

# Research and Design of Low Frequency Signal Generator

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**Abstract:**As a measuring instrument with a long history, the signal generator appeared as early as 1920s. With the continuous development of science and technology, people have higher and higher requirements on signals, and they are required to have the characteristics of accuracy, efficiency and high fidelity.[1] And the waveform signal generated by the new waveform generator can really meet the above requirements, so researching and designing a reasonable digital waveform generator has extremely high scientific research and economic value.

As a function signal generator, the waveform generator has excellent performance including optimization and intelligent interaction, and has a positive role in promoting industrial production, scientific research and development. Through continuous optimization and improvement, it will help to enhance the level and strength of China's overall industry and scientific research.[2]

This paper studies and designs a digital waveform generator based on AT89C52 single-chip microcomputer. The digital waveform generator can output different types and frequencies of waveforms according to the user pressing different buttons.[3] A total of sine wave, square wave, step wave and These four types of triangle waveforms are displayed on the display. Simulation experiments on the entire system, the results show that the digital waveform generator can output a good quality waveform, it is very simple in waveform conversion and frequency adjustment, and has high stability and high practical value.

**Keywords:**Digital waveform generator; MCU;

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## 1 INTRODUCTION

Frequency signal generator is currently one of the most commonly used test instruments in scientific experiments, its main role is to deliver the specified electronic signal to the circuit that needs to be tested. The signal generator is often used as the sending source or excitation source of the test signal, which is used to measure the amplitude characteristics, frequency characteristics, [4]transmission characteristics and other electrical signal parameter information of different electronic information systems or electronic devices, and is used to measure the characteristics and parameter information of electronic devices. Frequency signal generator is a kind of electronic equipment that can output triangular wave, sawtooth wave, square wave, sine wave and other waveforms by using trigonometric function equation. Any electronic instrument that can generate the required test signal can be called a signal source or a frequency signal generator, which is usually used to generate electrical signals with specific parameters required by the circuit under test [3]. In scientific research, in the electronic circuit, instrument testing, research, in order to obtain some signal

parameters of the measured circuit, such as: measuring frequency response, calibrating the degree for the voltmeter, etc., it is necessary to meet the required technical conditions of the electronic signal to be provided to the circuit to be tested, in order to simulate the trigger signal of the device to be tested in the actual. [5]For some systems requiring steady-state performance testing, sine wave signal sources with known amplitude and frequency must be used. When detecting the transient characteristics of the system, it is necessary to use a rectangular pulse with leading time, pulse width and repetition period, and adjust its parameters accurately, and require good stability. Therefore, it is necessary to have a stable signal source, that is, a frequency signal generator that can produce a stable signal. According to different signal output waveforms, frequency signal generators can generally be divided into four signal generator categories: sine wave pulse signal generator, rectangular pulse filter signal generator, function pulse signal generator and random pulse signal generator.[6] Because the method of generating sinusoidal signals is easier than other signals, and it is more simple and convenient to use sinusoidal signals to check the

circuit under test, sinusoidal signals are one of the most commonly used test signals at present, and sine signal sources can be divided into different types of signal generators according to different working frequency ranges [7].

## 2 WHOLE SCHEME DESIGN

### 2.1 System scheme design

The system uses 51 microprocessor as the control center, P3 port DAC0832 is the digital/analog input end, P1 port is connected to the keyboard, P0 port is connected to the LCD, by the program to control the waveform generated by P3 port, and then by the key to control the type of waveform, frequency size, and through the number of keys to control the waveform frequency value. Through DAC0832, the output current is converted to voltage, so that the digital signal is converted to analog signal. In addition, the real-time frequency and waveform are displayed on the LCD screen, and the generated waveform is displayed with an oscilloscope.[8]

Waveform synthesis: In the synthesis of waveform, the use of external interrupt signal high and low signal delay time to decode, in the sampling, sine wave, triangular wave, square wave and sawtooth wave each extract 20 sampling points, because the number of sampling points is less, the greater the frequency of the signal can be obtained, in the synthesis of all the amplitude points superposition to output a set of waveform.[9]

The frequency of the output signal can be controlled according to the requirement by using 51 MCU and DAC0832. Design idea: using 51 single chip microcomputer as controller; Waveform selection is selected by four buttons, and corresponding waveform can be selected by four buttons. The waveform is output by DAC0832. As the core of data processing and control, single-chip microcomputer completes the man-machine interface, system control, signal acquisition and analysis, signal processing and transformation, adopts key input, and uses virtual oscilloscope to display waveform.

