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Research and Design of Universal Proportional Valve Controller

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Abstract

In the current hydraulic field, there is a phenomenon that "many kinds of proportional valve exist, so the same kinds of proportional valve controller are required". In order to change this unreasonable situation, a research direction is proposed to develop a general proportional valve controller to fit a variety of proportional valve. The ratio of different functions can be realized by entering different control software and setting different parameters in the universal proportional valve controller. Through the communication between MCU and PC, PC is used as host computer to set, display and manage the parameters of proportional valve controller. The experiment shows that the controller has excellent flexibility, versatility, low installation and maintenance cost, high cost performance and it's suitable for popularization and application.

Subject Areas

Mechanical Engineering

Keywords

Proportional Valve Controller, Single Chip, Serial Communication, Host Computer

1. Introduction

Electro-hydraulic proportional control technology is one of the fastest developing technologies in machinery and equipment, and its application area has penetrated into almost all industrial sectors. The electro-hydraulic proportional valve replaces the original control part on the ordinary hydraulic valve by the electric-machine converter and its electronic control device. The pressure, flow and direction of the liquid flow are controlled continuously and proportionately

according to the given input electrical signal.

The working principle of the electro-hydraulic proportional valve is described in Figure 1. A given input signal U_i is added to the valve core displacement electrical feedback signal U (according to the valve core displacement y) and the servo feedback input signal, then the controller outputs a amplified voltage U_e or current I_e to control the E-M converter (usually proportional magnet) to produce a force or displacement y proportional to the input signal and drive the valve core [1].

At present, for the proportional valve control, because of the dispersivity of the simulator and the characteristics of the component circuit, its control function is very simple and it is difficult to adapt to all kinds of needs. What's more, there is obvious temperature drift and zero drift. The analog controller needs potentiometer to set parameters, and it is difficult to recover once the set parameters are changed. Frequent adjustment will cause wear and tear to potentiometers, and it is difficult for non-professionals to troubleshoot after failure [2].

The electronic controller can avoid the above-mentioned disadvantages, and the parameter setting can be accomplished by software through PC, avoiding the mechanical wear of the components. At the same time, by operating the key on the panel, the set parameters are intuitive and easy to remember. Replacing conventional analog control with digital controller can not only simplify the system, but also improve the versatility. The higher economy, reliability, flexibility and more convenient maintainability make it have broad application prospects [3].

2. Design Principle and Overall Planning

In the electro-hydraulic proportional control system, the controller generally has the following requirements: good steady state control characteristics; fast dynamic response and wide frequency band; low power consumption of power-amplifier

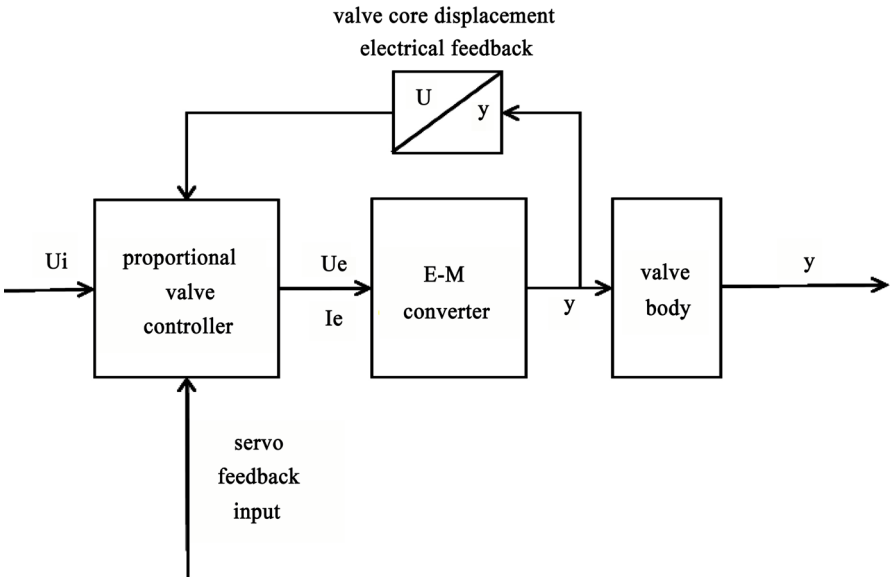

Figure 1. Theoretical drawing of proportional valve.

