

DESIGN OF A NON-CONTACT INFRARED THERMOMETER

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Abstract- In order to realize the human body temperature fast and non-contact measurement, an infrared thermometer is designed. The infrared human body temperature sensor is mainly used to convert the human body's infrared into voltage signal, an operational amplifier to amplify the signal, filter circuit to filter the signal, the analog signal into digital signal by the A/D conversion circuit, data processing by the MCU, LCD display and voice reporting body temperature and time, so the human body non-contact measurement is realized. The experimental results show that: the device can realize the temperature and time of acquisition, the measurement error is not more than 0.5℃, voice broadcast and liquid crystal display the temperature and time, overrun alarm and other functions.

Index terms*: infrared temperature sensor, MCU, LCD, voice broadcast.*

Ⅰ. INTRODUCTION

In daily life, the measurement of body temperature is a basic way to determine the normal life of the human body. Although the price of traditional mercury thermometers is cheap , the existing problems are as follows when it is used: Mercury thermometer must contact with the human body , and temperature measurement process need lasted 5 to 10 minutes, because infants is active, let parents become very headache for infant body temperature; And in the number of temperature meter reading, easy to read wrong due to external light and other factors; Mercury thermometer is easy to rupture when heated or stored improperly, It can lead to mercury poisoning due to human body exposure to mercury [1]. Infrared temperature sensor is used for measuring temperature, The measurement trouble of the traditional contact thermometer is avoided. It is especially suitable for infants and young children to measure the body temperature ,and the measured temperature is displayed by the liquid crystal display module, it is accurate, and it has the function of voice broadcast, it is convenient for the people with poor eyesight.

Ⅱ. PRINCIPLE OF INFRARED TEMPERATURE MEASUREMENT

In nature, when the temperature of the object is higher than the absolute zero (-273.15℃), Electromagnetic waves will continue to radiate around due to the thermal motion of molecules. the radiation of the electromagnetic wave contains the infrared radiation of 0.75 ~100μm, the radiation energy density and the temperature of the object are in accordance with the law of radiation[2-3]:

$$A = \alpha\beta(T_2^4 - T_1^4) \qquad (1)$$

In the formula: A is a radiation degree, the unit is W/m^3; α is the Stephen Pozman constant, α $=5.67\times10^{-8}W/(m^2 \cdot K^4)$; β is the radiation rate; T_2 is the absolute temperature of the object, the unit is K; T_1 is the ambient temperature, the unit is K.

The numerical value of the radiation rate is 0～1.0, which indicates the ability of the radiation electromagnetic wave. All real objects (including the surface of the human body), β values are less than 1.0. The main radiation infrared wavelength of the human body is 9 ~ 10 μ

m, human body surface temperature can be accurately measured by measuring the body's own radiation infrared energy. Because the light in the range of 9 to 10 μ m is not absorbed by air, the surface temperature of the human body can be determined by infrared energy.

The relationship between the temperature of radiator and detection voltage can be derived by the Planck formula, that is:

$$U = \mu\gamma\beta\alpha T_2^4 = \rho T_2^4 \tag{2}$$

In the formula: ρ=μγβα， T_2 is the absolute temperature of the object to be measured, μ is the sensitivity of the detector, γ is constant which is related with the atmospheric attenuation distance, β is radiation rate,α is the Stefan Boltzmann constant.

According to the formula (2), the output signal of the detector and the target temperature are nonlinear, and the T_2^4 is proportional to U,Therefore, the surface temperature of the object should be linearized, and the radiation rate can be corrected, so that the real temperature can be obtained, Correction formula is:

$$T_2 = \frac{T_0}{\sqrt[4]{\beta(T)}} \tag{3}$$

In the formula:： T_0 is the surface temperature (radiant temperature); β(T) is the radiation rate, it's value is 0.1 ~ 0.9.

The real temperature is higher than the ambient temperature after the radiation rate correction due to the influence of the radiation signal, so the ambient temperature is also compensated, that is: The temperature of the ambient temperature plus the actual temperature is the actual temperature of the measured object[4-6].

Ⅲ. DESIGN OF THE HARDWARE

a. Design of hardware circuit diagram

The hardware circuit diagram of the non-contact infrared thermometer is shown in Figure 1.

Infrared receiving signal emitted by the human body is converted to voltage by the infrared sensor module, the signal is amplified by operational amplifier, amplified signal is filtered by the filter circuit, analog signal is converted to digital signal by the analog to digital conversion circuit ,and the command signal is input the MCU processed .and the clock signal will be into the

microcontroller by the clock circuit, the results of the software to run is displayed through the LCD1602, Voice module playing sound, buzzer alarm when the results of the measurement to reach the warning value.

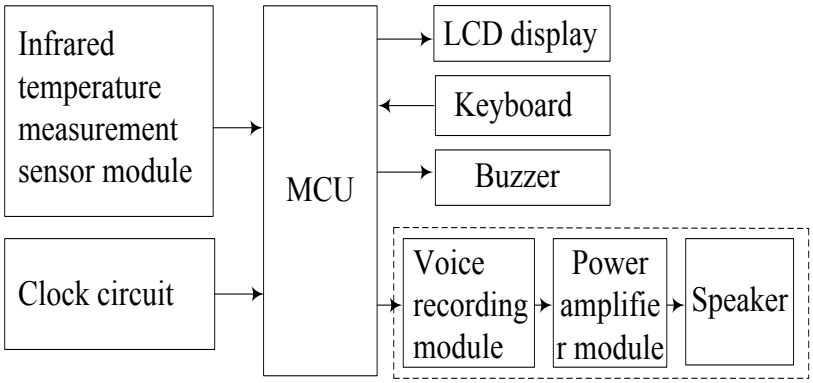


Fig. 1 The hardware circuit diagram of the non-contact infrared thermometer

b. Design of minimum system of MCU

STC89C52 MCU [7] is selected, Design of the MCU minimum system[8-9] as shown in Figure 2, MCU minimum system consists of reset circuit, clock circuit and MCU STC89C52.