Scheme: Using 51 microprocessor and digital to analog converter DAC0832 to form waveform. The waveform is generated by using the 51 microprocessor to process the waveform program, input the corresponding data into the input port of the DAC0832 converter, and then transform the output end of the DAC0832 through the op amp circuit to obtain the corresponding waveform. The P1 port of the 51 microprocessor can control the output of different waveform types and frequencies, and each waveform has a corresponding key mode. The principle of this

method is simple and applicable to practical operation, and relatively easy to implement.[10]

The design scheme can realize the control of four kinds of waveforms and their frequencies, and can change different waveforms and frequencies with the change of keys, and can display the generated waveforms on the oscilloscope. This scheme has simple circuit, high feasibility and can meet the design requirements. According to this design, an LCD1602 display can be added to the display of LCD1602, so that it can display information such as the name and frequency of the waveform on the display of LCD1602. [11]At the same time, the waveform output of the signal generator in this design is relatively stable and has high precision.

The following is the system block diagram of the entire digital waveform generator design and the schematic diagram of all the hardware.

Figure 1 System block diagram

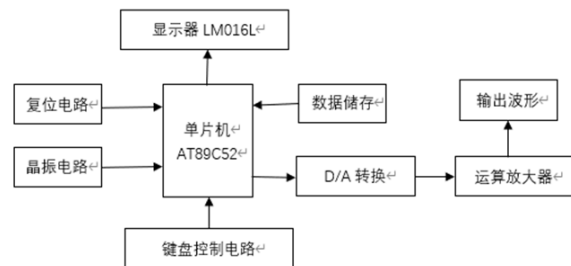
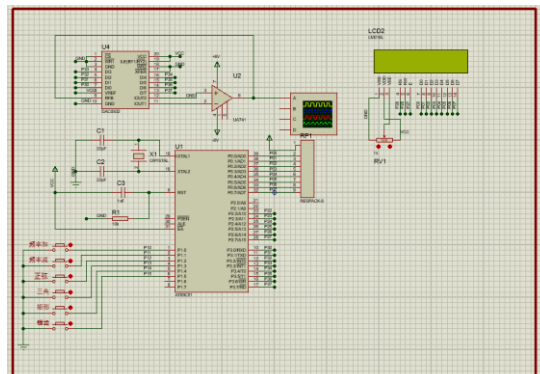


Figure 2 Hardware schematic diagram



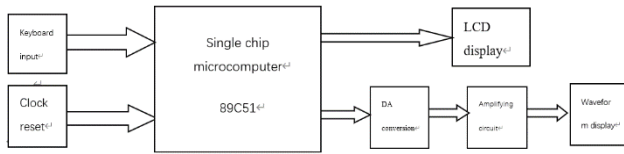
## 2.2 Hardware design of the system

### 2.2.1 Hardware schematic diagram

When designing the frequency signal generator, the 51 microprocessor is selected as the core structure, the program is used to generate various signals, and the D/A transformation and operational amplifier are output to the oscilloscope. Its structure is simple and its idea is clear. According to the basic needs of the operation manual, it is divided into different functional modules, which are related to each other and cooperate with each other, and the MCU is used to form a whole module.[12]

The overall hardware block diagram is shown as follows:

**Figure 3 Schematic block diagram of the circuit**



### 2.2.2 89C51 system design

The system is based on 89C51, which is composed of two timers, 32 parallel I/O ports, 1 serial I/O port and 5 interrupt sources. Because the scheme has the advantages of simple function, convenient data processing and large data storage capacity, the chip selection method is adopted to select the chip and decode the bit address. In the minimum system of the single chip microcomputer, the single chip microcomputer receives the keyboard input signal from the P1 port, outputs the control signal from the P3 port, and displays the output waveform through the D/A conversion chip and oscilloscope. P0 controls the code selection of the display segment, and the P2.5-P2.7 control bit mentioned in P2 is encoded, and outputs the display information. If a key is pressed, the controller side will appear to read the signal, so that the microprocessor can read the signal, if there is a signal output, the write signal will be generated in the write control side, and then the oscilloscope and the display display the corresponding information.[13]

SCM pin allocation is as follows:

RST: for reset circuit;

XTAL1, XTAL2: external crystal oscillator, generating clock signal;

P1 port: keyboard input signal.