stage; strong anti-interference ability, good stability and reliability; strong control function; standardization and normalization. Therefore, the circuit configuration of proportional valve controller should meet the above requirements. Figure 2 is a model constitution of the proportional valve controller, which is usually composed of input interface, signal processing, regulator, preamplifier stage, flutter circuit, power-amplifier stage, valve core displacement feedback input interface and so on.

In order to achieve universal, intelligent and modular design requirements, the design principle of "universal interface, digital function and intelligent control" is adopted. Specifically:

1) The controller interface design should take the possible demand of various proportional valve control systems into account.

2) All kinds of functional "circuits" of controller are realized by software algorithm.

3) The advantages of digital control technology should be given full play to achieve intelligent control.

According to this requirement, the digital controller is designed to fit all the proportional valves on the hardware function, and the parameter characteristics of various functional proportional valves are implemented by different software. Figure 3 is the system structure diagram.

The digital controller uses a 16 bit single chip as the core to meet the system requirement for operational capability. The signal value of every signal input interface is read through the A/D converter, and then converted to output control signal after digital operation. The power driver circuit is driven by the PWM and outputs current signal to drive the electromagnet.

The parameter adjustment of digital controller can be implemented by software at Windows interface. Through the communication between the controller serial port and PC, the parameters can be set in the Windows interface by PC. Set values, actual values, switching quantities, input and output states and other parameters can be displayed at the interface.

System signals include:

1) Input: 2 analog input ports and 1 digital switching input port;

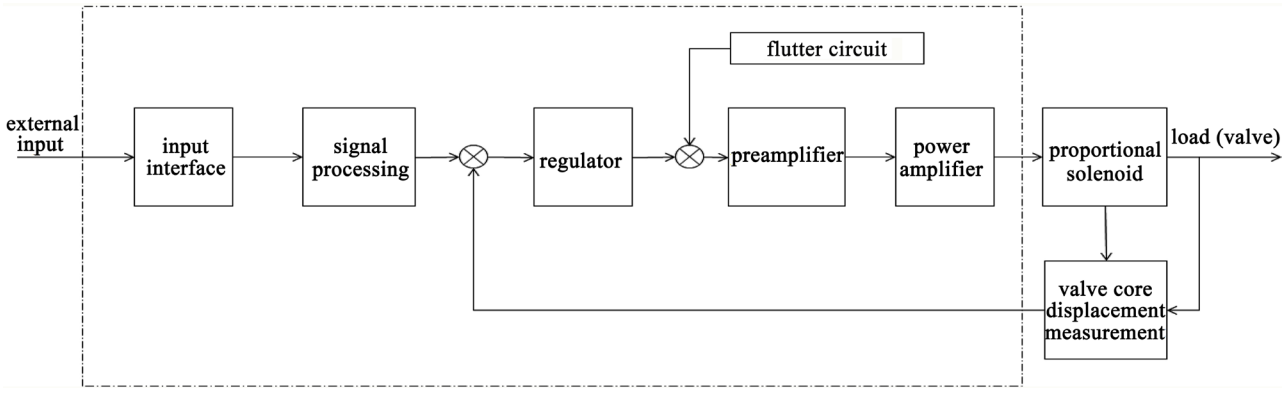

Figure 2. Proportional valve controller model constitution.

