer/counter, etc., concentrated in a core CPU (computing, control), RAM (data storage), ROM (programme storage), input/output devices (eg: serial port, parallel output port, etc.) system functions, so it is also known as microcontroller MCU (Single Chip Microcomputer). Output devices (eg: serial port, parallel output port, etc.) system functions, so it is also known as microcontroller MCU (Microcontroller Unit). Compared to ordinary microcomputers, microcontrollers are much smaller in size and are generally embedded in other instruments and equipment to achieve automatic detection and control, so they are also known as embedded microcontroller EMCU (Embedded Microcontroller Unit).

This design uses the STM32F103 microcontroller is a 32-bit microcontroller chip from STMicroelectronics, which belongs to the STM32F series of products. It adopts ARM Cortex-M3 core, which provides high performance and low power consumption.STM32F103 series chips have rich peripheral interfaces and large Flash memory, which are suitable for a variety of application areas, such as industrial control, automotive electronics, smart home and so on. The following are some of the main features and characteristics of STM32F103 chips:

(1) Processor: equipped with an ARM Cortex-M3 32-bit RISC processor with a main frequency of 72MHz, featuring high performance and low power consumption.

(2) Memory: with 64KB, 128KB or 256KB Flash memory and 20KB SRAM, to meet the storage needs of different applications.

(3) Peripheral interfaces: including multiple general-purpose IO ports, SPI, I2C, USART, CAN and other commonly used peripheral interfaces, which are convenient for communication with external devices.

(4) ADC and DAC: 12-bit ADC and 12-bit DAC, capable of high-precision analogue-to-digital conversion and digital-to-analog conversion.

(5) Timer: with multiple timer modules, such as general-purpose timer, advanced timer, etc., supporting PWM output, timing, counting and other functions.

(6) Low Power Consumption: With multiple low power consumption functions and modes, it can effectively reduce power consumption and extend battery life.

(7) Device-rich: The STM32F103 family provides chip models in different packages and memory sizes to meet the needs of different applications.

(8) Development tools: ST Microelectronics provides rich development tools and software support, such as STM32Cube software development kit, IAR Embedded Workbench, Keil MDK, etc., which are convenient for developers to carry out hardware and software development and debugging.

Overall, STM32F103 is a powerful and flexible 32-bit microcontroller chip with high performance, low power consumption and rich peripheral interfaces for a variety of applications. It has become one of the widely used chips in industrial control, embedded systems and IoT.

The STM32F103 chip has a very functional pinout, and the specific pins are shown in Figure 2.

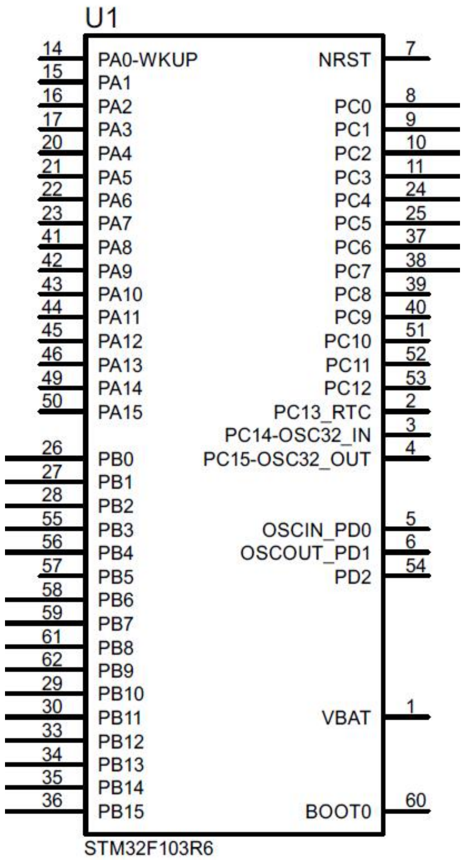

Figure 2: STM32F103 chip pinout diagram

The main categories of STM32F103 microcontrollers are as follows:

(1) GPIO pins: the STM32F103 chip has several GPIO pins that can be used for input and output operations. Each pin can be configured as input mode, output mode or multiplexed mode to suit different needs.

