Research on multi-point temperature detection and time display system

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Abstract. For the industrial environment with complex application environment and large amount of information display, quadruple high-bright digital tubes, external perpetual calendar chip and multiple digital temperature sensors DS18B20 are used to design and manufacture system display, time function module and multi-point temperature detection function modules, they are integrated by the automatic control core IAP15F2K61S2 as the full-featured multi-point temperature detection and time display system. Based on the system time provided by the designed time system, it realizes single-point and multi-point high-precision detection of system temperature, statistics and record of the system key control parameters, real-time dynamic monitoring of the system's key parameters through high-bright display and matrix keyboard with efficient human-computer interaction. The core control functions are encapsulated in a portable header file format, which can be used with other modules of the system to implement system function optimization and troubleshooting.

1. Introduction

Strong electromagnetic interference, dust, steam and other industrial environments put forward more stringent requirements for the temperature detection and display of the control system. In the operation process, the automatic control system needs to complete the relevant control functions with the axis of date and time, realize the corresponding control function at the set time, record the key parameters of the system before and after the event, which requires the control system to have accurate record date and time.

The collection of temperature signals is a common control requirement of automatic control systems. It is commonly used to detect the temperature of liquid materials such as water or oil, temperature detection of equipment operating environment, and automatic detection of equipment's own temperature [1, 2, and 3]. The multi-point temperature detection module is designed and manufactured by taking the water and environment temperature as an example. By simply changing the installation method of the sensor, the temperature detection of the control system can be conveniently performed.

2. Hardware design

2.1. The main circuit

According to the control requirements of this project, the general control core IAP15F2K61S2 series chip manufactured by STC Micro is selected. The chip adopts high-speed CPU with single clock/machine cycle (1T), facilitates the high-speed temperature acquisition function of the control system. STC eighth generation encryption technology, cannot be decrypted, the instruction code is fully compatible with the traditional 8051, but the speed is 8-12 times faster, with low power design mode as low speed, idle and power down, super anti-interference, ultra-low EMI, internal Integrated high-precision R/C clock (+0.3%), ±1% temperature drift (-40°C~+85°C), which guarantee the designed control system is able to operate normally in harsh industrial environments.

Powerful ISP/IAP programming and storage functions, the MCU program can write data to the program memory or modify the program. The frequency wide range can be set from 5MHz to 35MHz when ISP programming, built-in 2K bytes of large-capacity SRAM and 61KB Flash, 3-way CCP/ PWM/PCA make it easy to store control information and user-defined functions. 8-channel high-speed 10-bit A/D conversion (300,000 times/second), two sets of ultra-high-speed asynchronous serial communication ports (UARTI/UART2, which can be switched between 5 groups of pins, and can be divided into 5 serial port groups by time division multiplexing), 1 set of high-speed synchronous serial communication port SPI.

The main circuit of this product is designed with IAP15F2K61S2 microcontroller as the core, as shown in Fig.1. It adopts DC5V-1A universal switching power supply and A-type USB interface for dual power supply with small ship type switch and LED power indicator, serial communication transmission and reception are indicated by red and blue LED, 5-wire interface (2 power lines and 3 data lines), 4 spare lines facilitate the user to implement the custom extended update function. The host computer uses the USB interface for the serial download program of the MCU and the operation of the online monitoring system program. The control system circuit board adopts double-sided PCB, as shown in Fig.2, with the single-chip microcomputer as the core, peripherally designing power supply, communication interface and system reserved port.

