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Software and Hardware Design of a Program Process Protection Card Based on USB Interface

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Abstract: A process protection card based on USB interface is designed. The problems and solutions in the design process are proposed and solved one by one. The design data of hardware and software are given in detail. Compared with the traditional process protection technology, the new technology has more advantages. The new technology provides a new protection scheme for process protection.

Keywords: Software, Hardware, USB Interface, MCU

INTRODUCTION

Nowadays, computers are widely applied to every field of life. In the process of using computers, some software needs to run always. For example, in order to control certain operations of the restricted user, it is necessary to monitor the behavior of the user in some security systems. The monitor is a process that needs to be protected. And the user is not allowed to turn it off artificially [Hu, et. al., 2020]. In some remote control systems, process protection is also needed for the controlled terminal software installed on the controlled computer. Therefore, the technology of process protection is becoming more and more important. Most of the existing process protection technology is designed by software. But with the development of technology, there are corresponding cracking technologies. And some process protection technology is still in the development stage. Based on the above situation, a process protection card based on USB is designed and implemented in this paper. The new technology realizes a process protection technology by combining hardware and software. It has the characteristics of low cost and high security. It has an ideal protection effect for process protection.

SYSTEM ARCHITECTURE

The system takes the STC12C5A60S2 microcontroller made by “macro technology” as the core. The chip CH372 based on USB made by Qinheng company realizes the communication between SCM and computer. The system controls the computer through the optocoupler. The system is divided into two modules.One is the shutdown module encapsulated in the main box, which is used for the control of the computer shutdown. And it is the main part of the design. The other is shielding module, which is used to shield off shutdown modules. Under special circumstances, it can cancel the protection of process. The system structure is shown in Figure 1.

THE DESIGN AND IMPLEMENTATION OF HARDWARE

Several principles have been followed in designing circuit, making PCB board and selecting components. They are universal, compact, low cost and stable performance.

Component selection

With more than 2 billion new units installed per year, USB has become the most successful personal computer interface. Today, each computer has a USB port, which is connected to a keyboard, a mouse, a game handle, a scanner, a camera, a printer, a driver, and more devices. USB is reliable, high-speed, widely used, save electricity and cheap, and has been supported by main operation system [Zhang, et. al., 2020]. So the USB interface is selected. The selected USB protocol chip is CH372.CH372 has a 8 bit data bus which can be easily linked to the system bus of MCU. It has the function of reading, writing, chip select control line and interrupt output.CH372 also has the underlying protocol in USB communication, which has built-in firmware mode and flexible external firmware mode. In the built-in firmware mode, CH372 automatically handles all the transactions of the default endpoint 0.And the local MCU is only responsible for data exchange, so the single chip computer program is very concise; In the external firmware mode, all kinds of USB requests are processed by external microcontroller according to their needs, so that they can meet all kinds of USB specifications.

STC12C5A60S2 microcontroller is a single clock / machine cycle (1T) microcontroller produced by “macro technology”. It is a new generation of 8051 MCU with high speed / low power consumption and