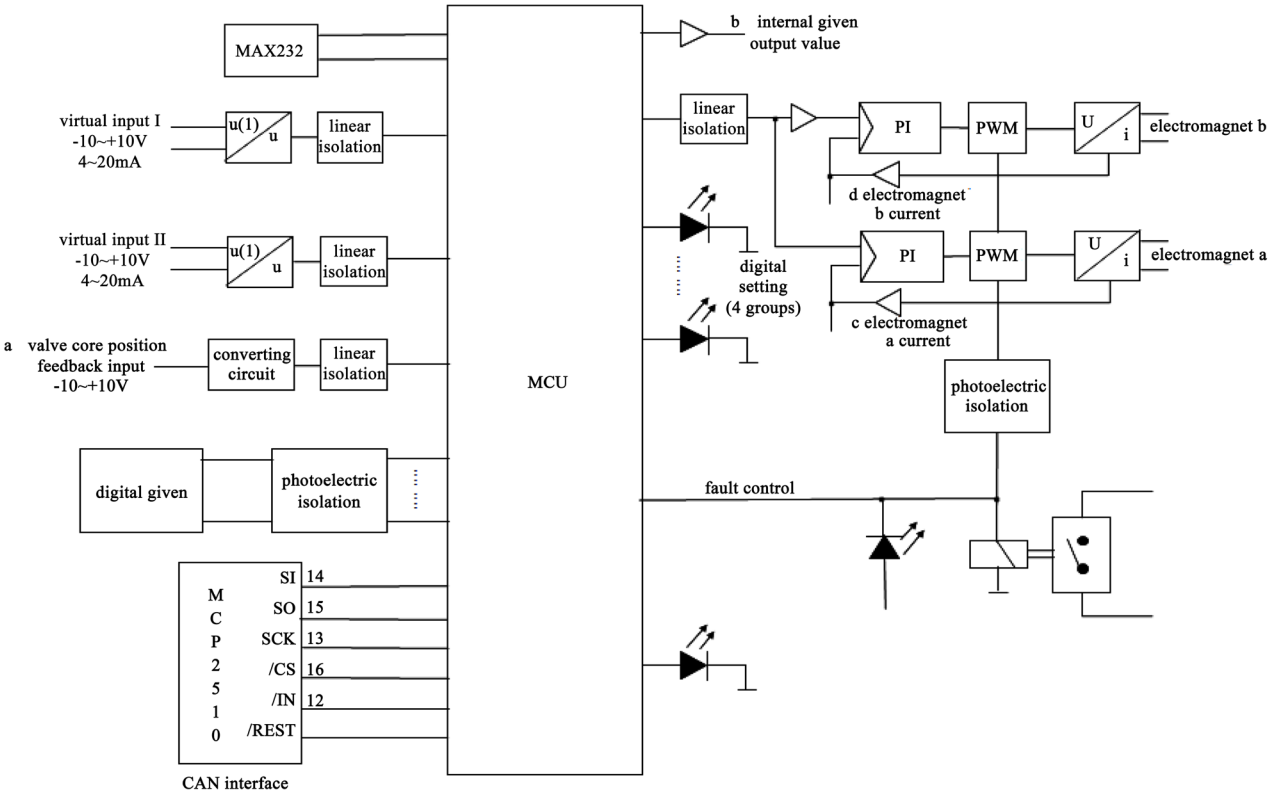

Figure 3. System structure diagram

2) Communication: 1 serial port and 1 CAN bus interface;

3) Feedback: 1 feedback input interface of valve core position sensor (−10V - +10V);

4) Measurement signal output: 6-cores measuring socket;

5) System output: 2 reverse current outputs and fault emergency control output;

6) Light display output: power indicator, fault monitoring, system startup and fault code display.

3. Hardware Circuit Design

To design a single-chip system with rich functions, complex components and independent work, the first thing to consider is the hardware circuit design of the system.

The hardware circuit design of a single chip application system contains two parts. One part is system expansion, that when the capacity of MCU function unit such as ROM, RAM, I/O port, timer can't meet the requirements of the application system, expanding outside the chip is needed. Select the appropriate chip and design the corresponding circuit. The other part is system configuration. According to the system function requirements, the appropriate interface circuit should be designed to outfit the peripheral equipment, such as keyboard, monitor, printer, A/D converter etc.

