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# GREENHOUSE INTELLIGENT CONTROL SYSTEM BASED ON STM32F107 AND SWITCHED ETHERNET

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**ABSTRACT**

For complicated wiring and high-cost, non-uniform protocol and other issues in the common greenhouse cluster control system, a new system is designed, based on Ethernet and 32-bit ARM STM32F107.The STM32F107VCT6 is the core of lower machine, using its built-in 12 bit A/D converter to acquire data of soil moisture, light intensity, ambient temperature and other environmental factors, and coming with full-speed USB (OTG) interface and Ethernet 10 /100M MAC modules to achieve the exchange of data with removable storage devices and the Internet connection, using the touch screen to set up and display of the relevant parameters. For the host computer using the B/S mode, the user can access to remote data and control of greenhouse. Practice shows that the application of highly integrated and broadband technologies reduce system costs, improve communication quality and system stability.

**Keywords:** *Intelligent Greenhouse, STM32F107, Ethernet, Measurement and Control System*

## 1. INTRODUCTION

Along with the rapid development of electronic technology and information technology, the intelligent control of the greenhouse has made rapid development. Greenhouse monitoring and control system, commonly used in such ways: Firstly, based on 8-bit microcontroller and RS485 bus, the advantage is low cost and maturity of the technology of RS485. The disadvantage is that the RS485 bus is susceptible to interference, repeaters must be added when the transmission distance is far away, communication protocol is not uniform and lack of versatility. In addition, limited by the CPU, the degree of man-machine interface’s intelligence is too low and inconvenient to perform[1-3].Secondly, PLC is the master controller of the system, the advantage is high reliability, and simple programming. The biggest drawback is the high cost, moreover, environmental information is collected in the greenhouse, it requests that the PLC have the AD module, which further improves the cost[4].Thirdly, the system based on microcontroller and CAN bus, the advantage is ownerless from the points of the machine, the node can shut down automatically when the error is serious. The drawback is that the communication distance is restricted and the need to add the repeater and PC CAN receiver card[5]. Fourthly, measurement and control system based on wireless networks, easy installation and saving wiring are the advantages. The disadvantage is that the communication error rate is high, subject to weather and environmental factors, and reliable wireless transmission module costs actually exceed the cost of the actual wiring[6,7]. The last

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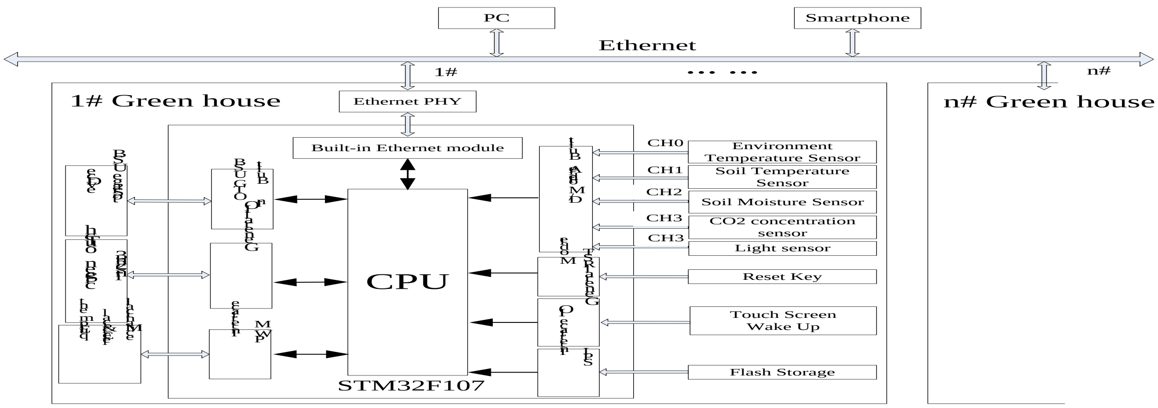


*Figure 1: Block Diagram Of The System*

kind is based on the traditional Ethernet measurement and control system, the typical characteristic is the low degree of integration, and can't solve the problems of real-time in Ethernet[8].