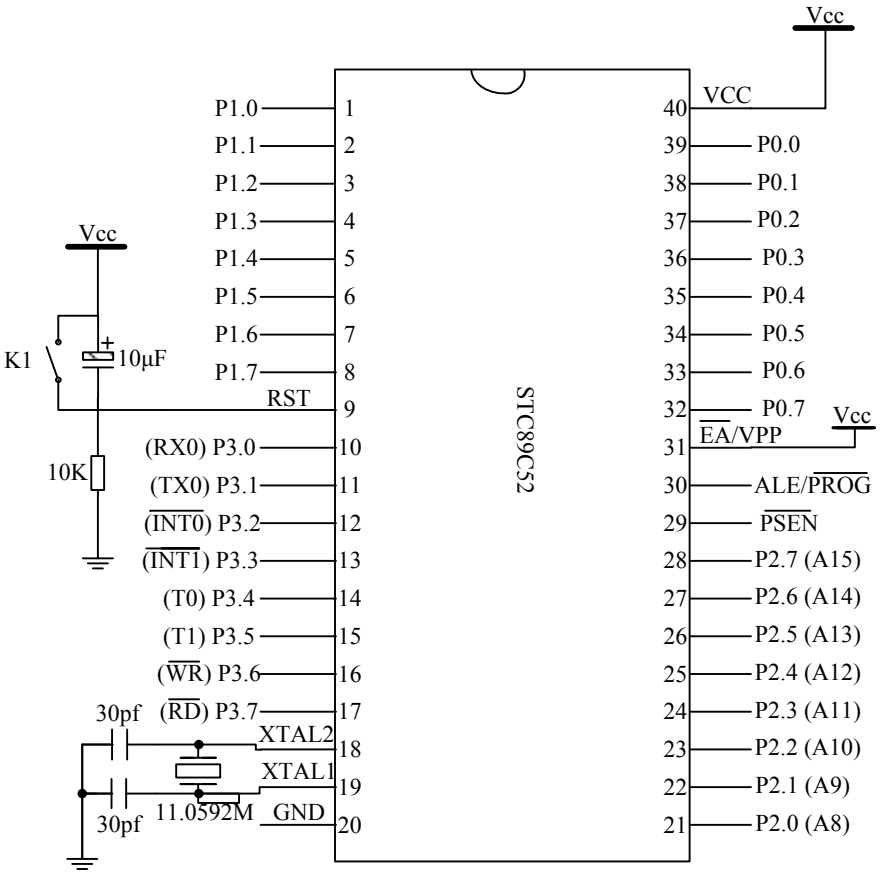


Fig. 2 MCU minimum system

Reset circuit of MCU is generally divided into three kinds: manual reset, automatic power on reset, manual and automatic reset. The power on reset through a capacitor and a resistor in series to achieve, when the electric MCU system, capacitor for charging takes time, so keep a high level for a period of time at the RST end, MCU completed reset after the capacitor charging because of the effects of RST end resistance recovery low level. The manual reset is through a button and a resistor in series, when the button is pressed, resulting in high RST end, when the button is released, RST terminal becomes low, the MCU complete reduction. System reset circuit with manual and automatic reset mode, it not only has the automatic power on reset function, but also can through the small button to manually reset.

MCU clock source is provided in two ways, one is the external clock source to provide the clock for the microcontroller, another is the internal clock chip. The internal clock mode is selected in the system clock circuit, an external crystal oscillator is connected between the MCU $XTAL_1$ and $XTAL_2$ pins, 11.0592MHz crystal was selected, the internal clock frequency is 11.0592MHz, two 30pF ceramic capacitors were chosen in order to help the crystal oscillator, which is connected in series with the crystal legs.

STC89C52 MCU is a 8 bit CMOS and low-power microcontroller, it is compatible with 51 series microcontroller, its interior has 8k bytes FLASH program storage space and 256 bytes of internal RAM, 32 programmable I/O interface, three 16 bit timer / counter, full duplex UART serial interface, built-in the watchdog timer, double data pointer.

c. Infrared sensor temperature measurement module

TN901 infrared detector is a non-contact infrared sensor temperature measurement module, which is produced by the Ling Yang company. The measurement accuracy is high, the response speed is fast, the measurement range is wide, the environment temperature and the target temperature can be measured simultaneously.