In the design process of the circuit, drawing on the successful experience of others is needed and helps to improve the rationality of the design scheme. Besides, it also needs to be taken the mutual influence of the hardware structure and the software scheme into account. Because software is designed to implement as many functions as possible to simplify the hardware structure, the hardware response time is much longer than that directly implemented by hardware and takes up CPU time [4].

Due to limited space, the following only introduces the selection of single chip and serial communication interface.

3.1. The Selection of Single Chip

In the early stage of project development, the initial choice of single chip computer must be made. The hardware platform has a considerable impact on the later software and hardware design decisions. The selection of single chip mainly considers the following aspects:

1) Whether the performance of the selected single chip meets the needs of the tasks;

2) Whether the selected single chip has enough internal storage to store the required data and code, if not enough, then the single chip is allowed to use appropriate external storage;

3) Whether the selected single chip has proper on-chip modules (for example, CAN interface and PWM interface) to support the tasks needed;

4) Whether the selected single chip has enough port pin (or suitable serial interface) to satisfy all requirements for connecting external components, such as keyboard and LCD;

5) Whether the power consumption of the selected single chip is suitable.

The electro-hydraulic proportional control system is a typical mechanical and electrical integration device. Its complete system is usually composed of the controller, the motor conversion device, the liquid conversion device and the feedback device. The controller is generally used to control position, manage system and control input and output parameter, and the output signal is processed and amplified. The valve core is driven by a proportional electromagnet to control the pressure or flow. Therefore, the function of the controller is required to adapt to a variety of control objects, such as fast response of the system, no oscillation and overshoot in the transition process, high steady state precision and a smaller hysteresis loop. Secondly, it requires low cost, high reliability and strong anti-interference.

According to the above requirements, the proportional valve digital controller of the project adopts MSP430F167 as the CPU of the system. MSP430 microcontroller is a 16 bit, ultra low power mixed signal processor produced by Texas Instruments (TI). According to practical application needs, many analog circuits, digital circuits and microprocessors are integrated on this chip. In this system, the pin port usage allocation of MSP430F167 chip is shown in **Figure 4**.