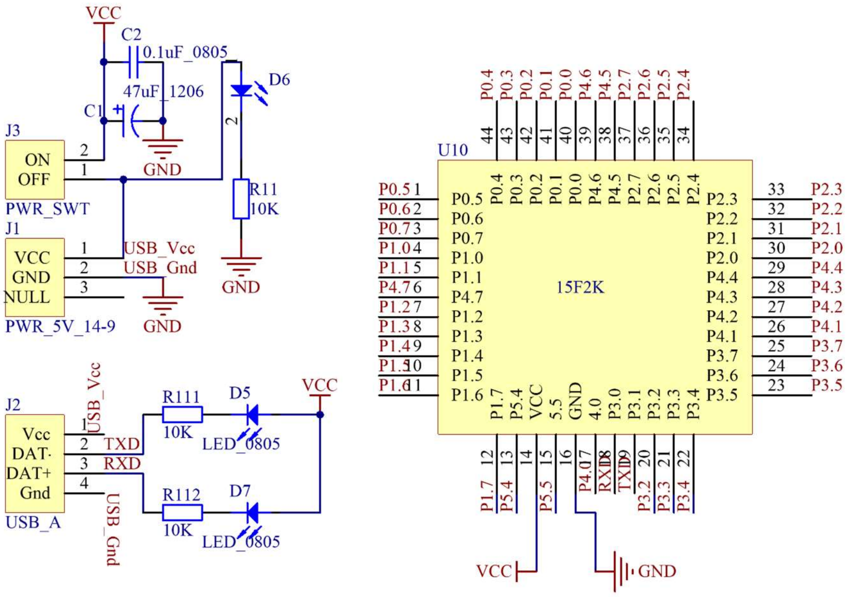

Figure 1. Schematic diagram of the main control circuit

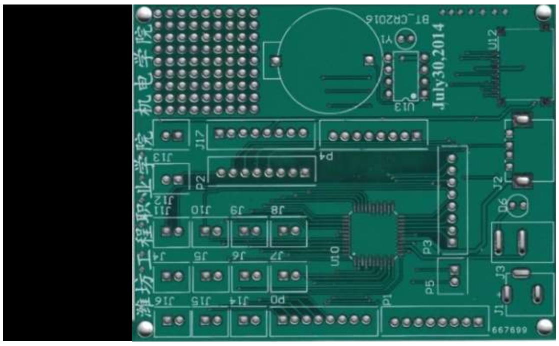

Figure 2. PCB of the main control circuit.

2.2. Time circuit

The time circuit is designed with Dallas 1302 perpetual calendar chip as its core, the DS1302 is a trickle-charged clock chip from DALLAS that includes a real-time clock/calendar and 31-byte static RAM. The real-time clock/calendar circuit provides information of second, minute, hour, day and date, automatic days of the month and leap years. The clock operation can be determined by the AM/PM indication in 24 or 12 hour format. The crystal frequency is 32.768 KHz, and an external clock circuit is designed to accurately generate the date and time information.

The DS1302 uses dual power pins for mains and backup power supplies. Vcc1 is a programmable trickle charge power supply. The Vcc2 is powered by a separate 3V button lithium battery CR2016, ensuring information save during power-down. The DS1302 and MCU can simply communicate in synchronous serial mode, and the clock function terminal DS1302_Sclk (P1.0), the I/O function terminal DS1302_IO (P1.1) and the enable terminal DS1302_RST (P1.2) are implemented. For control operations, the clock/RAM read/write data is communicated with burst of 1 byte or 31 bytes. Such circuit is integrated near the main circuit with smaller PCB area, as shown in Fig3. The time circuit is designed for low power consumption, its power of maintaining data and clock information is less than 1mW.

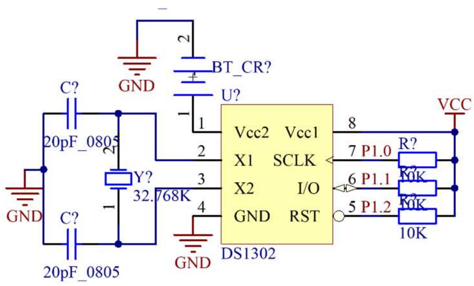

Figure 3. Schematic diagram of time circuit

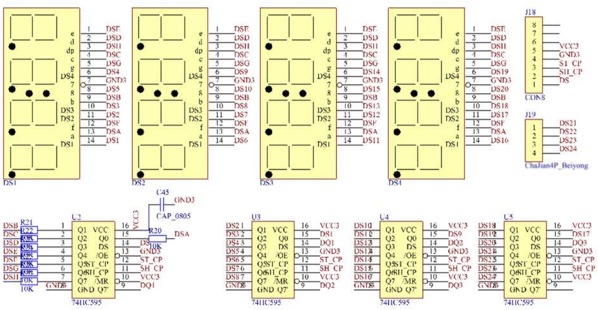

Figure 4. Schematic diagram of display circuit

2.3. Human interface circuit design

In order to comprehensively improve the efficiency and function of this display, select four quadruple high-bright digital tubes to build this display. This component is packaged in 14-DIP. It has a colon interval for time display in the middle. It is convenient to realize the display of control system status information such as temperature, time and speed with 14 pins. The serial-to-parallel 8-bit shift register 74HC595D is used as the driving chip of the display with SOP-16 package, which can greatly reduce the volume of the PCB circuit board and improve the cost performance of the product under the premise of ensuring performance.