(2) Peripheral Interface Pins: The STM32F103 chip supports a variety of peripheral interfaces such as SPI, I2C, USART, CAN, etc., each of which has corresponding pins for data transmission and control. These pins usually have specific functions, such as MISO, MOSI, SCK pins for SPI and SDA, SCL pins for I2C.

(3) ADC and DAC pins: the STM32F103 chip integrates internal ADC (analogue-to-digital converter) and DAC (digital-to-analogue converter) modules for analogue signal acquisition and output. These modules need to be connected to the corresponding pins for analogue signal input and output.

(4) Timer pins: several timer modules are integrated inside the STM32F103 chip for functions such as timing, counting and generating PWM signals. These timer modules need to be connected to the corresponding pins, and the corresponding operating modes and functions are set through the pins.

(5) Interrupt pins: The STM32F103 chip supports an external interrupt function, which can be triggered by configuring certain pins to interrupt trigger mode, and triggering the corresponding interrupt when the status of the pin changes. These pins are usually used for external event triggering and processing.

In addition, the STM32F103 chip has some other types of pins, such as reset pins, power supply pins, clock pins, etc., which need to be configured and connected according to specific application requirements.

3.2 ADC0832

ADC0832 for 8-bit resolution A/D converter chip with a maximum resolution of 256 levels, which can be adapted to the general analogue conversion requirements. Its internal power input and reference voltage multiplexing, making the chip's analogue voltage input is between 0 and 5V. The conversion time of the chip is only 32μS, and it has dual data outputs that can be used as a data verification to reduce data errors, fast conversion speed and strong stability. Independent chip enable inputs make it more convenient to connect multiple devices and processor control. Channel function selection can be easily achieved through the DI data input. The main features are as follows:

(1) Input Output Level Comparable to TTL / CMOS compatible;

(2) 5V power supply Input Voltage between 0 and 5V;

(3) Operating Frequency is 250kHz. Conversion time is 32μS;

(4) Typical power consumption is only 15mW;

(5) 8P, 14P- DIP (Dual In-line), PICC packages;

(6) Commercial grade chips have a temperature range of 0°C to +70°C and industrial grade chips have a temperature range of -40°C to +85°C;

Chip Interface Description:

(7) CS_Chip Select Enable Enable Low level Chip enable.

(8) CH0 Analogue input Channel 0, or used as IN+/-.

(9) CH1 Analogue input channel 1, or use as IN+/-.

(10) GND Chip reference 0 level (ground).

(11) DI data signal input. Selection Channel Control.

(12) DO Data Signal Output, Conversion Data Output Convert Data Output.

(13) CLK Chip Clock Input .

(14) Vcc/REF Power Input and Reference Voltage input (multiplexed).