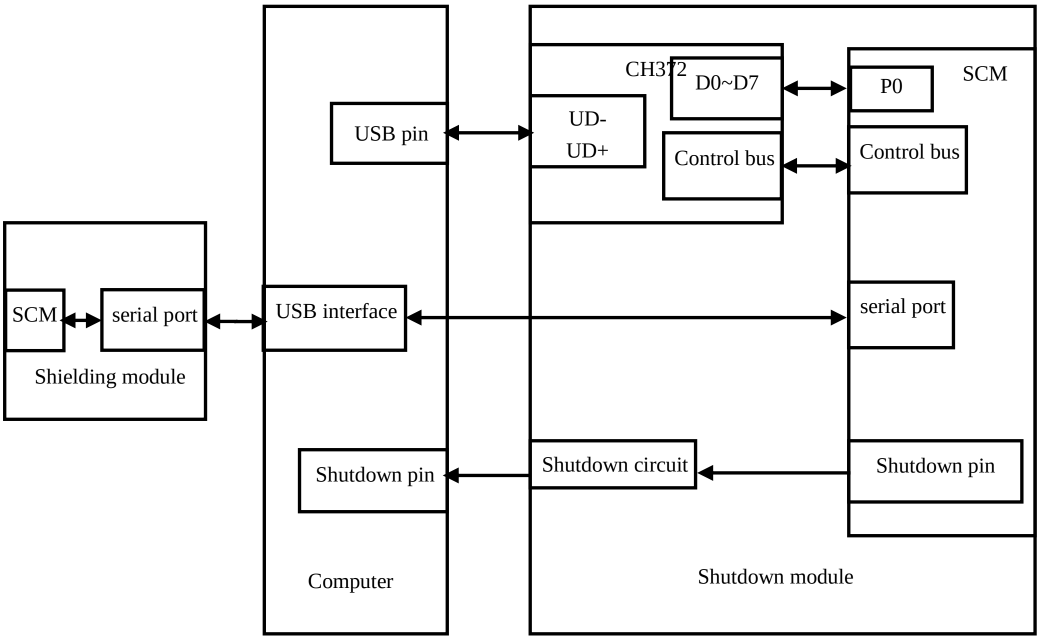

Figure 1 System Structure Diagram

super strong anti-interference. The instruction is completely compatible with traditional 8051, but its speed is 8-12 times faster. As the system needs to be installed inside the main box, it must be strictly limited in volume. Therefore, a smaller package type is selected when selecting components. Singlechip chooses LQFP-48 package, CH372 chooses SSOP-20 package, optocoupler chooses SOP-4 package, and other small components have also chosen patch type (patch type crystal oscillator has encountered many problems in welding, so it chooses cylindrical type in this system).

Because products need to be applied to computers with different brands, its universality must be considered. There are mainly two aspects: one is the voltage of the motherboard pin, the other is the sequence of motherboard pins.

The first choice is transistor because of considering the cost when designing the shutdown circuit.But there will be three problems: (1) The voltage between the shutdown pins of some computers and the GND is 3V, and some others is 5V; (2) when the computer is shut down, the USB port may be charged and may not be charged (some computers can be set);(3)Because the shutdown pin is directly connected with the shutoff module.It is equivalent to directly connects the shutdown pins to the ground when the module is out of power,which will not only affect the use of computers, but also will damage the main board circuit.If the transistor is used, the system will need to design two corresponding circuits. This not only increases the number of devices, enlarges the area of the module, but also is not convenient to use and there will be a lot of trouble in the design of the program, so the optocoupler is finally adopted. Optocoupler is a device that uses photoelectric conversion to achieve isolation effect. It is actually made by sealing a light emitting diode with a photoelectric triode in an opaque packagea [SHI, et. al., 2018] . Because optocoupler has these characteristics, it can solve the above problems well. About the interface, the shutdown module designs the corresponding interface according to the most applied pin arrangement in the market, which is accord with the universality principle. The pin arrangement is shown in figure 2.

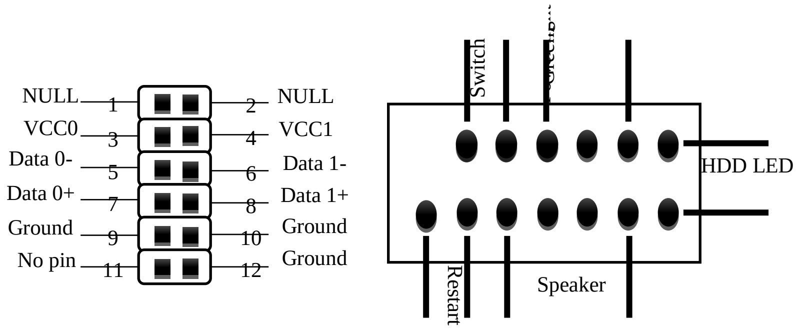

Figure 2 Pin Arrangement Diagram

Schematic diagram

The connection between STC and CH372 is shown in figure 3. D0~D7 is a eight bit data bus that can be uesd to transfer data or commands. KZ[0..4] is the control bus.where A0 is the command and data selection pin, CS is chip selection, RD and WR is read and write pins respectively, INT is interrupt pin.