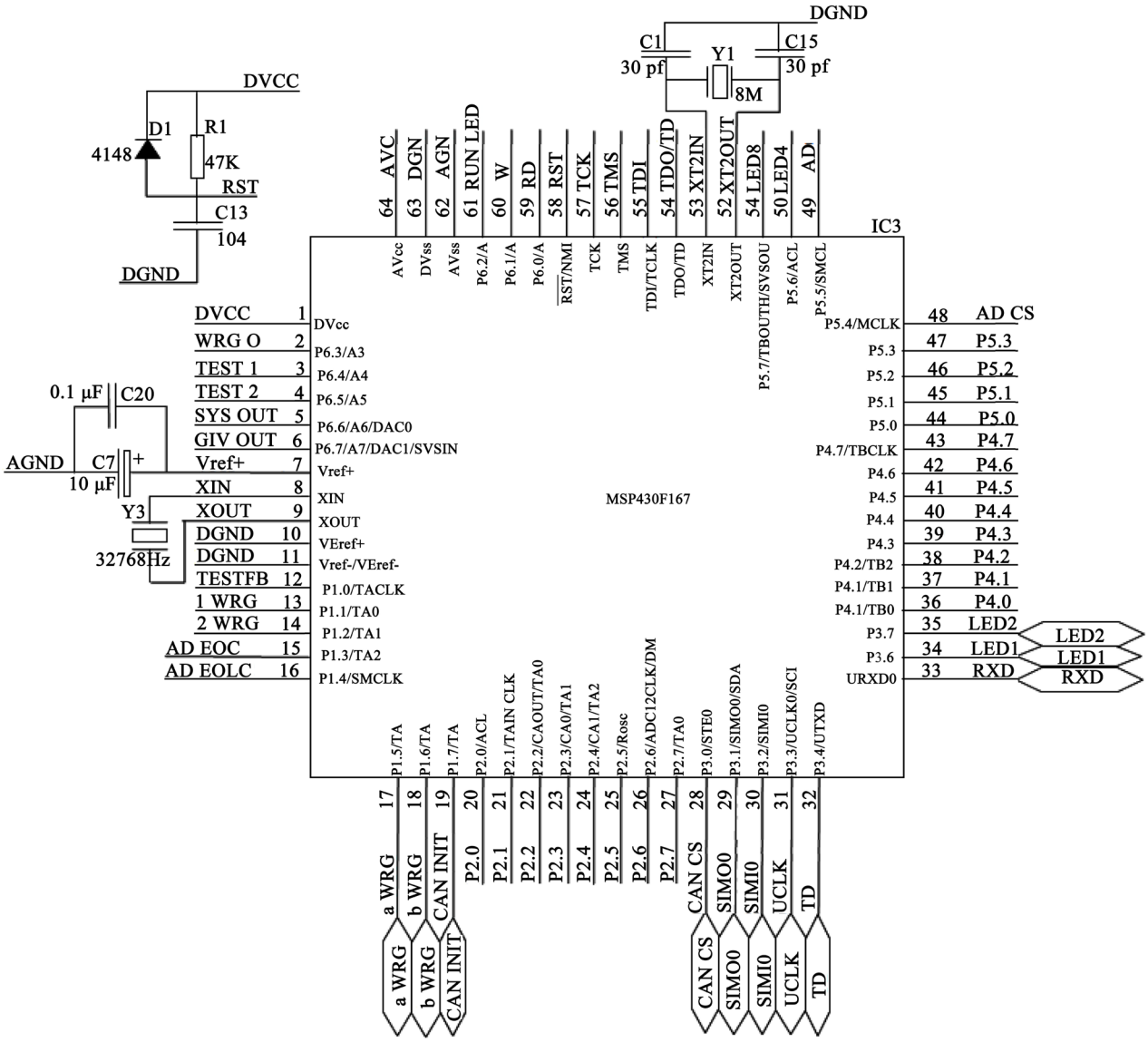

Figure 4. MSP430F167 pins chart.

3.2. Serial Communication Interface

Serial port is an important means to connect the system to the outside module. In the development and application process of embedded system, host computer is often used to set parameters, debug, collect and control field data. Usually through the serial communication technology, the serial port configured by the host computer connects and communicates with the embedded system. In this system, RS-232 communication module is used to realize communication between host computer and controller, such as debugging, downloading system parameters and uploading data.

RS-232 interface is one of the most commonly used serial communication interfaces and is suitable for point to point short distance or modem communication. The maximum data transmission rate is 20kb/s and the maximum trans-

mission distance is 15 m for one-way data transmission. Because the digital power supply of the system adopts 3.3V DC, the MAX3232 with voltage range of 3.0 - 5.5V is used as the conversion chip of MCU level and RS-232 level.

As is shown in Figure 5, it is very simple to connect MAX3232 with single chip (RXD and TXD separately connect with URXD0 and UTXD0 of single chip). C1+, C2+, C1-, C2-, V+, V- are power convertor. In practical applications, devices are sensitive to power noise. Therefore, VCC must add decoupling capacitor C10 to Earth, its value is 0.1 μF. The values of C38, C39, C40, C41 are all 0.1 μF, these capacitors help to improve the ability to resist interference and should be placed with MAX3232 as close as possible. The inputs of unused channels in MAX3232 are connected to earth, avoiding producing harmful interfere.

4. Software System Design

After the hardware circuit design, the system software determines whether the main functions of the system can be realized. Whether the system can work normally or reliably, besides the reasonable design of the hardware, it is inseparable from the software design with perfect function. The design of software system includes of single-chip computer system programming and host computer management system software [5].