Take full account of two factors: cost and degree of intelligence, the system takes 32-bit ARM processor STM32F107VCT6, based kernel Cortex_M3, as controller. By using of its built-in resources extremely, the system completed the information collection and control of external devices, as well as Ethernet connection. The results show that the system has a low cost, high degree of integration, network connectivity, protocol uniformity and ease of remote control features.

## 2. SYSTEM SCHEME DESIGN

The system block diagram of the overall scheme is shown in Figure 1. The controller based on STM32F107， detects and controls the entire greenhouse environment parameters. Parameters by sensors collected such as temperature, humidity, C02 concentration, light intensity and so on, are converted into digital signals by built-in A / D converter module, and compared these with data existed in FLASH chip. According to certain control requirements, the system give the appropriate control signals to complete the regulation of the greenhouse temperature, humidity, and control rolling machines, fill light, sprinkler irrigation and CO2 generator institutions et al .For the convenience of extracting the relevant data, the system support for USB removable storage devices. To further enhance the convenience of the human- computer interaction, a low-cost 3.2-inch touch screen are used to display information about the greenhouse, through a virtual keyboard the user can enter the setup information. The connection with Ethernet is achieved by using the STM32 built-in MAC interface and an external PHY chip (DP83848), the server terminal is built by B / S Mode, the user only with the PC or smart phone by logging on the browser (Browser) can real-time access to data needed, and control the terminal auxiliary equipment to achieve the remote control and information management on greenhouse [12,13].

## 3. SYSTEM HARDWARE DESIGN

### 3.1 Sensor Module

There are two 12-bit successive approximation A/D converters in STM32F107, they can measure sixteen external channels' signal. Conversion of each channel can be a single, continuous scanning or intermittent execution, the results of the ADC can be stored, in the left or right aligned, in 16-bit data register. Using five channels to acquire information of temperature, moisture, CO2 concentration et al. For facilitating the system's future expansion, three AD channels are set aside. For the outputs of transmitters are standard, so the connection is very convenient between the controller and transmitters, which only needed to connect the corresponding signal output to the AD channel. The parameters of each sensor are shown in Table 1.

*Table 1: Sensor Parameters*

| Sensor type | Technical parameters |
|---|---|
| Soil moisture sensor | Ranges：0～100%；Output voltage：0～2.5V； Accuracy：0～50% |
| Light sensor | Ranges：0～200K1x；Output voltage：1～5V；Accuracy：±3% |
| Soil ttemperature ssensor | Ranges：0～50℃；Output voltage：0～5V；Accuracy：±0.2℃ |

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| | |
|---|---|
| Eenvironment temperature sensor | Ranges：0～50℃；<br>Output voltage：0～2.5V；<br>Accuracy：±0.5℃ |
| $CO_2$ concentration sensor | Ranges:0～10000ppm；<br>Output voltage:0～3V；<br>Accuracy：±2% |

**3.2-Inch Touch Screen Module**

For better man-machine interface functions，the system support the touch function with 3.2-inch TFT LCD module. With external FLASH memory downloaded GB font, the module can display any characters including Chinese. The LCD's controller is SSD1289, resolution is 240*320 and the output gray-scale is 16-bit true color. 1M flash SST25VF016 and touch control chip TSC2046 are used in this module.

In order to reduce system power consumption and extend the life of the screen, it works in two ways: normal and power-down. Cutting off the power of the touch screen when the touch screen in 10 seconds no operation, the switch circuit controlled by the power transistor switch chip GS2010;When it's normal working time, the system receives an external key input signal and supply power to the touch screen. Circuit of touch screen module is shown in Figure 2.