The driver chip and the digital tube communicate through serial-in and parallel-out (SIPO), as shown in Fig.4, the display information of the digital tube (segment selection) is transmitted by U2, the position of the digital tube (position selection) and the colon control information is transmitted by U3, U4 and U5, 1 frame of the display data is 32 bits, the PCB of the display circuit is as shown in Fig.5. Such display circuit and the integrated 4×4 array keyboard form the human-computer interaction device, which effectively saves the hardware interface resources of the control core, clearly displays rich control information, realizes efficient human-machine information interaction.

Figure 5. PCB of the display circuit

2.4. Multi-point temperature detection circuit

The high-precision digital 1-bus temperature sensor 18B20 with 64-bit serial number is selected as the core to design multi-point temperature detection circuit. The power supply allowable range is DC3.0V~5.5V, the temperature range is -55~+125°C, the monitoring point temperature can be converted to 12-bit digital signal within 750ms, it is convenient to implement multi-point temperature detection in this system.

The temperature sensor adopts a special 304 stainless steel and mounting flange, is connected to the control core of the main board through an aviation plug and an anti-jamming communication line, as shown in Fig.7, ensuring efficient and stable transmission of control signals and temperature detection signals. The choice of other housing packages and the number of sensors can be applied to multi-point temperature signal detection and control in a variety of applications. The temperature detecting circuit adopts a pull-up resistor design, as shown in Fig.8, which can realize simple single-point temperature detection or accurately detect temperature by means of average distributed multi-point detection using averaging method, realize control function related to the temperature of the measuring point.

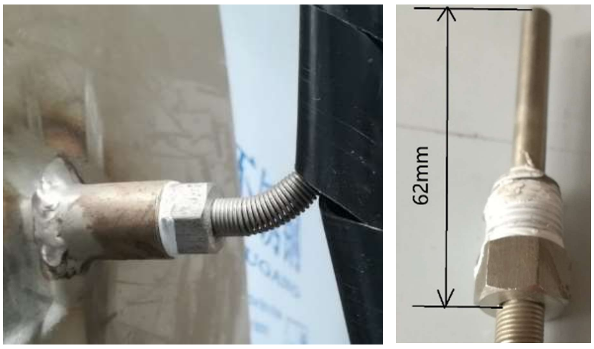

Figure 6. Temperature sensor package

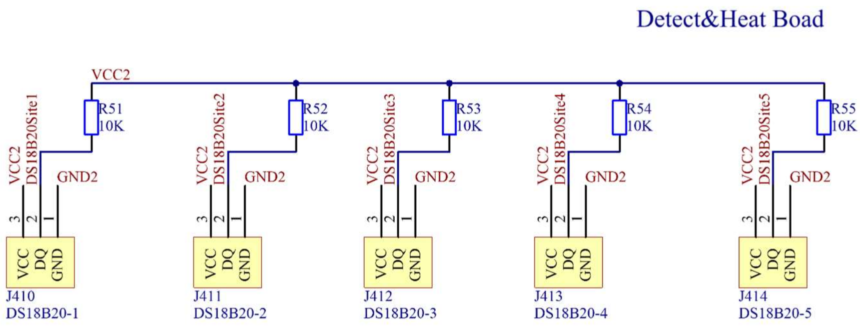

Figure 7. Schematic diagram of multi-point temperature detection circuit

3. Program of control system

On the designed hardware platform, the main control program achieves the function through 4 module control header files, which are the display (Disp4_4_7SegLed.h), keyboard (MatrixKeys.h), electronic clock (DS1302.h) and temperature detection (DS18B20.h), etc. The control program is designed by the modular programming method of C language. The main program achieves its function by containing the required function header files, using global control variables, the parameter lists of global variables, arrays, subroutines. Other system can easily use these functional modules to implement related control functions.

3.1. Man-machine interface control module

As the most basic control requirement of the control system, the system display control module is designed with 3 arrays and 3 subroutines. Under the coordination of the control main program, the system display information is stored in the display buffer array, and showed on this display with highlight mode by calling the display subroutines, enabling a variety of display functions such as static and dynamic display.

A 2-dimensional display code array is designed, which is convenient for displaying complex information: unsigned char TAB[CodeNO][2]={0,0x3F,1,0x06,2,0x5B,3,0x4F,4,0x66,5,0x6D,6,0x7D, 7,0x07,8,0x7F,9,0x6F,0X0A,0x77,0x0B,0x7C,0x0C,0x39,0x0D,0x5E,0x0E,0x79,0x0F,0x71}.