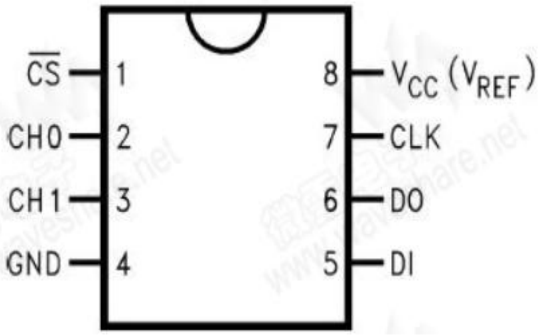

Figure 3: ADC0832 pinout diagram

3.3 MAX485

The MAX485 is used for RS-485 with RS-422 communication Low Power Transceiver MAX485 driver can achieve up to 2.5Mbps with unlimited transmission rate The MAX485 is designed to operate from a single +5 V supply. Operating from a single +5 V supply, the Rated current 300 µA, and adopts half-duplex communication mode. It completes the process of converting TTL level to RS-485 level MAX485 chip structure and pin are very simple, contains an internal driver and receiver. The RO and DI terminals are the outputs of the receiver and the inputs of the driver, which are connected with the microcontroller When connecting with the microcontroller, you only need to connect with the microcontroller's RXD and TXD of the microcontroller respectively; /RE and DE terminals are the receiving and transmitting The /RE and DE terminals are the enable terminals for receiving and transmitting respectively. When /RE is logic 0, the device is in the receiving state; when DE is logic 1, the device is in the transmitting state, because the MAX485 works in half-duplex state, so you only need to use one pin of the microcontroller to control these two pins; A and B terminals are connected to the RXD and TXD of the microcontroller. B are respectively the receiving and transmitting differential signal When the level of pin A is higher than that of pin B, the data sent is 1; when the level of A is lower than that of pin B, the data sent is 0. The wiring is very simple when connecting with the microcontroller. Only one signal is needed to control the reception and transmission of MAX485. At the same time between the A and B terminals plus matching resistor, generally optional 100Ω resistor. Specific pins as shown in Figure 4.

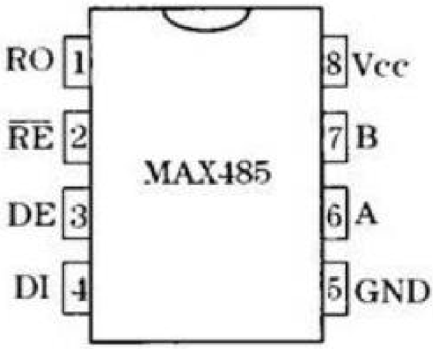

Figure 4: MAX485

3.4 LCD12864

The 128X64 with Chinese libraries is a 4-bit/8-bit parallel, 2-wire or line or 3-wire serial interface The 128X64 is a dot-matrix graphic LCD module with 4/8 bit parallel, 2-wire or 3-wire serial interfaces, and internal Chinese character libraries in simplified Chinese. Display resolution 128×64, built-in 8192 16*16 Chinese characters, and 128 16*8 ASCII characters. ASCII character set. Using the module's flexible interface and simple and convenient operation instruction The module can be used to form a full Chinese human-machine interaction graphical interface The module can display 8 x 4 rows of 16 x 16 dot matrix Chinese characters. It can display 8×4 rows of 16×16 dots Chinese characters. It can also display graphic display . Low Voltage Low Power Consumption is another remarkable feature. The LCD solution composed of this module is comparable to the same type of graphic Dot matrix liquid crystal display module, regardless of the hardware circuit structure or display programme Are much more concise, and the price of the module is also slightly lower than the same dot matrix graphic LCD module The price of this module is also slightly lower than the graphic LCD module with the same dot matrix.

4. HARDWARE CIRCUIT DESIGN

4.1 Introduction to the simulation software proteus

Proteus 8 is an integrated electronic design automation (EDA) software that provides a complete set of tools, including schematic design, circuit simulation, PCB layout and simulation. Schematic design is one of the core functions of Proteus 8. It provides an intuitive interface that allows users to easily create and edit schematics of circuits. Users can select the desired components from a rich library of components and place them in the schematic through drag-and-drop operations.Proteus 8 supports common electronic components and symbols, such as resistors, capacitors, inductors, transistors, integrated circuits, and so on. In addition, you can customise components and symbols and save them to a library for future use.

Another important feature of Proteus 8 is circuit simulation. It has a powerful built-in simulation engine that can simulate and analyse the performance of designed circuits. Users can set input signals and parameters and observe the output results of the circuit to evaluate the behaviour of the circuit. Simulation results can be visualised in the form of waveform plots, graphs and datasheets, and can be exported to other formats such as images, PDF and Excel.

PCB layout is another key feature of Proteus 8. It provides an advanced PCB layout tool that converts schematics into actual PCB designs. Users can select the specifications and number of layers as needed and use automatic routing tools during the layout process.Proteus 8 also supports a rule checking function to ensure that the design meets the requirements for PCB manufacturing. Once the layout is complete, users can export the design as a Gerber file for production by the PCB fabricator.