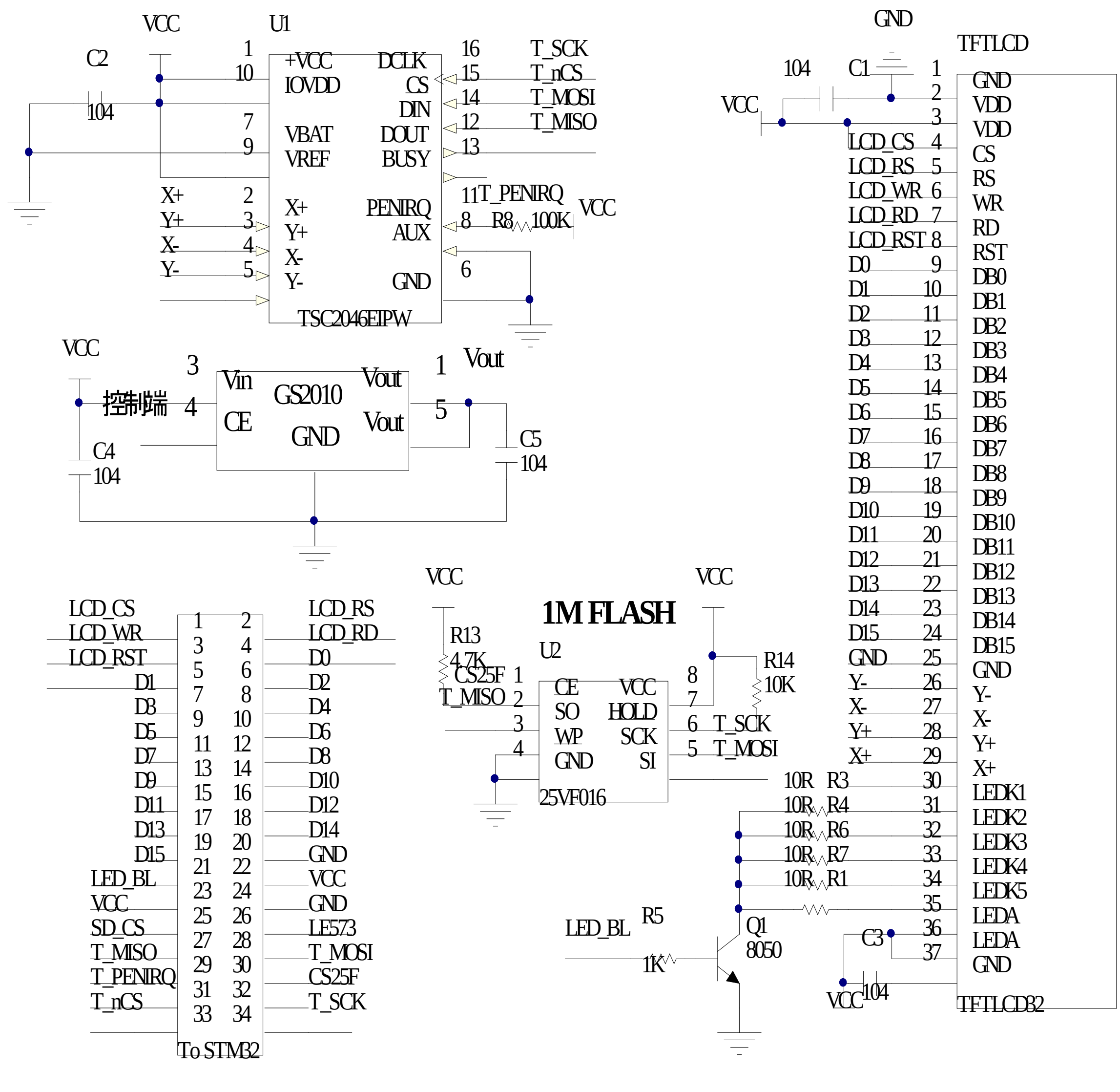


*Figure2: Circuit Of Touch Screen Module*

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### 3.3 Ethernet Module

Through an industry-standard media indepen-dent interface (MII) or reduced media independent interface (RMII), the STM32F107 provide supp-orting IEEE-802.3-2002 media access controller for Ethernet LAN communications. The STM32-F107 requires an external physical interface device (PHY) to connect to the physical LAN bus. MII defines the interconnection of the MAC sublayer for data transmission between the 10Mbit/s and 100 M bit / s PHY. STM32F107 series don't come with the physical layer device PHY, and need external PHY connecting to Ethernet. Connection diagram is shown in Figure 3.