The special characters required by the control process are extended to the display code table by changing the number of array lines, a code conversion subroutine is designed to extract the digital tube segment code: unsigned char CodeConvert (unsigned char InData) {unsigned char i; for (i=0; i< DSCharCodeMax; i++) {if (InData==CodeTable [i] [0]) return CodeTable[i][1]; }return 0;}.

Two 1-dimensional arrays are designed as the display buffers for segment and position selection, which are used to store the control data to be displayed: unsigned char DSBuffer[16]={ Store the data to be displayed here }, DSIndex[3]={0x7F,0xFF,0xFF}.The segment selection array DSBuffer[16] contains 16 elements, which respectively correspond to the display information of the display position. The position selection array (DS Index [3]) contains 3 bytes, 16 bits are used to enable 16 digital tubes, and 4 bits are used to control the colon for time display.

The driver subroutine of the digital tube driver chip is designed to transmit digital tube segment and position selection data through 595: void SendByte_595 (unsigned char dat) {unsigned char i; for (i=0; I <8; i++) {HC595_SHCP=0; if (dat&0x80) HC595_DS=1; else HC595_DS=0; dat << =1; HC595_SHCP= 1; }}.

The display driver subroutine is designed to coordinate arrays and other subroutines to implement the display function of this system: void DScan (unsigned char *DSBufP, unsigned char DSInfor) {unsigned char i, j, c, k, SecLED=0xBD, TempDot=0x00; DSInD [2]= 0xFF; DSInD[1]=0xFF; DSInD[0]=0xFE; if(DSInfor==0x01) {k++;if(k<22) SecLED=0xFD; else if(k<44) SecLED= 0xBD; else k=0; } if (DSInfor==0x80) SecLED=0xBD; for (i=0, j=0; i<=15; i++) {if(DSInfor==0x80&&(i==0x06||i== 0x0E)) TempDot= 0x80; else TempDot= 0x00; for(c=0; c<=6;

c++) {HC595_STCP=0; SendByte_ 595(DSInD [2]&0xF7); SendByte_595 (DSInD [1]&SecLED); SendByte_595 (DSInD [0]&0xEF); SendByte_595 (CodCvt (*DSBufP) |TempDot); HC595_STCP=1; } DSBufP++;DSInD[j] =_crol_(DSInD[j], 1); if(i== 0x03||i== 0x07||i== 0x0B||i== 0x0F) DSInD[j] =_crol_ (DSInD[j], 1); if(i== 0x06||i== 0x0C) {DSInD[j]= 0xFF; j++; DSInD[j]=0xFE;}}}. The driver continuously executes the SendByte program for 4 times to send one frame of display data, illuminates a digital tube, continuously transmits 16 frames of data to realize full-screen information display. The time colons of quadruple high-bright digital tubes are controlled by the 4 bits of the position selection array. The time flag is set to illuminate corresponding time colon when the time display is required. The display driver is implemented by calling the DScan program in the header file Disp4_4_7SegLed.h [4].

The input driver implements real-time adjustment of the electronic clock and system control parameters by calling subroutines such as MatrixKeys and MatrixKeysFun in the header file MatrixKeys.

3.2. Time control module

This control module specifically realizes the recording of the date and time by subroutines and arrays included in the header file DS1302, including clock initialization program Init1302, byte read and write programs WriteByte1302 and ReadByte1302, information communication programs Write1302 and Read1302, time setting program DS1302_SetTime and DS1302_ReadTime, clock ON/OFF program EnableClock and DisableClock, the time display program: Void GetClockToDS() {DS1302_ ReadTime (Clk); DSYear_0= Clk[6]%16; DSYear_1= Clk [6]/ 16; DSMon_ 0= Clk[4] %16; DSMon_1= Clk [4]/ 16; DSDate_ 0= Clk [3]% 16; DSDate_1= Clk [3]/ 16; DSHour_0= Clk [2]% 16; DSHour_1= Clk [2]/16; DSMin_0=Clk [1] %16; DSMin_1=Clk [1]/16; DSSec_0=Clk [0]%16; DSSec_1=Clk[0]/16;DSDay_0=Clk[5]%16;if(DSMon_1==0)DSMon_1=16;if(DSDate_1==0)DSDate _1=16;if(DSHour_1==0)DSHour_1=16;if(DSMin_1==0)DSMin_1=16;if(DSSec_1==0)DSSec_1=16; DSDay_1=16;DScan(DSClkBuffer);}. Taking the acquired system time as the axis, it is convenient to realize continuous recording of system parameters, assist in completing the function optimization and upgrade.