IR-SoC(Infrared System on chip)technology and batch calibration technology are adopted by TN901 infrared detector, so that the product size and cost may be reached to the minimum, battery voltage is not more than 9V, which contains a temperature sensor, it can be directly converted into digital quantity, its resolution is 9,10, 11, 12bit, factory default setting 12bit, resolution can be programmed, temperature conversion accuracy can be configured by setting internal registers. The conversion accuracy of the temperature is four kinds, thay are 0.5℃、0.25℃、0.125℃、0.0625℃. When the format of converted temperature is 16 bit, it is stored in

the scratchpad RAM, the temperature information can be read from 1-Wire interface by reading scratchpad RAM command (BEH). Its format of transmission data is high bit in behind and low bit in front[10-11]. Parasitic power supply mode is adopted by TN901, that is energy can be obtained from the single BUS, it is stored in the internal capacitance, the energy is consumed in the signal line at a low level and added in the signal line for high power. 3 ~ 5.5V external power supply can also be used by TN901. Therefore TN901 has two ways to connect with the microcontroller, one is the external power supply, it is connected to the Vcc, the GND of TN901 is connected to the GND of the microcontroller, I/O pin of TN901 is connected to the I/O pin of microcontroller; Another is the internal parasitic power supply, that is, the GND and U_{DD} of TN901 are connected to the GND, I/O pin of TN901 is connected to the I/O pin of microcontroller. Both the use of external power supply or internal power, the 5kΩ pull resistors is connected with the I/O port. Temperature compensation technology is used in the TN901 infrared thermometer module, the ambient temperature can be accurately measured by The thermal reactor MEMS. Since the SoC technology is applied by the infrared temperature module TN901, the integration and cost ratio is improved, the heat attack can reach 10℃.

TN901 pin diagram is shown in figure 3. Among them, V is supply voltage pin V_{CC}, + 5V power supply can be connected; D is data receiving pin, it can be connected to the microcontroller pins P1.2, if D is high level, it is shown that no data is received; C is 2 kHz clock output pin, it can be connected with the MCU P1.1 pin, the clock signal is provided for infrared sensor module by using the software delay; G is grounding pin; A is temperature signal start pin, low level effectively, it can be connected with the MCU P1.0 pin.

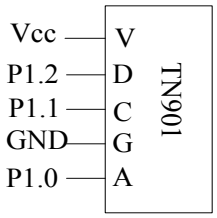


Fig. 3 TN901 pin map

The timing diagram of infrared temperature measurement module is shown in Figure 4.The infrared sensor temperature module receives the data at the falling edge of CLOCK, and when the temperature is measured, the data of the 5 byte are received. In these 5 bytes, the target measuring temperature item is 0x4c; the ambient temperature item is 0x66; the high eight bits data of receiving temperature is MSB; the low eight data of receiving temperature is LSB; the

verification code is Sum. When the receiving data is correct, Sum=Item+MSB+LSB; when the end of the symbol CR is 0x0dH, the reception of a temperature data is completed.

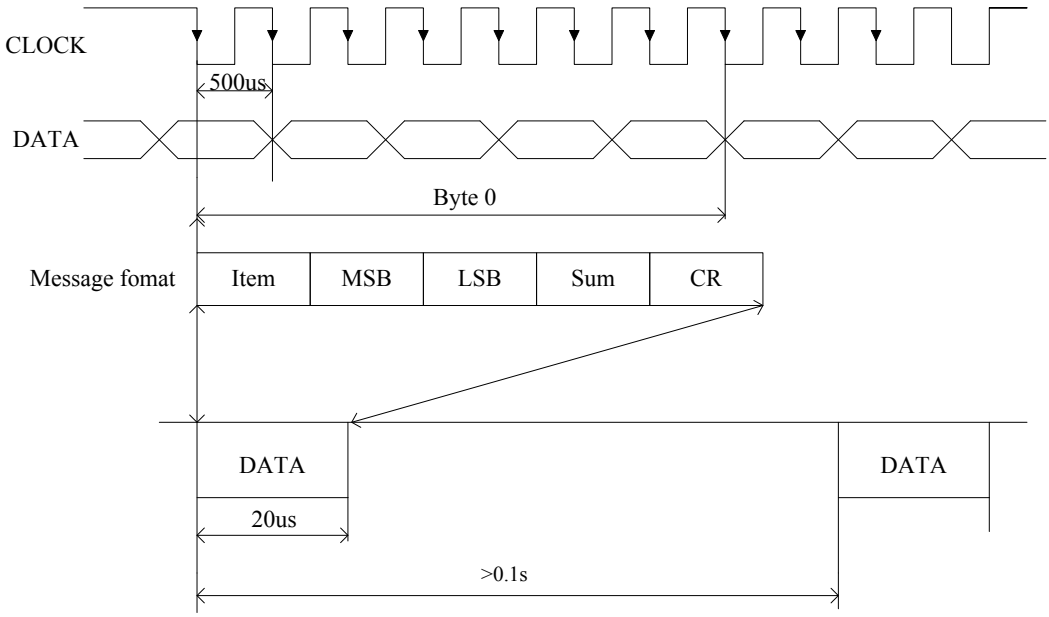


Fig. 4 The timing diagram of infrared temperature measurement module

When the checking and testing item is 0x66H or 0x4cH, whether the measurement is the ambient temperature or the target temperature, when CR is 0x0dH, the formula for calculating the temperature is the same, that is:

Ambient temperature/target temperature = Temp/16 - 273.15 (4)

Among them: When the decimal Temp is converted to hexadecimal, LSB is low eight bits, MSB is high eight bits; For example, when the LSB is 0x6bH, MSB is 0x13H, the hexadecimal Temp is 0x136bH, the decimal is 4971, the measured temperature value is:4971/16-273.15=37.5375℃。

d. Design of voice broadcast circuit

The design of voice broadcast circuit is shown in Figure 5.

SYN6288 speech synthesis chip is used in voice broadcast circuit, the chip SMT packaging, which has a simple hardware interface, low power consumption, high performance price ratio, The text data to be synthesized is received through the asynchronous serial communication mode, which is converted from the text to speech. The data of SYN6288 voice chip is transmitted with a microprocessor or PC through a set of full duplex asynchronous communication interface. Buttons S_1 and S_2 and S_3 can be applied in the circuit and control the recording and playback, S_1 is the record button, S_2 is the playback button, falling edge trigger, S_3 is level controlling button.