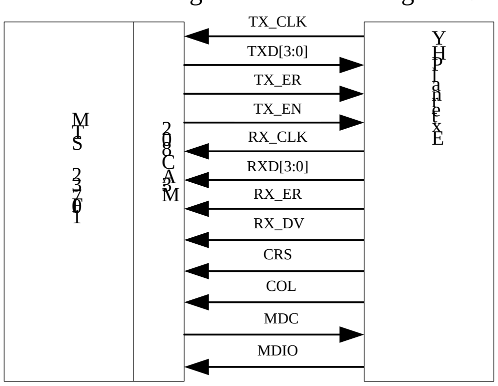


*Figure 3: MII Interface Connection*

DP83848CVV is used as the PHY chip. DP83848 is National Semiconductor production with energy detect mode, supporting low-power performance and single physical layer connection.

## 4. SYSTEM SOFTWARE DESIGN

The lower machine is programmed using the C language and development environment using keil company Real View MDK 4.20, debugging tools with J-Link V8.0. When the system is powered on, the clock, input/output port, touch screen and network port are initialized, and then the value of each sensor is sent to storage for preservation, and compared with the default values then decided to do the corresponding action or not. At the same time, the system display relevant content according to the touch screen operation and monitor network. Due to the sensor signal acquisition and actuator driver relative simple, the programming design is mainly about TFT touch screen and network link. The host computer is built using B/S (Browser/Server) mode, the server program is completed utilizing ASP.NET3.5 software and C# language.

### 4.1 Touch Screen Programming

As major parts of the man-machine interface system, various parameter' s setting and display will be done through the touch screen. When pressing the external key to activate the touch screen, the interface of "setting" and "display" will be shown for your selection. To set parameters, clicking "setting" button, to display correctly clicking the "display" button. When displaying, the system parameters such as temperature, moisture content and concentration in real time value and the setting value will be displayed by scrolling; in setting state a particular parameter can be choose to set, the data input is done by a virtual keyboard.

The interface configurations and initializations are completed in this part, which is about TFT screen, touch chip and flash memory. The process is shown in Figure 4.

### 4.2 LwIP and Bottom Network Design

The connection， between STM32F107 and the network，is completed by using protocol stack of LwIP, and API provided in LwIP to write the network program. Firstly, you need to initialize the protocol stack of LwlP, complete the initialization of the underlying network, by using a network interface initialization function, including of adding and configuration of underlying network interface, the establishment of the receiving/-sending of the underlying thread, the creation of TCP/IP thread, etc.

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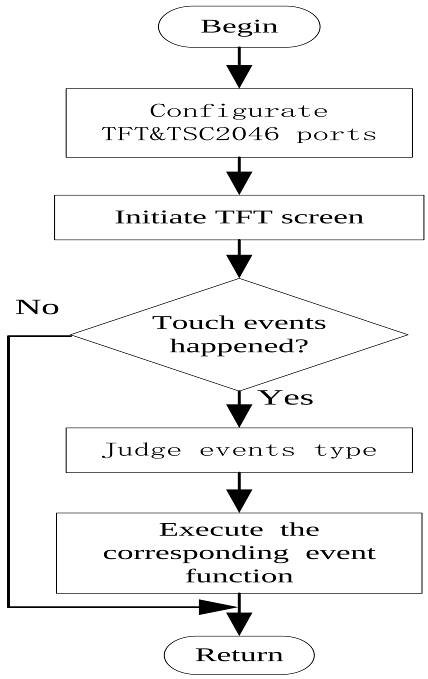


*Figure 4: Touch Screen Working Process*

The initialization of LwIP's underlying interface is mainly to realize the data link layer and the physical layer, includes the following several aspects.