3.3. Multi-point temperature detection control module

Based on the requirements of temperature detection, the temperature detection header file "DS18B20.H" is designed, including a temperature buffer array and 5 subroutines. The main control program realizes the corresponding functions by include the header file and calling the system display, temperature control and other functional subroutines.

Temperature display buffer array: unsigned char DSTempBuffer [16] = {'P','o','t',5,' ',' ',' ',' ','s','e','t',5,' ','1','9','0'}. It is used to store and display the temperature set value, real-time temperature and other information of the monitoring point.

Sensor initialization subroutine: void Init_DS18B20 () {CY=1; while (CY) {DQ= 0; DelayXus (240); DelayXus (240); DQ=1; DelayXus (60); CY=DQ; DelayXus (240); DelayXus (180); DScan (DSTempBuffer, DSTemp) ;}}. The initialization of the sensor is implemented to enter the detecting state.

Sensor write control byte subroutine: void WriteByte18B20(unsigned char dat){unsigned char i=0;for(i=8;i>0;i--){DQ=0;DelayXus(1);dat>>=1;DQ=CY;DelayXus(60);DQ=1;DelayXus(1);}}.

Read byte and temperature data subroutine: unsigned char ReadByte18B20(){unsigned char i=0;unsigned char dat=0; for(i=0;i<8;i++){dat>>=1; DQ=0; DelayXus (1);DQ=1; DelayXus (1); if(DQ) dat|=0x80; DelayXus (60);}return(dat);}.

Monitoring point temperature reading subroutine: unsigned int ReadTemperature0(){signed int TemperatureInt;Init_DS18B20();WriteByte18B20(0xCC);WriteByte18B20(0x44);hile(!DQ);InitDS18 B20();WriteByte18B20(0xCC);WriteByte18B20(0xbe);tempL=ReadByte18B20();tempH=ReadByte1 8B20();TemperatureInt=((tempH*256)+tempL);if(TemperatureInt<0){TemperatureInt=~TemperatureI nt+1;NegativeTempFlag=1;}else NegativeTempFlag=0;TemperatureUInt=TemperatureInt*0.0625*10+0.5;TemperatureFloat=Temperat ureInt*0.0625+0.05;return TemperatureUInt;}. The data communication between the controller and the digital temperature sensor is completed, and the temperature data returned by the sensor is processed accordingly, including positive and negative temperature values, temperature setting values, real-time temperature detection, and temperature value accuracy setting.

Based on the design requirements of the control system, a subroutine for obtaining temperature values and display functions is designed: void GetTempToDS () {unsigned int TemperatureUInt, TemperatureUInt0; TemperatureUInt = ReadTemperature0 (); if (NegativeTempFlag== 1) {DSTempBuffer [4]='-';DSTempBuffer [5]= TemperatureUInt /100; DSTempBuffer [6]= (TemperatureUInt% 100) /10; DSTempBuffer [7]= (TemperatureUInt% 100) %10; } else {DSTempBuffer [4] = TemperatureUInt/ 1000; TemperatureUInt0= TemperatureUInt%1000; DSTempBuffer [5]= TemperatureUInt0/ 100; DSTempBuffer [6] =(TemperatureUInt0%100) /10; DSTempBuffer [7] =(TemperatureUInt0%100)%10; } if (DSTempBuffer [4] == 0)DSTempBuffer[4]=' '; DScan (DSTempBuffer, DSTemp);}. The temperature detection function of multiple monitoring points is realized, and the control program can be conveniently transplanted to other control systems requiring temperature detection.

4. Conclusion

Based on the functional requirements of our research, the multi-point temperature detection and time display system is researched and produced through the system function design, controller design, schematic diagram design, PCB production, product assembly, driver design, function debugging and other steps. Through system testing, multi-point temperature detection, high-bright digital tube display, matrix keyboard input, perpetual calendar and other functional modules can achieve preset functions. The results have been successfully applied to Weifang Science and Technology Plan Project (Automatic Control of Poultry Slaughtering Equipment Constant Temperature Control), popularized to Qingzhou Dingchang Filling Machinery Co., Ltd. and other enterprises for assisting relevant products to complete the temperature detection, system key parameters record, fault troubleshooting and function optimization.

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