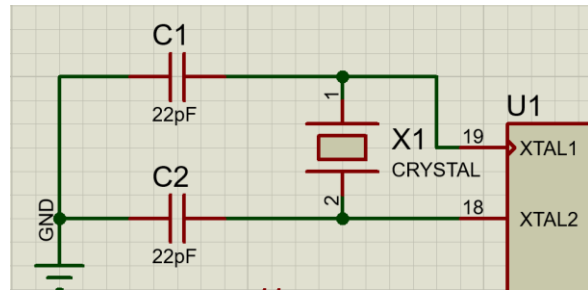
Port P3:8-bit digital signal output, transmitting the signal to DAC0832.

P0 port: LED display segment code selection;

Port P2: P2.5-P2.7 control bit selection code.

### 2.2.3 Clock circuit

Figure 4 Clock circuit diagram



Generally, the clock signal of a monolithic microprocessor is divided into internal oscillation and external oscillation. A crystal oscillator is added to the XTAL1 and XTAL2 pins to form an internal vibration mode. Due to the high gain reverse amplifier of the monolithic microprocessor, a self-excited oscillation will be generated after the crystal vibration, resulting in an oscillating clock pulse. Crystal oscillators of 6 MHz, 12 MHz and 24 MHz are usually selected. We choose 12MHz crystal oscillation, the crystal oscillation is connected to XTAL1, XTAL2, where C1 and C2 are 30 pF, the frequency of the oscillator has a certain stability, and at high frequencies, the delay of each point in the waveform generated is a few microseconds, so to get a larger frequency waveform also need to add the instruction time.

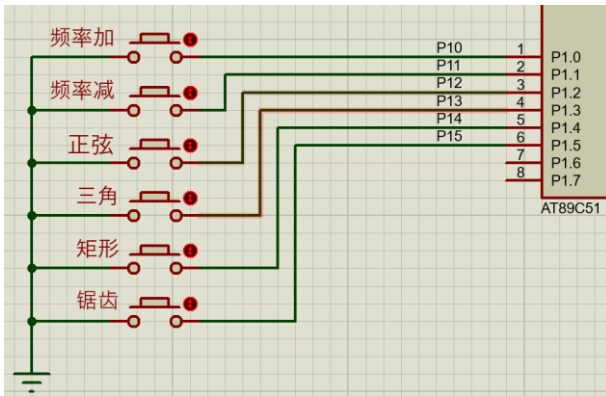
### 2.2.4 Reset circuit

The Schmidt trigger connects the reset pin RST to the reset loop, and the Schmidt trigger is used to eliminate noise. The common reset circuit has two ways: automatic reset on power and manual reset by pressing the button. [14]In each cycle of S5P2, the output level of the Schmidt trigger is sampled by a reset circuit, and then the signal required for an internal reset operation is obtained. When the system is working, the switch is pressed and the disconnection of the RST will produce a high level, causing the clock circuit to reset. At this point, the high level is output from ALE, PSEN, P0, P1, P2, P4, and resumes from the reset state after the RST input returns to the low level.

### 2.2.5 Keyboard interface circuit

Usually used keyboard circuit is matrix, but in this design, we use ordinary keyboard interface output signal to achieve program simplification. In this scheme, P1.2-P1.5 is used as the waveform selection. When P1.2=0, sine wave is output, triangle wave is output at P1.3=0, prescription wave is output at P1.4=0, and sawtooth wave is output at P1.5=0. P1.0 realizes the control of frequency addition; P1.1 realizes the control of frequency drop.[15].

**Figure 5 Keyboard interface circuit**



## 2.2.6 LCD display circuit

The LCD1602 is a passive display that does not emit light, but only adjusts the brightness of the light. At present, LCD is generally used based on the contortion-nematic effect. It can display 16x02, or 32 characters, at the same time. (16 lines, 2 lines). We are exposed to LCDS every day. LCD module has become a transmission component of many electronic products, such as calculators, multimeters, electronic watches, etc., in many household appliances can see it, which is mainly used to display numbers, special symbols and graphics. In the man-machine interaction interface of the single chip computer, the usual output modes are: light emitting tube, LED digital tube, LCD liquid crystal display tube. Leds and LCDS are the most common because their software and hardware are simple.

LCD has two driving modes, one is static mode, the other is dynamic mode. Depending on the LCD, you need to use different driver modes. LCD uses static drive mode, each field of each display to lead out the electrode, all the display of the common electrode connection, the number of displays, the number of leads increases, the number of the corresponding drive circuit increases, so it is suitable for the display of a small number of cases. The dynamic drive mode can effectively reduce the lead out line and the corresponding drive circuit of the LCD display, so it is suitable for use on the large screen [16].