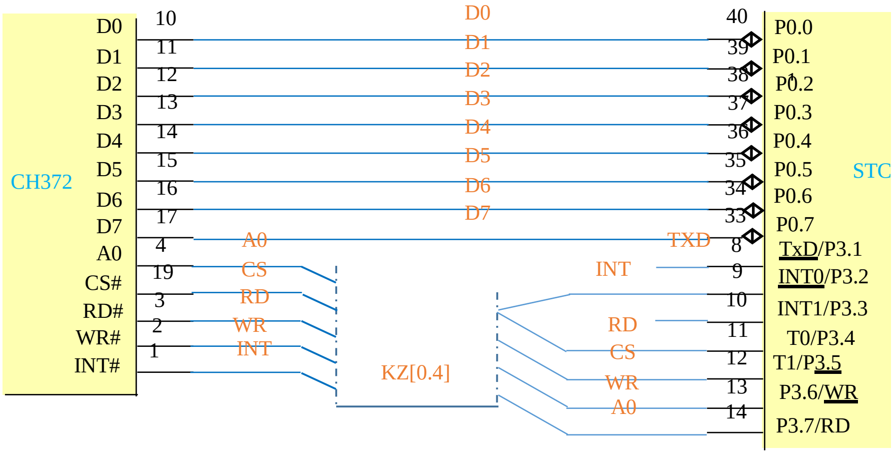

Figure 3 Connection Diagram Between STC and CH372

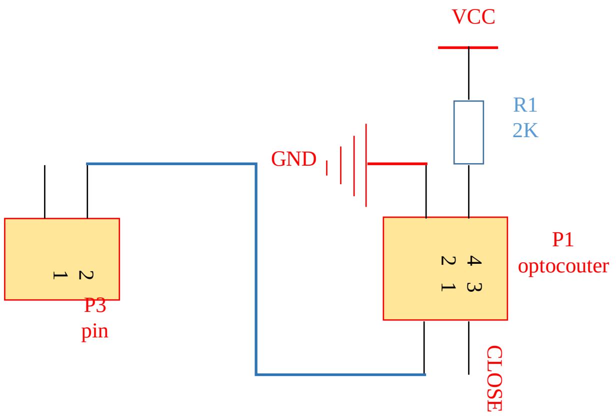

Figure 4 Principle Diagram of Optocoupler Shutdown

CH372 completes the communication between SCM and USB port by interruption.The downlink data transmission:when CH372 receives the data from the USB host,it requests interruption to singlechip microcomputer with the INT pin.The MCU enters the interrupt service subroutine and executes the GET_STATUS command to get the interrupt state. The microcontroller sends the RD_USB_DATA command to read the data received by CH372 after the state is "successful downlink data transmission". The uplink data transmission:first, the microcontroller executes the WR_USB_DATA command to write data to CH372.When the USB host takes away the datas, CH372 requests interruption to the microcontroller with the INT pin.Then the MCU enters the interrupt service program and executes the GET_STATUS command to get the interruption state. After the "successful uplink data transmission", the singlechip can continue to transmit the data or execute the UNLOCK_USB command to release the CH372 buffer and prepare for the next communication.

The principle of optocoupler shutdown is shown in Figure 4. When the “close” pin of the singlechip microcomputer sends low power, there is current passing through the optocoupler 1 and 2, so that 3 and 4 are connected. The shutdown pin is pulled down by GND, resulting in the shutdown of the computer.

In order to ensure the correct installation of positive and negative poles,the anti plug circuit is designed as shown in figure 5.

Although the shielding module uses USB connector and is inserted on the USB port of the computer, the communication between shielding module and shutdown module is achieved through serial port on two singlechip computers. Now most computers have two rows of USB lines, and the transmission between shutdown modules and shielding modules is only one row. For this reason, two rows are also selected when designing the circuit, so that another USB port can still be used normally. As shown in Figure 6, the left part is the needles connected to the shielding module, the right part is the needle connected to the USB on the main board.And the 5678 pin of the two USB pin are directly connected, Its meaning is that it can be used normally and there is no circuit connection between USB and the shutdown module.