When the 25 pin of SYN6288 is high level, it shows that the recording beyond the time limit (memory overflow) or the recording ended or playback ended. To segment the recording, speech information and segmented address of the control table can be listed in advance, through the control table to select the address of the recording, press the recording key to start recording, release the recording key to end the recording, repeat can be required to enter into the chip. The A_0 and A_1 are connected to the ground to ensure that the interval is greater than 0.5s, at least four sections, and the recording information is not overlapped. Core fragment end mark (EOM) is used in the end of each segment of the user's recording, the overflow flag (OVF) is used after the chip recorded.

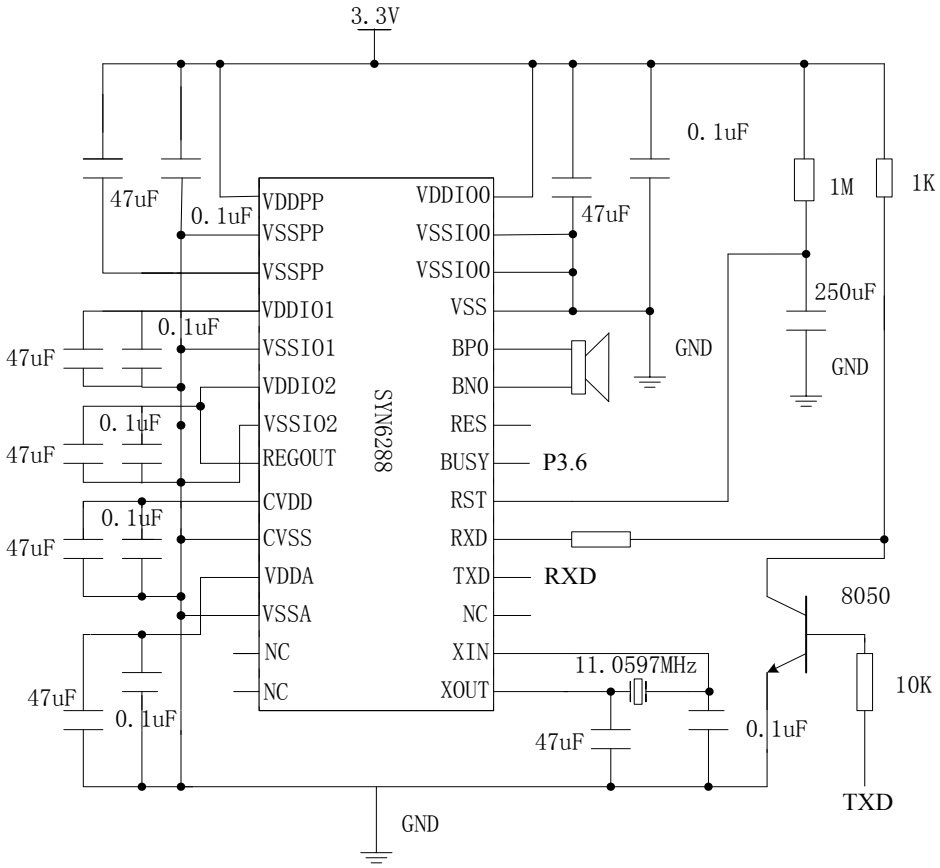


Fig. 5 The voice broadcast circuit

The process of sampling, processing, storing and realizing the sound signal is: the sound signal is amplified and converted into digital signal by AD converter, which is stored in the memory after being processed by MCU. The D/A converter is controlled by MCU in the playback process, the data in the memory is converted into voice signal to drive loudspeakers. Output pin of SYN6288 is BP0 and BN0, the speaker can be directly started, but the volume is small, the power amplifier circuit can be added to increase the volume and save the I/O port[12-14].

e. Design of clock circuit

DS1302 chip is adopted in the clock circuit ,which introduced by the DALLAS company of United States, the chip power consumption is low, performance is good, static RAM additional 31 bytes, SPI three wire interface is used for synchronous communication with CPU, And burst mode can be used to transmit multiple bytes of clock signal and RAM data. Real time clock can provide year, month, week, day, hour, minute and second. It has a leap year compensation function, and can be automatically adjusted when it is less than 31 days of the month. It has 2.5 ~ 5.5V dual power supply (main power and standby power supply), standby power charging mode can also be set[15-16]. Design of the DS1302 clock circuit as shown in figure 6.

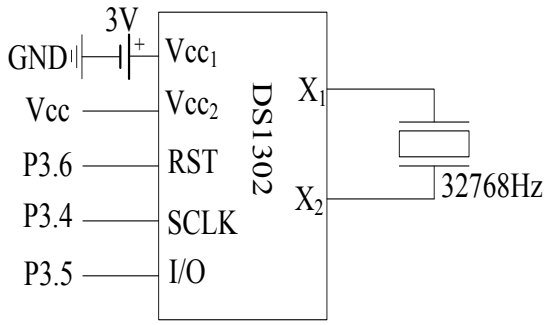


Fig.6 S1302 clock circuit

The function of each pin is as follows: the main power supply is V_{cc1}; the backup power supply is V_{cc2}. When V_{cc1}+0.2V is less than V_{cc2}, the power supply is provided by V_{cc2} to DS1302,and when V_{cc1} is greater than V_{cc2}, the power supply is supplied to DS1302 by V_{cc1}.The output and input of the data is controlled by the serial input of the clock SCLK. The 32.768kHz crystal is connected in the source X_1 and X_2 pins. RST is reset or chip select line, All data transfer is started by setting the RST input to the high level. The RST input has two functions: first, the RST is connected to the control logic, which allows the address or command sequence to be sent to the shift register; Secondly, RST provides the means to terminate of the single byte or multi byte data. When RST is high, all data transfers are initialized, allowing operation on the DS1302.If the RST is low, the data transfer is terminated, and the I/O pin is a high impedance state. When the power is switched on, before the V_{cc} is larger than 2.5V, the RST must be kept for low voltage. RST is high only when SCLK is low. I/O is the data serial output and input (bidirectional). When the RST reset pin is set to high voltage and the command information and the 8 bit address are loaded into the shift register, DS1302 start working. Data are serially input to specify the top 8 access addresses on the rising edge of the SCLK clock, when the shift register is