**4.2.1 LwIP initialization**

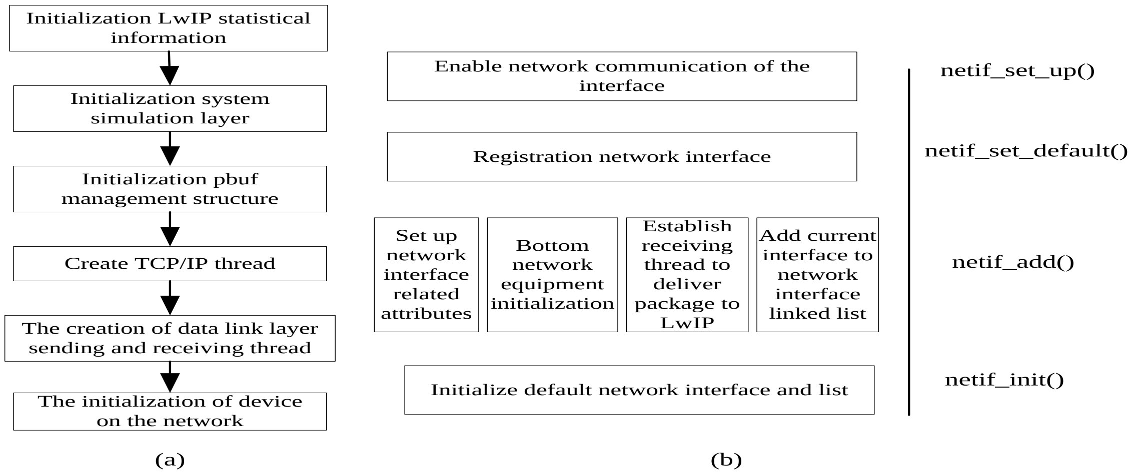


*Figure5*: *Network Modu*le Initialization Process

The initialization of LwIP is about protocol stack and network module. LwIP protocol stack initialization can be achieved by calling RawAPI. For the data link layer and physical layer drive, LwIP protocol stack provides the framework of realizing for developer, the developer's design can be completed, according to the needs of the application and the specific hardware platform. The initialization process as shown in Figure5 (a).

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#### 4.2.2 Abstraction layer equipment initialization

The abstract layer is a universal interface provide d by LwIP to different bottom network, its initialization process is completed in the direction of arrow from down to up in Figure5 (b). Its initialization is to initialize netif structure body and registration process, the key is the initialization of underlying network equipment.

#### 4.2.3 Ethernet controller initialization

Controller initialization includes the following steps: (1) Setting network card's MAC address;(2) Network card initialization, establishing stable physical link; (3) Sending functions to the LwIP registration link layer; (4)Creating receiving thread; (5) Opening ARP table timing update process.

Network card initialization contains the follow-ing process: (1) Shutting off the FEC module; (2) closing interrupt; (3) Registering interrupt vector and handling functions; (4) Opening interrupt; (5) Setting MAC address and flash memory; (6) Setting send control register (TCR) and receive control register (RCR); (7) Initialization of sending and receiving buffer; (8) Opening FEC module.

#### 4.2.4 Use LwIP realize WEB server links

Length of be confined to, a simple server link part of the function is shown using a minimum of API.

```
#include "api.h"
/* the actual web page data, generally in ROM */
const static char indexdata[] = "……";
const static char http_html_hdr[] = "……";
/* Process connection, open the TCP server */
static void process_connect(struct netconn *conn)
{
struct netbuf *inbuf;
… …
/*Read data to inbuf, including complete request*/
inbuf = netconn_recv(conn);
/*Get pointer to the first data fragments in netbuf*/
netbuf_data(inbuf, &rq, &len);
{ ……
/* Send head data */
netconn_write(conn, http_html_hdr,
sizeof(http_html_hdr), NETCONN_NOCOPY);
/* Send actual web page */
netconn_write(conn, indexdata, sizeof(indexdata),
NETCONN_NOCOPY); .
/* Close connection */
netconn_close(conn);
}
}
/* main function*/
int main()
{ ……
/*Creat TCP handle, no connection or data
transmission*/
conn = netconn_new(NETCONN_TCP);
/*Connect 80 port,binding local IP address*/
netconn_bind(conn, NULL, 80);
/*Access monitoring state, monitor port 80*/
netconn_listen(conn);
……
while(1) {
/*Accept new connections,until 80 port get
connection*/
newconn = netconn_accept(conn);
/*Process connection, goto processing function*/
process_connection(newconn);
/*Delete connection handle*/
netconn_delete(newconn);
} ……
}
```