In addition to schematic design, circuit simulation and PCB layout, Proteus 8 offers several other useful features. For example, it allows users to perform real-time simulation and debugging to better understand and optimise designs. It also provides a rich library of components and models, including digital and analogue components, sensors, microcontrollers, etc., which makes it easy for users to quickly select the right components and models for their designs.

Overall, Proteus 8 is a powerful and easy-to-use electronic design automation software that provides a wide range of tools and features for electronic engineers and students to perform tasks such as circuit design, simulation and PCB layout. Since this design uses STM32F03, Proteus 8 is used for the simulation of the hardware.

4.2 A/D conversion module

In general, the ADC0832 interface with the microcontroller should be four data lines, respectively, CS, CLK, D0, DI, but due to the D0 end and DI end of the communication is not valid at the same time and the interface with the microcontroller is bi-directional, so the circuit design can be D0 and DI in parallel in a data line to use. When the ADC0832 does not work when its CS input should be high, at this time the chip is disabled, CLK and DO / DI level can be arbitrary. When you want to carry out the A/D conversion inches, you must first put the CS terminal to a low level and keep it low. Until the conversion is completely finished. At this point, the chip starts to convert, while the processor provides clock pulses to the chip clock input CLK, and the DO/DI terminals use the DI terminals to input the data signals for channel function selection. Before the first clock pulse arrives, the DI terminal must be high, indicating the start bit. Before the second and third clock pulses arrive, the DI terminal should input two bits of data for channel selection.

Table 1: ADC0832 Functionality Table

Input form	Configuration Bits		Select Channel	
	CH0	CH1	CH0	CH1
Differential input	0	0	+	-
	0	1	-	+
Single-ended input	1	0	+	
	1	1		+

4.3 Keypad module

In microcontrollers, if fewer keys are required, a stand-alone keypad can be used. 4 keys are connected to one I/O line of the microcontroller for each key, and all four I/O lines are high when no key is pressed, and when a key is pressed, the I/O line connected to it will get a low input.

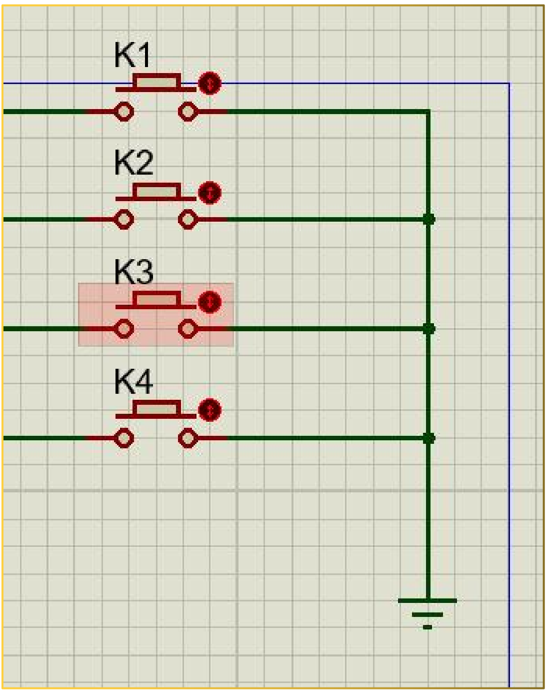

Figure 5: Key Module Diagram

5. SOFTWARE DESIGN

5.1 Software design principles and tools used

Keil5 is an integrated development environment (IDE) developed by Keil Software for software development for embedded systems. It provides a powerful set of tools including a code editor, compiler, debugger and emulator so that developers can easily write, compile, debug and deploy embedded software.
The following are the key features and functionality of Keil5:

Support for a wide range of common embedded microcontroller architectures: Keil5 supports a wide range of embedded system architectures, including ARM, 8051, C16x and XC16x. developers can develop different embedded systems while using the same IDE.