loaded into the command word, read operation output data,writing operation input data. DS1302 contains 12 internal registers, Among them, the 7 registers are related to the clock and calendar, and the stored data is BCD code. In addition, the DS1302 also has a charge register, the year register, control register, and the RAM related to the register of the timely clock burst register, etc.. In addition to the charge register, calendar, time register and control word, the clock burst register can be read and written in one time.

f. Design of Keyboard and display circuit

Design of the keyboard control circuit is shown in Figure 7.

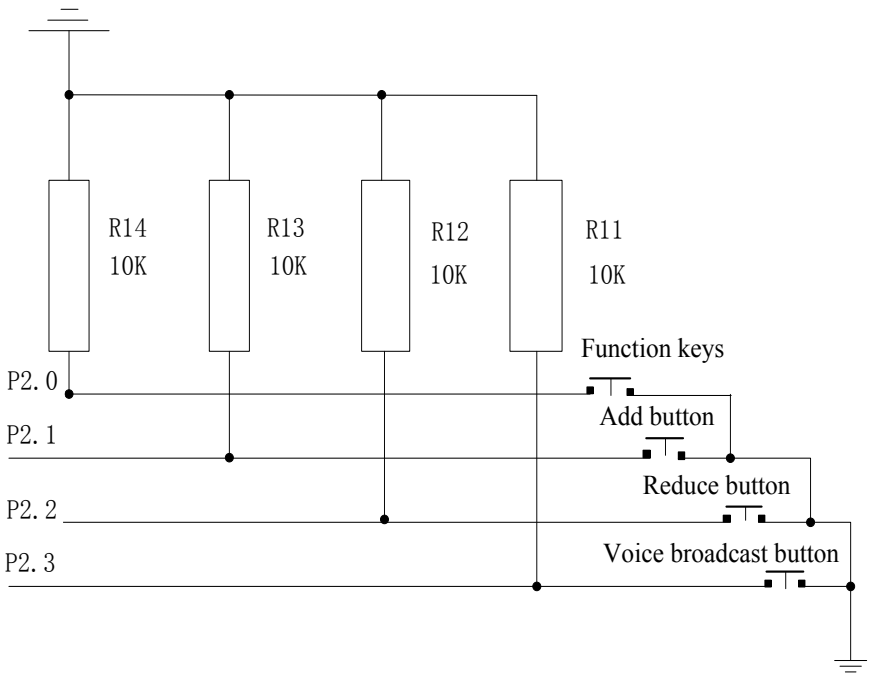


Fig. 7 Keyboard control circuit

Key independent structure can be used in the keyboard control circuit. The opening or closing state of the key can be changed to a high or low level by a certain line. When the key is closed, a negative pulse is generated at the I/O port. The process of closing and opening is required to be stable, and this process is a kind of instability between the low and high level, it is often called the wobble. Four functional control buttons are applied to the system, 4 independent keys can be connected to the 4 I/O ports of P2, using software to remove jitter, when a button is pressed, it can be postponed 10 ~ 20ms, and then search whether there is a key press,if no key is pressed, the result is that the last search results are interference or jitter; if there is still a key is pressed, then the stability of the closed key.

LCD1602 is used in the display circuit, which can simultaneously display time and temperature. LCD display interface circuit as shown in figure 8.

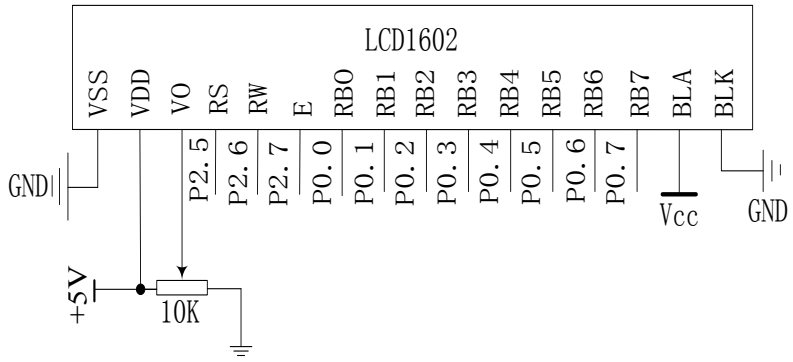


Fig.8 The interface circuit of liquid crystal display

Third pin VO is the LCD contrast adjustment end, the contrast is the highest when it is connected to the ground, and the contrast is the weakest when it is connected to the positive power. The LCD will produce "ghosting" when the contrast is too high,it is eliminated by the way of adjusting the contrast of a 10k potentiometer. Fourth pin RS is the register selection, the instruction register is selected when it is low, the data register is selected when it is high. Fifth pin RW is read and write signal lines, read operation is indicated when RW is high, the write operation is indicated when RW is low. Displayed address or written instruction can be operated when RS and RW are low level, busy signal can be read when the RW is a high level and RS is the low level, and data can be written when RW is low level and RS is a high level. Sixth pin E is enabled, the liquid crystal module command is executed when the E terminal is changed from a high level to a low level. Seventh ~ fourteenth pin RB0 ~ RB7 are the 8 bit data line[17].