4.1. Single-Chip Computer System Programming

Considering the requirements of the system, the system program of the single chip computer needs to complete the functions such as the adjustment of the valve core and the system, producing the necessary interrupts and timing to ensure the program performing properly according to a certain sequence, and collecting, inputting and processing data. The program design includes main program design and function module design. The main program is used to manage and monitor the operation of single chip computer system, and coordinate the management of each function module. Each function module completes the sampling and storage of the external signal, completes the scale transformation

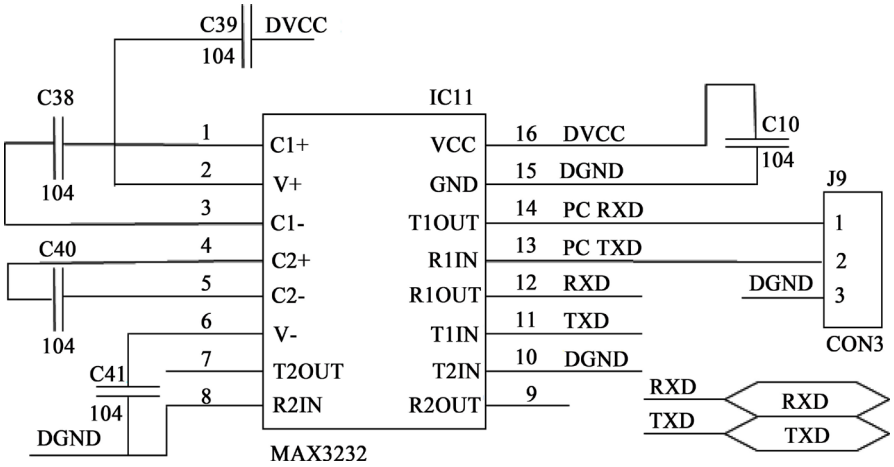

Figure 5. Circuit of the telecommunications interface chip MAX3232.

of various quantities, carries out high precision mathematical operation, drives the external hardware circuit, and communicates with the outside [6]. Due to limited space, the following is a brief introduction to the main program design of the system (Figure 6).

The main program of the system mainly completes the following works:

1) Initialize the subprogram;

2) Start the 10 ms timer to ensure that the cycle period of the main program is a fixed value;