### 4.3 Server program design

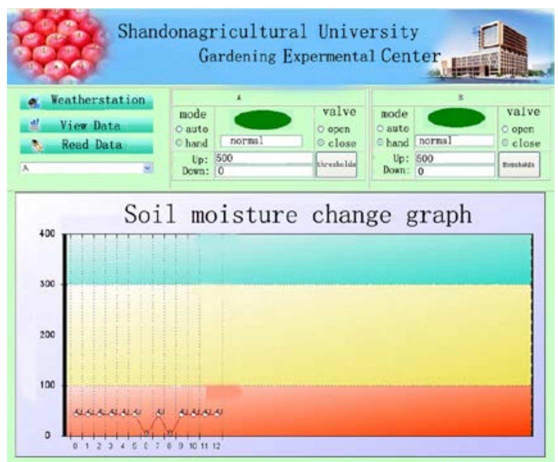


Figure6: Soil moisture observation interface

The system adopts B/S model construction, the user as long as through the Browser can real-time access to data, according to access data infor-mation, through the Server software control terminal auxiliary equipment remotely[8,9]. The server terminal control software is programmed based on c# language of ASP.NET 3.5. Using multi-threading technology, the conversation with terminal equipment process in independent thread, improving the program concurrent processing power and guaranteeing the software execution efficiency. Figure 6 for through the browser observation soil moisture interface.

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### 4.4 Ethernet Real-Time Improvement

Ethernet adopt "Carrier Sense Multiple Access/Collision Detect (CSMA/CD)" protocol, when a node sends information, it first monitors network channel state. If channel leisure, it begin to send; If the channel is still in use, it will still monitor, until the channel has spare time, then send data. Each node has a counter, used to record the number of continuous conflict. 16 times after the conflict, the node will discard data and report the failure to upper layer. Therefore any node must fight for right of use before transmitting data, the time is uncertain from its ready to be sent to the success of sending. That's to say, using CSMA/CD Ethernet fundamentally is not real-time [10, 11].

In the switched Ethernet, the exchange divides Ethernet into several small segments, it increases each network segment throughput and bandwidth. Every micro segment as a child collision domain, each domain is segregated through the exchange. At the same time, the switch between each port can form more data channels in the meantime, so that each node has a private individual channel connected to another node, therefore port data between input and output, don't need competition in bottom transmission channel, no longer subject to the CSMA/CD protocol constraints.

Based on the simulation software Opennet Modeler, [11] compared the real-time between the traditional Ethernet and switched Ethernet. The result showed that switched Ethernet reduced the delay time, improved the real-time of network.

## 5. CONCLUSION

This system in Shandong Agricultural Univer-sity Horticulture Experiment Center has been assembled and debugged successfully and been in motion stably about for a year. The results show that the system can not only realize the greenhouse data acquisition and equipment control, but also the remote data access and control. Comprehensive performance meets the design requirements, and provides a great convenience for research and management.

### 5.1 System cost and performance comparison

Table 2 compares the system with the current widely used greenhouse control systems in performance and cost. The "Cost" includes main control board, display unit and matching epistatic machine equipment. The comparison shows the system's performance-to-price ratio has greater ascension.

### 5.2 System innovation

System innovation can be summarized as follows:

(1)Through the use of Cortex_M3 kernel which based on the ARM processor, the equipment costs is greatly reduced, so that the application and promotion of the system become possible in large area, and not only stay in the experimental application.

*Table 2: System Performance-Price Ratio Comparison*

| Processor | A/D Module | USB Interface | Network mode | HMI | Epistatic machine equipment | Cost |
|---|---|---|---|---|---|---|
| 8/16 bit MCU | Mainly external | None | RS485 | Key& LCD | RS485/RS232 convert | About ￥150 |
| | | | CAN bus | Key& LCD | CAN receive card | About ￥700 |
| PLC | Build-in/ external | None | Profibus | Special HMI | Profibus card | Above ￥2000 |
| ARM7 | Build-in | None | Ethernet, need external controller | Key& LCD | None | About ￥160 |
| | | | GPRS&Ethernet, need external controller&GPRS module | Key& LCD | GPRS module | About ￥600 |
| STM32F107 | Build-in | Build-in | Build-in Ethernet&external PHY chip | Touch screen | None | About ￥120 |

(2)The application of switched Ethernet access technology improve communication stability and real-time of the system, communication protocol is further standard.

(3)The use of touch screen improves the man-machine interface intelligent degree of the system, and enhances the operation convenience.

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