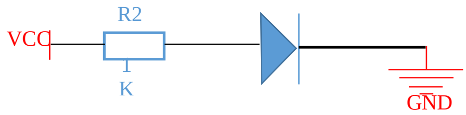

Figure 5 Anti Plug Circui Diagram

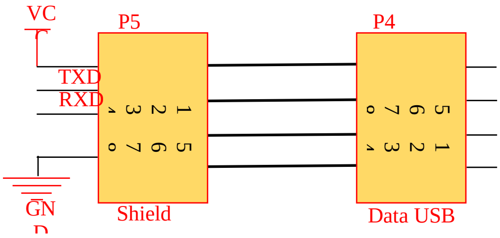

Figure 6 Donnection Diagram Between Shield USB and Data USB

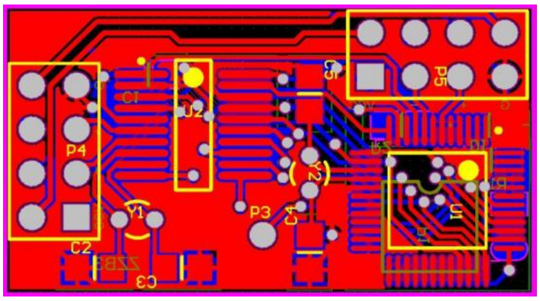

Figure 7 PCB Diagram

PCB diagram

The software ”Altium Designer 10” is used to design PCB diagram.The PCB diagram is designed with a double-sided plate.It not only guarantees the stability and anti-interference ability, but also minimized the width of the line and the width of the through hole which effectively reduces the module area. The anti-interference ability is enhanced by widening the ground wire, power line and large area of copper clad. When drawing data bus and control bus, the author try to ensure that the lengths of each line and the number of through-holes between them are approximately equal, so as to ensure the stability of transmission data.Considering the convenience of use, the location of each component is also adjusted reasonably. The shutdown module PCB diagram is shown in figure 7.

DISCUSSION--THE DESIGN AND IMPLEMENTATION OF SOFTWARE

The principle of shutdown module is to check whether the corresponding process is running by checking the data emitted from the process in the computer circularly. If no data is detected or the detected data is wrong, the microcontroller will turn off operation. The transmission data is generated by the rand () function, then is randomly inserted into the effective data according to certain rules and encrypted by DES encryption algorithm.So it has strong security [He, et. al., 2022]. The following is a key description about the singlechip computer program The flow chart of the program is shown in figure 8.

After the MCU is powered on, the program first checks whether the computer is in boot state.If the computer is in boot state, it will be delayed for 3 minutes.Then the program checks whether the shielding module matching the protection card has shielding signal.If the program does not receive the shielding signal from the shielding module, it checks whether the protected process will send the correct data.If no correct data is received from the protected process, it starts the shutdown program.If the shutdown program is executed for three times, the computer cannot be turned off, then the power is cut off.The program in the singlechip computer is in the working condition and the computer is connected with the shielding module supporting the protection card. Even if the computer does not run the protected process, the computer will not be turned off.