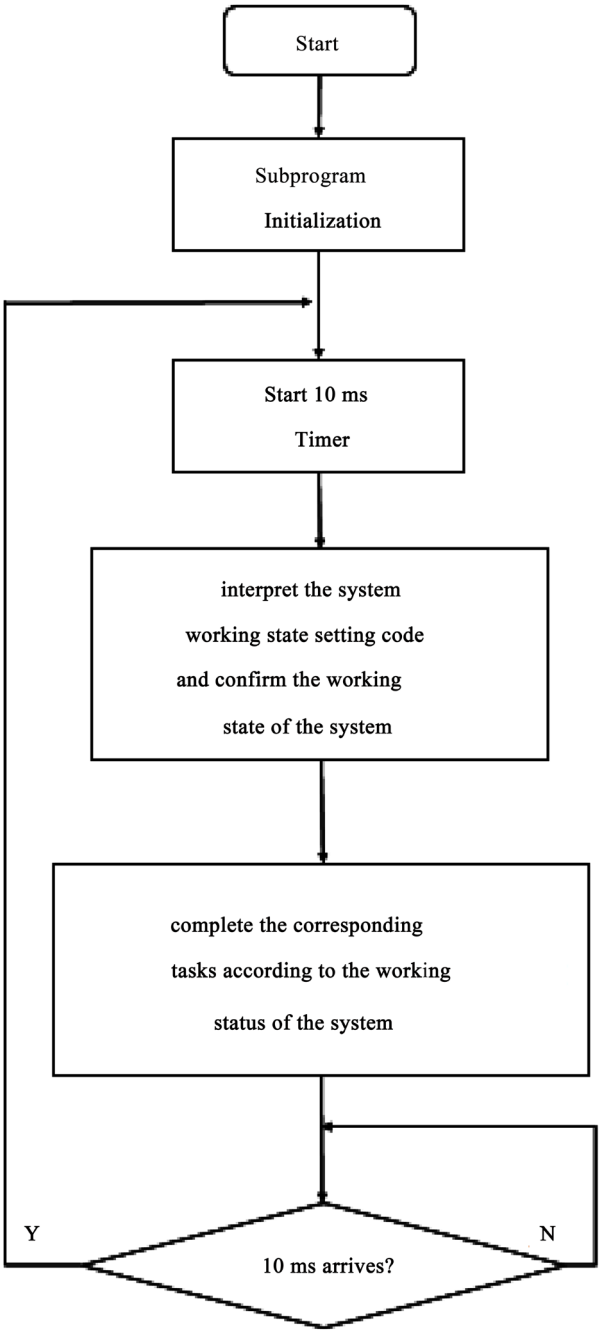

Figure 6. System main program flow chart.

3) Scan system working state setting switch, interpret the setting code and confirm the working state of the system;

4) Complete the corresponding system tasks according to the working status setting of the system.

4.2. Host Computer Management System Software

The host computer system software is mainly used to configure parameters, debug and manage the digital controller. Its specific implementation functions include:

1) Display and modification of controller parameter configuration;

2) Manual control and system debugging;

3) Management of parameter database;

4) System working state display (in the form of figure or a continuous curve);

5) Fault diagnosis and corresponding maintenance advice.

The software is designed in Visio Studio 2015 development environment, combining MFC and SQL technology. It communicates with the controller through a serial port and realizes serial communication function by using MS Comm control. The main interface is shown as Figure 7.

5. Summary

By the design process of universal proportional valve controller, the function circuit design concept of "replacing hardware with software" is practiced. Through the joint test of hardware and software, the main functions are basically realized and the expected design goal has been accomplished preliminarily, so

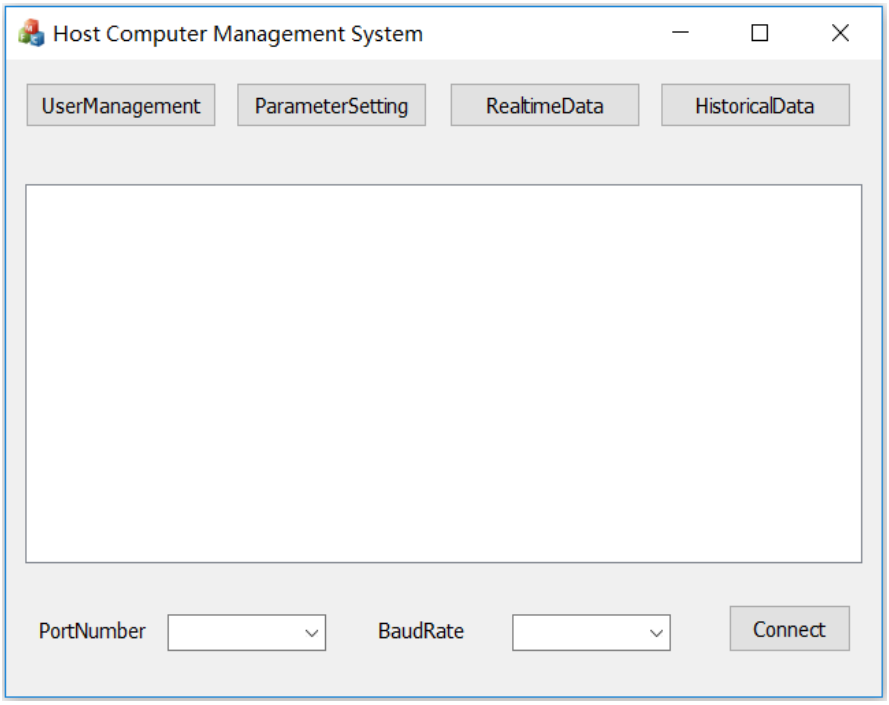

Figure 7. Main interface of management system software.

that the feasibility of the technical scheme is proved. In the next phase, the controller design will be optimized to improve the stability and anti-interference ability, satisfy the requirement of customer and fill the market gap.

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