Ⅳ. DESIGN OF SOFTWARE

Software is composed of the main program, the measurement temperature subroutine, the voice play subroutine and so on.

a. Design of the main program

The main program flow chart is shown in Figure 9.

The first of all the subroutine and control port is initialized, after the TN901 and DS1302 is started, whether the measurement temperature is determined, if measurement the temperature is entered into the subroutine of the temperature, the current temperature is measured in real time. After measuring temperature, it is necessary to determine whether the temperature is exceeded

the set temperature of upper limit and the lower limit, if it exceeds the upper and lower temperature, the alarm subroutine is called, otherwise the temperature and time is voice broadcast and LCD display.

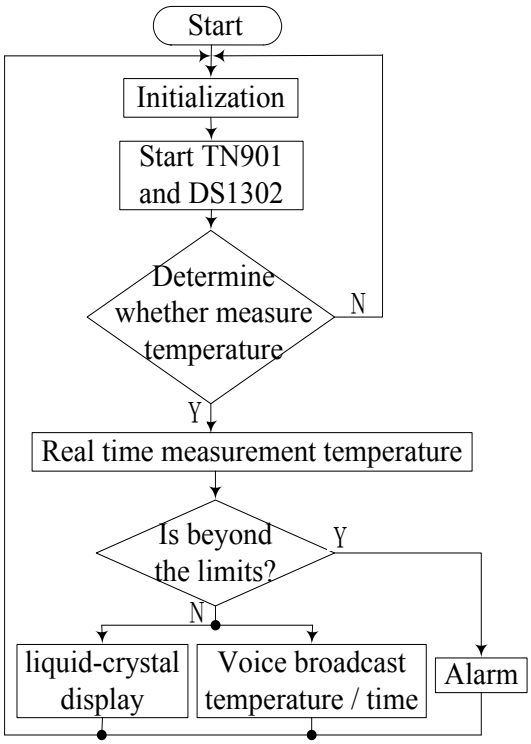


Fig.9 The flow chart of main program

b. Design of measurement temperature subroutine

The design of the measurement temperature subroutine flow chart shown in figure 10.

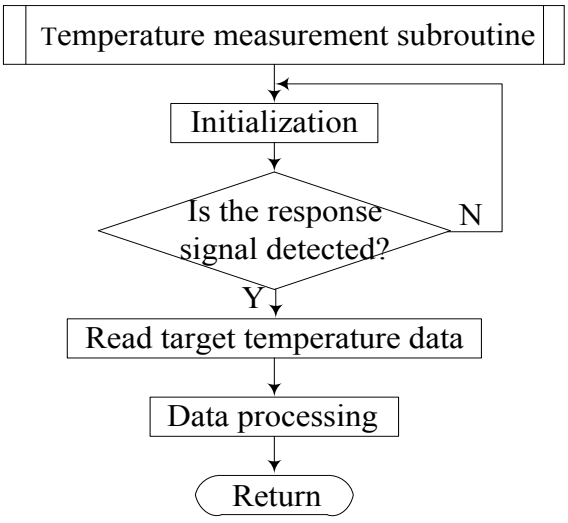


Fig. 10 The flow chart of temperature measurement subroutine

First, the TN901 temperature measurement module is initialized, and then the signal is transmitted. The program judges whether the response signal of the temperature measurement module is correct, if it is correct, the data is read, if it is not correct, it will be returned to continue monitoring the response signal until correct. Finally, the data is processed and returned to the main program.

c. Design of clock subroutine

Design clock subroutine flow chart as shown in Figure 11, the use of single-chip timer to achieve the clock.

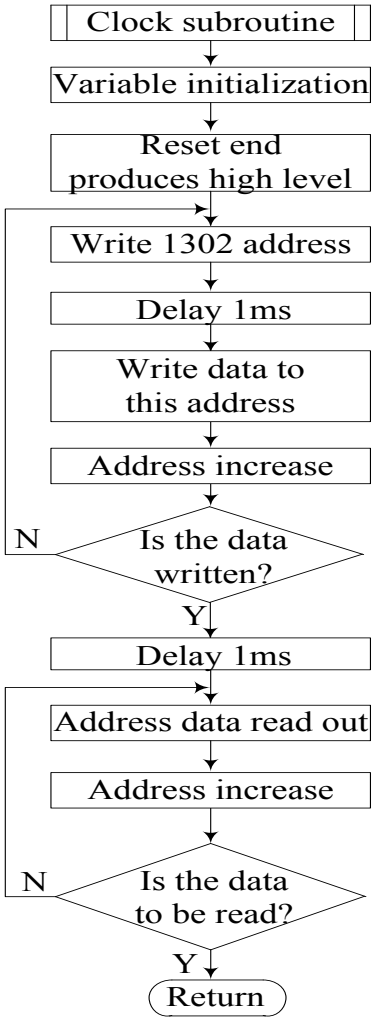


Fig. 11 Clock subroutine flow chart

d. Voice broadcast subroutine

Frame format of SYN6288 supported is: Frame head(FD)+data area length+data area. When the temperature measurement key is pressed, the temperature value and time to be stored in an

array to be broadcast, SYN6288 to the text of the array is synthesized for voice playback. Voice playback subroutine flow chart shown in figure 12.