Simple User Interface: Keil5 has an intuitive and simple user interface that makes it easy for developers to browse and manage project files, write code, and debug. It provides a rich set of code editor features, including syntax highlighting, auto-completion, code folding, and more.

Efficient compilers and optimisers: Keil5 has a powerful set of built-in compilers and optimisers to compile source code into efficient machine code. It supports a wide range of programming languages, including C, C++ and assembly languages, and provides a rich set of compilation options so that developers can have fine-grained control over their code.

Powerful debugging and simulation features: Keil5 integrates a powerful debugger and simulator that allows developers to perform real-time debugging on embedded systems. It supports features such as single-step debugging, observing the values of variables and registers, and setting breakpoints in the code. Hardware debugging can also be performed by connecting to the target hardware through the emulator.

Multi-core and analysis features: Keil5 also provides support for multi-core microcontrollers and complex embedded systems. It can analyse and optimise the performance and power consumption of a system and provides a rich set of performance analysis and tracing features so that developers can gain insight into the behaviour and bottlenecks of a system.

In summary, Keil5 is a powerful and easy-to-use embedded development tool for software development for a wide range of embedded systems. It provides a range of tools and features to help developers improve development efficiency, shorten development cycles, and ensure software quality and reliability.

5.2 UC/OS-II operating system

5.2.1 Introduction to the UC/OS-II operating system

UC/OS-II (Micro-control Systems Operating System II) is an embedded real-time operating system (RTOS) developed by Micro-control Systems, an embedded real-time operating system development company. UC/OS-II provides a simple, yet powerful set of core functions for the development of embedded systems. UC/OS-II provides a simple but powerful set of core functions for embedded systems development.

The features of UC/OS-II include: simplicity and efficiency, real-time, multi-tasking support, task priority, event notification mechanism, memory management, interrupt support, portability and other features. It is widely used in various embedded systems, including industrial automation, consumer electronics, communication equipment, home appliances and other fields. It provides an efficient and reliable operating system solution for embedded system development and management.

5.2.2 Porting the UC/OS-II operating system

The general procedure for porting UC/OS-II to the STM32 platform is as follows:

(1) Configure the STM32 hardware environment: Configure the system clock source, peripherals and interrupt controllers, etc. on the STM32 hardware. This requires an understanding of the STM32 hardware architecture and pin assignments, and modifying the UC/OS-II kernel configuration files accordingly.

(2) Ensure OS stack and heap space settings: Set the stack and heap space sizes for OS tasks according to system needs and UC/OS-II requirements.

(3) Port the interrupt control: according to the interface of UC/OS-II, port the interrupt control code of STM32 so that UC/OS-II can handle and schedule interrupts correctly.

(4) Port the clock source: Configure the clock source of STM32 according to the clock requirement of UC/OS-II, and modify the clock source setting of UC/OS-II appropriately.

(5) Modify applications: Modify and port existing applications to ensure they will run correctly on UC/OS-II. This includes modifying task priorities, inter-task communication and synchronisation mechanisms.

(6) Conduct debugging and testing: Conduct system-level debugging and testing to ensure that UC/OS-II can run stably on the STM32 platform and meet the real-time and reliability requirements.

5.3 Analogue-to-digital conversion procedure

This design is based on the serial port data acquisition system, analogue-to-digital conversion module with ADC0832 chip, the collected analogue voltage quantities through the ADC0832 processing into digital quantities. the ADC0832 processing flow is shown in Figure.

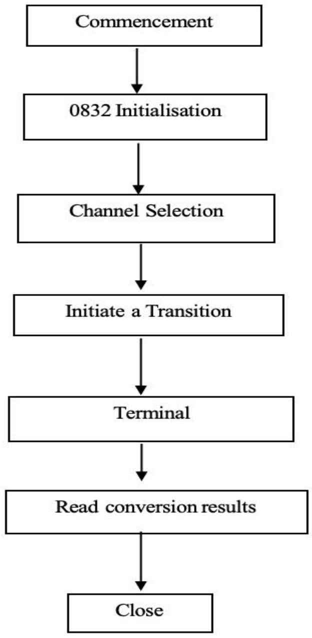

Figure 6: ADC0832 flowchart.