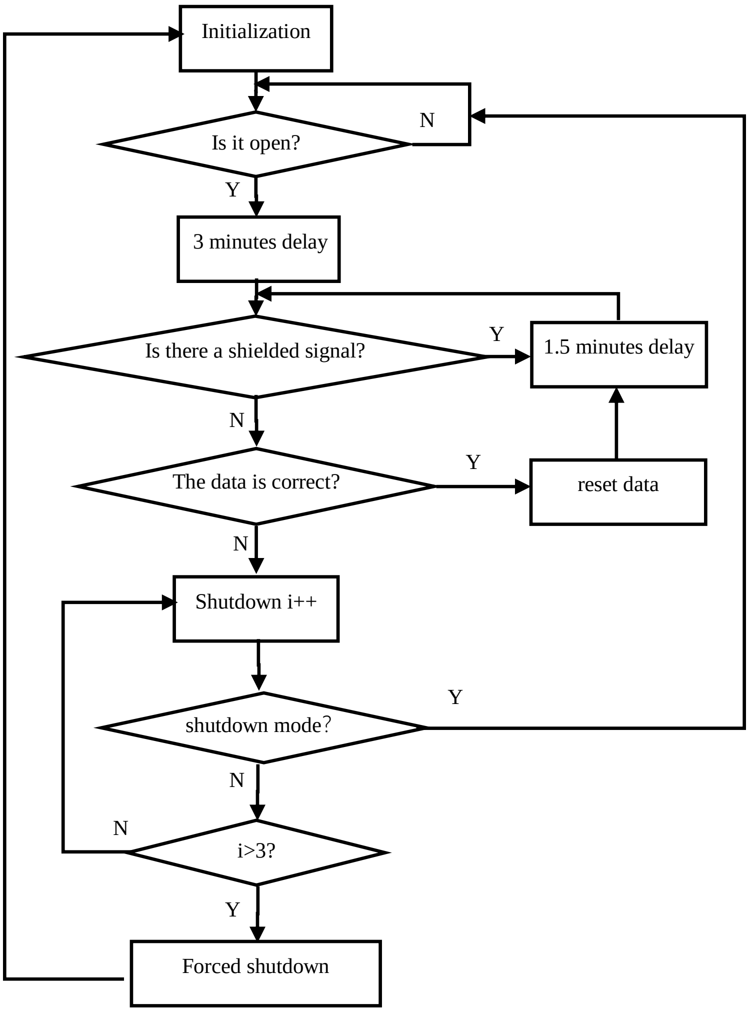

Figure 8 Flow Chart of the Program

Transplantation of encryption algorithm

DES encryption algorithm is a symmetric encryption algorithm, which is widely used now, especially in protecting the safety of financial data. The workflow of the DES algorithm is as follows: if it is an encryption mode, Key is used to encrypt the data . The password(64 bit) form Data is generated as the output of DES;if it is decryption, mode, Key is used to decrypt the data and restore the data's plain coed form (64 bits) as the output result of DES. At both ends of the communication network, the two sides agree on the same Key. In the source of communication, the core data is encrypted by Key, and then transmitted to the terminal of the communication network in the public communication network (such as telephone network) in the form of cryptography. After the data arrives at the destination, the same Key is used to decrypt the cryptographic data, and the core data of the plain code form is reproduced. This ensures the safety and reliability of the core data transmission in the public communication network [Xu, et. al., 2019].

Although with the development of computer technology, DES encryption algorithm has revealed some shortcomings, it still has high security. Moreover, the DES algorithm is not entirely dependent on the design procedure. The algorithm is mixed with the random number in the data. It uses the particularity of the data transmission mode so that it can meet the security requirements well. When DES algorithm is transplanted from computer to MCU, there is a problem to be solved, that is the storage way of multibyte data. When data items are more than one byte, there are two ways of storage in memory:the order of nature(store the leftmost bytes first)or the reverse order(store the leftmost bytes last).The first way is also known as big-endian, the second is called the little-endian. C does not require the order of storing data, because it depends on the CPU used when the program executes. Some CPU use big-endian method, the others use little-endian method. Here the CPU of X86 architecture uses the little-endian mode, the MCU uses the big-endian mode.So the conversion from the little-endian method to the big-endian mode is needed during the data transmission.In this way, the macro definition is used.