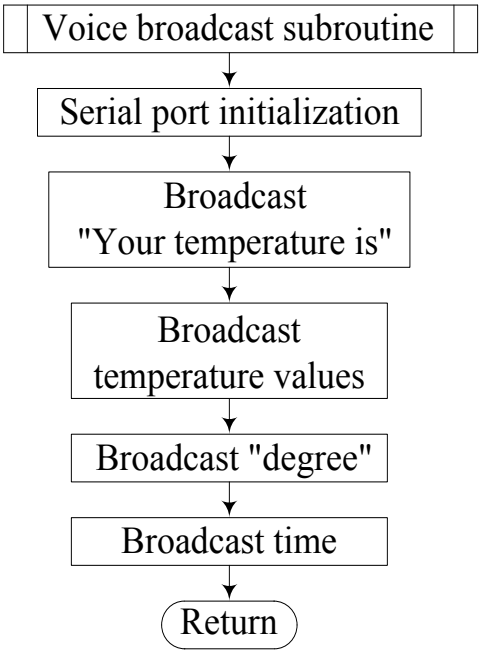


Fig. 12 The flow chart of voice broadcast subroutine

According to the flow chart, it is compiled on the KEIL IDE Vision4 platform with the C programming language [18].

V. SOFTWARE COMPILATION AND DOWNLOAD

KEIL IDE Vision4 compilation process is:

(1) Start μVision4, KEIL software integrated development environment is entered, the "Project→ New Project..." Menu is selected, a directory is selected or created for the New Project in the pop-up "Creat New Project" dialog box, and the name of the Project file is input, a Project file (.μv2) is automatically generated. Click the "save" button, select the target chip window.

Target CPU is selected in the window, Keil C51 support a lot of CPU, AT89C51 chip of Atmel company is selected, click the "ok" button, a dialog box asked if the standard AT89C51 boot file is chosen and added the project, click "yes" button, it will join the rest of the project file.

Return to the main window, "Target1" is appeared in the project window file page, there is the "+" in front. Click the "+", you can see the next layer of "Source Group1", then click the "+" in the "Source" Group1, you can see a STARTUP. A51 file. This file is just to join, it is suitable

for most AT89C51 derived series startup file code. Startup code is executed first starting target chip code in main () function before, it is used to remove data memory, hardware initialization and again into the stack pointer.

"File→ New..." is selected, a new file input window is opened on the right side of the project manager, the source program is input in this window, letter of uppercase and lowercase letter and the semicolon after each row is noticed, don't lose and leakage input wrong. After the input, "File→ Save" is selected, the File is named and saved. You must add extension, the name of this design using C language, so the extension is ".c", here it is named "mms. c", if the program is written in assembly language, the extension is the ".asm". After the file is saved, the window can be closed.

Then need to manually add source program to the project, click on the "Source Group1", make its reverse display, and then click the right mouse button, a shortcut menu appears, the Add file Group "and" Source Group1 "is selected, a dialog box appears, it is asked to find the source file. Double-click the mms. c file, the file is added to the project. Note that after the file is to join the project, the dialog does not disappear, waiting for continue to add other documents. At this point, click the "Close" to return to the main window, after the return, click the plus sign in front of "Source Group1", mms. c file is in it, double-click the file name, the source program has been opened.

(2)The project Settings

After building project, further engineering is set to meet the requirements. Double-click the Project window "Target1" first, and then click the right mouse button, the "Project→ Option for target" and "Target1"are selected from the shortcut menu, Project Settings dialog box appears. This dialog has 10 pages, including the driver pages, target pages, output pages, a list of pages, C51 pages, A51 pages, BL51Locate pages, BL51Misc, debugging and utility pages, most of items is set by default.

(3)Compile and link

After project settings, it can be compiled and links. Menu "Project → Build target" are selected, the current engineering is connected, if the current file has been modified, it will be to compile the file first, and then be connected to generate the target code; If the "Rebuild All target files" is selected, it will recompile all the files in the current project, and then be connected, the goal of eventually produce code is to ensure that the latest; The "Translate..." item is compiled

only the current file, don't connect. The above operations can also be directly via the toolbar button, from left to right are: compiling, compile link, all the reconstruction, stop compiling, download to Flash Memory and to set up the project.

Compile information will appear in the output window in the process of the Build page, compile results display window as shown in figure 13.

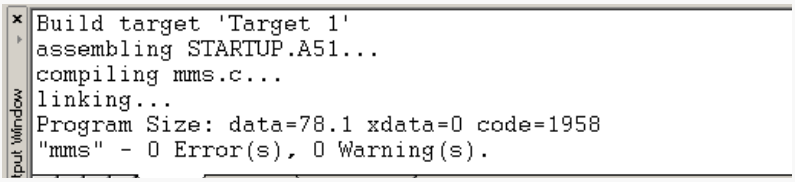


Fig. 13 Compile results display window

If the source has grammatical errors in the program, there will be a bug report, double-click on the bank, the location of the error can be positioning, compile again after the source program to modify, until the error is 0. At the same time, the amount of code of the program, internal RAM usage, external RAM usage information and so on can be seen in the window. In addition, compile and link also have some other relevant documents, including the relocatable object files (.obj), relocatable file list. (.lst), an absolute address the target file (no suffix), an absolute address list file (. m51), connecting the input file (.inp), these can be used for simulation and debugging of Keil C51 to start debugging after this step.