5.4 Serial communications

This design uses RS485 serial port communication transmission protocol. After initialisation, the serial port is opened and the serial port starts to receive the transmitted information, the received information is processed according to the RS485 serial communication protocol and the processed data is added to the database and displayed in the interface in real time at the same time. The flow chart is shown in Figure 7.

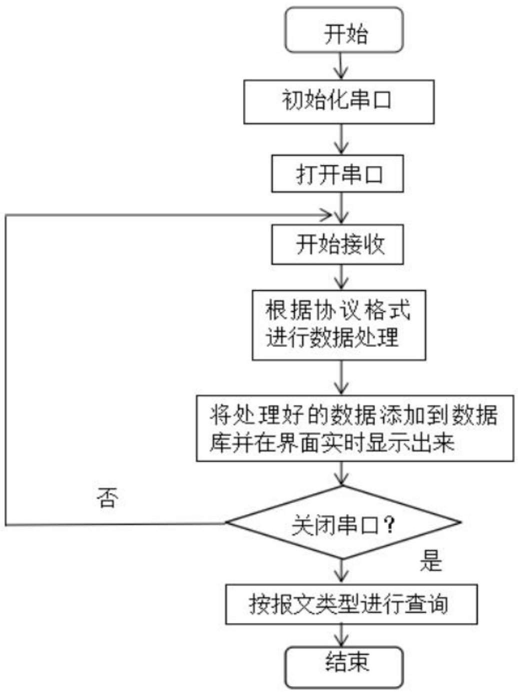

Figure 7: Serial communication flowchart

6. SYSTEM COMMISSIONING

The μcos OS code path is first linked to the STN32F103, as shown in Figure 8.

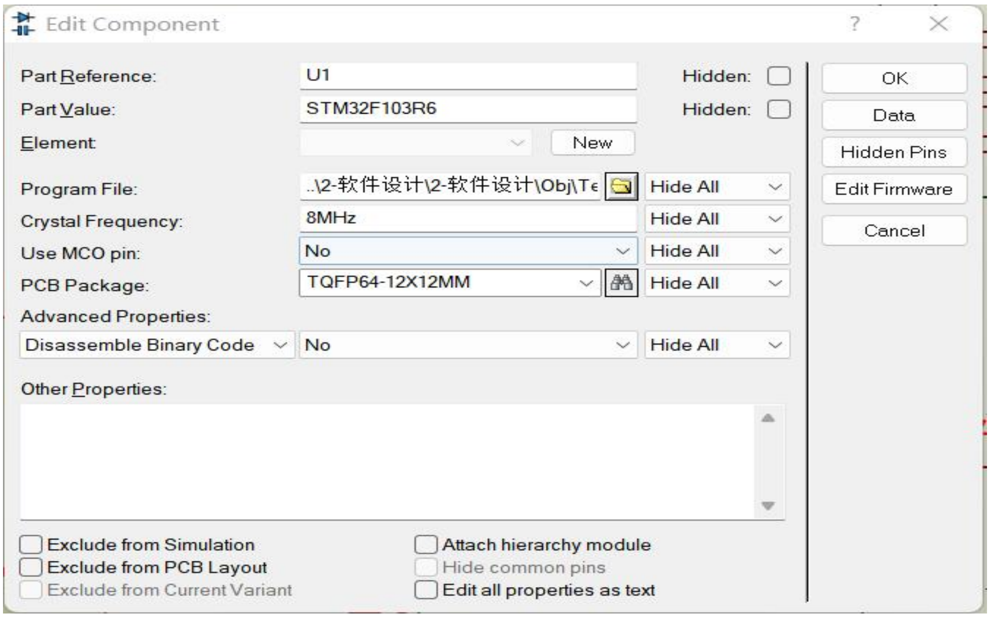

Figure 8: Interface diagram of Proteus to keil code

System debugging is mainly to detect whether the design system can complete the task required functions, so that the system automatically and continuously run. This design through the keyboard control to select the path, the collected voltage analogue into digital real-time processing to the microcontroller to display the collected voltage and address value, and at the same time to achieve the collection of the four voltage final control of the implementation of the microcontroller and the PC serial communication. Press the main switch, the system starts to collect voltage. The upper computer receives the display data. The simulation is shown in Figure 9.