The LCD screen as the output device of the single chip microcomputer has the following advantages: each point of the LCD will maintain the original color and brightness after receiving the signal, and continue to emit light, and the cathode ray tube display needs to constantly update the bright spot. In this way, the LCD image quality is high, there is no flicker phenomenon. LCD all use digital control, compared with MCU interface is more simple, reliable, easy to use. LCD is the use of electrodes on the display screen to achieve the display of liquid crystal molecular state, its weight is much smaller than the

conventional display. Relatively speaking, the power consumption of LCD is mainly concentrated on its internal electrodes and driver ics, so the power consumption is lower than other displays.

The following is a description of the individual pins in the LCD1602, the first pin VSS is the ground power supply. The second pin is VDD, usually powered by 5 V forward. The third pin is VL, which is the contrast adjustment end of the LCD, the minimum contrast when connected, the maximum contrast when grounded, there will be "ghost" in high contrast, when in use, you can use 10 K potentiometer to adjust the contrast. The fourth pin is RS, which is used to select the register, in the case of high level, select the data register, in the case of low level, select the command register. The fifth pin, R/W, is the signal line for reading and writing, performing reads at high levels and writes at low voltages. When RS and R/W are both low, it can write or display, when RS is low and R/W is high, it can read the busy signal, and when RS is high and R/W is low, it can write data. The sixth pin E terminal is the enable terminal and executes the instruction when the E terminal jumps from high level to low level. The seventh to fourteen pins D0 to D7 are eight-bit bidirectional data lines.[16] Pin 15 is a positive electrode for the backlight. Pin 16 is a backlight negative electrode [17].

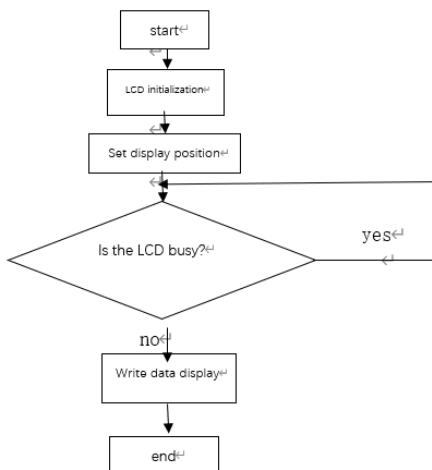
LCD1602 LCD module character generation memory, has stored Arabic numerals, English case, common symbols, Japanese kana and other 160 different dot matrix character graphics, the code of each symbol is fixed, for example, the English "A" capital letter is 01000001B (41 H), when displaying, The module will display a dot matrix symbol on the 41H address, and we can see it. Its read and write operation, screen operation, cursor operation are controlled by the program (note: 1 indicates high level, 0 indicates low voltage).

Here is what each instruction does, the first instruction is the clear display command, command code 01 H, the pointer reset to address 00 H. The second instruction is the cursor reset command, which returns the cursor to the 00 H address. The third instruction is the setting of the cursor and display mode. I/D: Cursor movement direction, high level to the right, low level to the left. S: All the text on the screen moves to the left or right. A high level represents movement, while a low level represents no movement. The fourth instruction is a control command that displays the switch. D is the whole display on and off, high level is on display, low level is off display. C is the control of the cursor switch, high level is the cursor, low level is no cursor. B is

the control of whether the cursor flashes, high level flashing, low level not flashing. The fifth instruction is cursor or display shift S/C: at high power levels, move the displayed text, and at low power levels move the cursor. The sixth instruction is a function setting instruction, in this instruction, DL: in high power times for 4-bit bus, in low power times for 8-bit bus; N: Under low level, single line display, under high level, double line display; F: At low power level, the dot character is 5X7, at high power level, the dot character is 5x10. The seventh instruction is a RAM address setting indication for a character generator. The eighth instruction is an address setting instruction for DDRAM. The ninth instruction reads the busy signal and cursor address. BF is busy flag bit, the high level represents busy, at this time, the module can not accept instructions or data, and at low power level, it represents not busy, that is, can receive the corresponding instructions or data. The tenth instruction is write. The eleventh instruction is read.[17]

The LCD module is a slow display, so before executing each command, make sure that the busy flag of the component is low, indicating that it is not busy, otherwise the command will fail. When you want to display a character, you first enter a displayed character address, that is, it can tell the module where to display the character.