Pressed Ctrl + F5 key combination or use the menu "Debug→ Start/Stop the Debug Session" can be entered into a state of debugging. Most of the command on the Debug menu can be found corresponding shortcut button in the run and Debug toolbar. Generally from left to right in turn is reset, running, pause, single step, process step, the execution of the current subroutine, run to the current line, the next state, to open the tracking, observation, the disassembly window, observation window, code analysis, 1 # serial window, memory window, performance analysis, tool button command window.

Debug interface diagram as shown in figure 14, after debugging success under the interface block diagram shows "0 Error (s)".

Download software used on STC official download software, the target file is directly open after the port is selected, and then click download, and the MCU with electricity, software download can be completed.

Program download interface as shown in figure 15. If the download is successful, the "Program OK" will be displayed in the lower left corner block diagram.

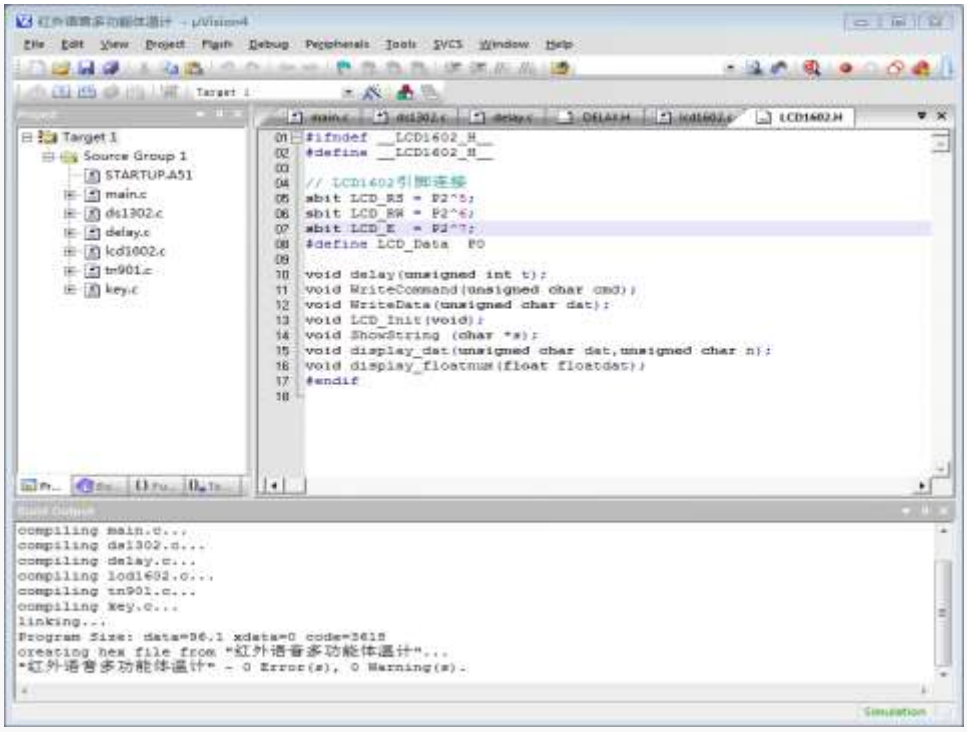


Fig. 14 Debug interface diagram



Fig. 15 Program download interface

VI THE EXPERIMENTAL RESULTS

All unit circuit are simulated on the Proteus platform, the PCB board is designed and produced after simulation, the MCU of download the program and other components are welded on the PCB board [19-20], physical diagram is shown in figure 16. power on, the function is test.

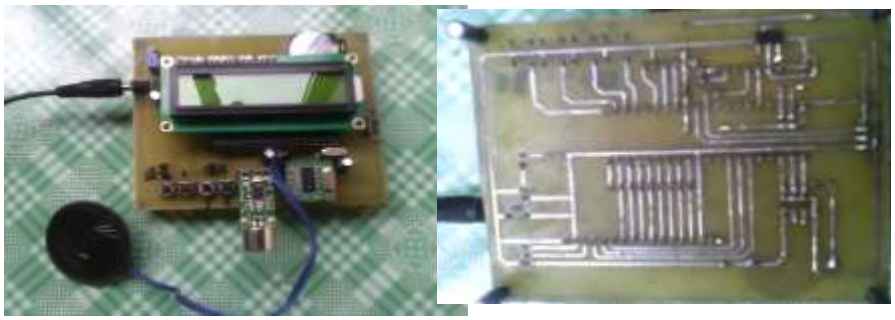


Fig. 16 Physical diagram

The temperature of the water is simulated by the human body temperature, it is measured at the same time with mercury thermometer and non-contact infrared thermometer, time is counted with the clock, the temperature is set at 30^{o}C to 50^{o}C. The measurement results are: the error of the temperature is less than 0.2^{o}C, the measurement time is about 4 seconds with the non-contact infrared thermometer, voice broadcast and LCD display temperature and time, the data is more accurate. The water temperature of less than 30 ^{o}C was detected by non-contact infrared thermometer, buzzer alarm, voice broadcast: "your temperature is abnormal——Ultra low"; Water temperature at 30 ^{o}C ~ 50^{o}C, voice broadcast and LCD display temperature and time; Over 50^{o}C, buzzer alarm, voice broadcast: "your body temperature abnormal——Super high".

ⅦCONCLUSION

In this paper, the infrared temperature measurement module for the measurement of body temperature, the measurement of the traditional contact thermometer is avoided, it is particularly suitable for measuring body temperature for infants and young children. The measured temperature is displayed through the LCD module, and it has the function of voice broadcast, it can be used by the man of poor eyesight. Non - contact measurement, measuring speed is quick, the body temperature is measured in the larger flow of people (such as stations, terminals, etc.).

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