The conversion of two byte data :

```
#define BigtoLittle16(A)   (A=(( ((uint16)(A) & 0xff00) >> 8)|(( (uint16)(A) & 0x00ff) << 8))  )
```

The conversion of four byte data :

```
#define BigtoLittle32(A)   (A=((( (uint32)(A) & 0xff000000) >> 24)|(( (uint32)(A) & 0x00ff0000) >> 8)|(( (uint32)(A) & 0x0000ff00) << 8)|(( (uint32)(A) & 0x000000ff) << 24)))
```

Judgement of shutdown state

Because the principle of computer startup and shutdown is the same. The system connects the shutdown pin to the ground instantly. Therefore, the shutdown module needs to judge the state of the computer before shutting down the operation and prevent the reverse operation.The judgement is based on the USB enumeration process. Because the external firmware mode is used, it is easy to modify the enumeration process by singlechip program.The method is as follows.The first thing is to set up a variable to represent the state of the computer. Assign the value to the variable in the program segment of the enumeration, The principle of query state function is to make the shutdown module re enumerated and judge the correspondence between variable and value. The code for the query state function is as follows:

```
int Check_Stat(void)
{
    Check_Shut = 0;//Set zero for detection
    CH375_WRCMD(CMD_SET_USB_MODE);    //Setup work mode
    CH375_WRDAT(0);    //disconnect
    Delay_ms(100);
    CH375_WRCMD(CMD_SET_USB_MODE);    //Setup work mode
    CH375_WRDAT(1);                   //set the external firmware mode
    Delay_ms(100);
    Delay_ms(2000);                   //Delay until the enumeration is completed
    if(Check_Shut == 0)
        return 0;    //computer shutdown
    else return 1;                    //computer startup
}
```

Communication with shielding module

The two module is a direct wired communication through serial ports on each microcontroller. As long as the frequency of the crystal oscillator on the hardware and the baud rate of the software is the same, the normal communication can be realized.

Other important functions

The delay function adopts the way of timer interrupt which ensures the accuracy of the delay. The timer interrupt processing function is as follows.

```
void T_C0(void) interrupt 1  //using 1
{
    TH0 = 0x3C; // High 8-bits of 16 bit count register T0 （the initial value ）
    TL0 = 0xB0; //Low 8-bits of 16 bit count register T0 （0x3CB0 = 50mS delay）
    t++;
    if(t>=20)//1s

    {
        t=0;
        TR0 = 0;
    }
}
```

The interrupt handling function ensures that timer interrupt is automatically closed after entering the interruption for one second.The two delay functions are as follows.

```
void DelayT0(unsigned int c)
{
    unsigned int i;
    for(i=0;i<c;i++)
    {
        TR0=1;       //Open the timer and shut down after 1 second automatically
        while(TR0==1);
    }
}
/*************************************/
void DelayT0_2(unsigned int c)
{
    unsigned int i;
    for(i=0;i<c;i++)
    {
        if(Delay2_Jump == error)    //It means that some data is sent and has no need for delay.
            break;
        if(Delay2_Jump == correct)
        {
            TR0=1;     //Open the timer and shut down after 1 second automatically
            while(TR0==1);
        }
    }
}
```

The principle of DelayT0 function is to carry out c round cycles.Each cycle is executed for 1 second, and the timer is automatically stopped. DelayT0_2 added a condition on the basis of DelayT0. That is to say, after the shutdown module receives the data from the computer, it automatically jumps out the delay. DelayT0_2 is mainly used in computer startup delay, waiting for the computer to start and the application is ready. The purpose of setting this condition is to prevent some computers starting too fast which result in the process is in a state of no-protection for a long time (5 minutes).At the same time,the forced shutdown function is set up to prevent shutdown failure in the program. For example,computers are running large software or documents are not saved. All these problems may lead to shutdown failure.

```
while(Check_Stat()==1)//loop when computers
start
{
P42 = 0;            //P42=0,computer
shutdown
DelayT0(2);
if(x>=3)
{
DelayT0(5);     //Prolonging the time of
pulling pin down. (the forced shutdown)
}
P42 = 1;
x++;
DelayT0(30);
}
```

Once the loop has been executed for 3 times and it has not been shut down successfully,the forced shutdown function would been executed.

CONCLUSIONS

In this paper, a process protection card based on USB is designed and implemented. The process is protected by hardware. It ensures that the process can not be stopped when the computer is open.And the security is enhanced with the DES encryption algorithm.It has also made great improvements in universality.It has the advantages of low cost, convenient operation and high popularization value.

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