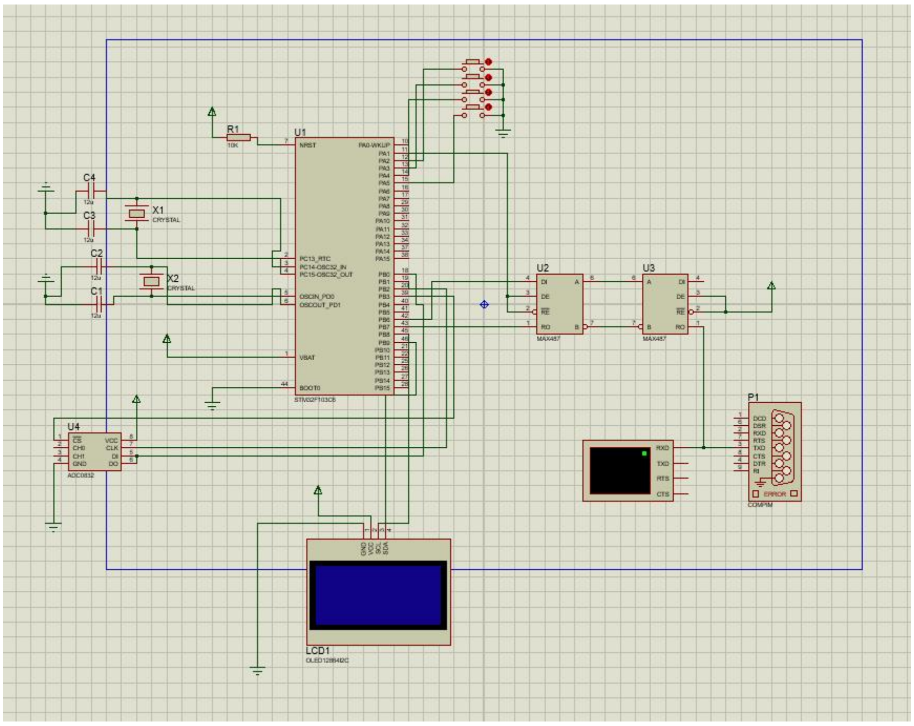

Figure 9: Proteus simulation diagram

The midterm serial communication module can be debugged with parity bits for error checking. For even and odd parity, the serial port will set the parity bit (one bit after the data bit), with a value to ensure that the transmitted data has an even or odd number of logical high bits. For example, if the data is 011, then for an even check, the parity bit 0 ensures that the number of logical high bits is even. If it is an odd check, the parity bit is 0, so that there are three logically high bits. The high and low bits do not really check the data, but simply set the logical high or logical low checksum. This allows the receiving device to know the status of a bit and have the opportunity to determine if noise is interfering with the communication or if the transmitted and received data are out of sync.

7. CONCLUSION

After the functional analysis of the system and theoretical assumptions and design test, we successfully design and complete a serial port based data acquisition system. During the design and production of this system, the total control is carried out through the microcontroller stm32f103 as CPU, the analogue-to-digital conversion of the collected voltage data is carried out through the analogue-to-digital converter ADC0832 and the converted data is transmitted to the upper computer through the serial port RS-485, which is responsible for the acceptance and processing of the data, and the collected voltage results are displayed with the LCD liquid crystal display. The upper computer is responsible for data acceptance and processing, and LCD liquid crystal display is used to display the collected voltage results. The system can monitor the voltage of the target in real time, with different sensors can be used in various scenarios.