**Figure 6 LCD flow chart**

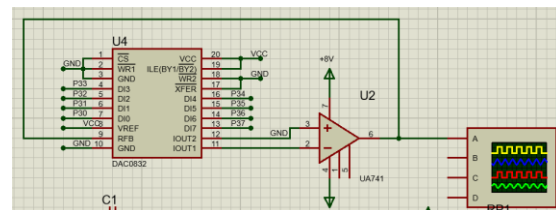


The basic principle of LCD is to use the physical properties of LCD to control the display area of the display through voltage, so that when it has electricity, it can be displayed, so that the image can be displayed. Because of the thin thickness of LCD, suitable for large-scale integrated circuit direct drive, easy to achieve full color display, so it has been widely used in portable computers, digital cameras, PDA mobile communication equipment.

## 2.2.7 Digital-to-analog converter

Because the single chip microcomputer is output in digital mode, so in order to obtain the waveform of the analog signal, it needs to carry out the digital-to-analog transformation. This paper uses DAC0832 digital-to-analog converter, which includes 8-bit input latch, 8-bit DAC register, 8-bit D/A converter and conversion control circuit. Finally, the output waveform is displayed with an oscilloscope.

**Figure 7 D/A conversion circuit**

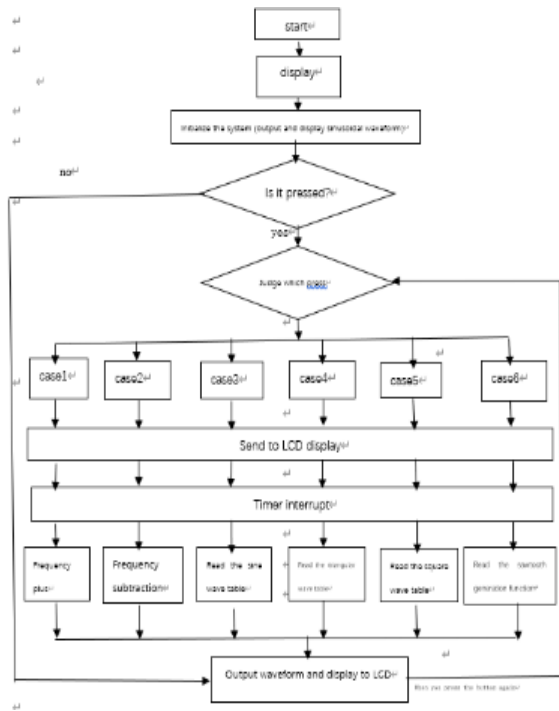


## 2.3 System software design

### 2.3.1 Software flow

The flow chart of this program is shown in the figure below. The hex file will be generated using the program code written by keil software, and then the hex file will be downloaded to 51 MCU. After the power supply is turned on, the program will run and display the initialization system. One side sends the signal to the LCD display, and when a key is pressed again, the process repeats. When different keys are pressed, different functions are calculated, and the type and frequency of the waveform can be changed by pressing different keys.

**Figure 8 Flowchart**



### 2.3.2 Keyboard interface software design

```
void keyscan() //Keyboard scan
function
{
    keyword=key&0x3f;
    if(keyword!=0x3f)
    {
        while((key&0x3f)!=0x3f); //Wait for key release
        switch(keyword)
        {
            case 62: {
                if(div>=100) THHL=65536-39; else
                {div++;THHL=65536-3906/div;}//frequencyup
                fre[0]=div/100 + '0';fre[1]=div/10% 10 +
                '0';fre[2]=div% 10 + '0';

                TR1=0;LCD_send(2,11,fre,5);TR1=1;
                break;
            }
        }
    }
}
```

```

}
case 61: {
    if(div<=1) THHL=65536-3906; else
    {div--;THHL=65536-3906/div;}//frequencydown
    fre[0]=div/100 + '0';fre[1]=div/10% 10 +
    '0';fre[2]=div% 10 + '0';

    TR1=0;LCD_send(2,11,fre,5);TR1=1; break;
}

case 59:
{Signal_chose=0;TR1=0;LCD_send(1,5,"Sin
",10);TR1=1; break;} //Sinusoidal wave

case 55:
{Signal_chose=1;TR1=0;LCD_send(1,5,"Triangular",10);
TR1=1; break;} //Triangular wave

case 47:
{Signal_chose=2;TR1=0;LCD_send(1,5,"Square
",10);TR1=1; break;} //Square wave

case 31:
{Signal_chose=3;TR1=0;LCD_send(1,5,"Sawtooth
",10);TR1=1; break;} //Sawtooth wave

default:{break;}
}
}
}
```

void keyscan() is the interface design of keyboard and the most important program in all programs. Six cases correspond to six different keys in P1 port. By pressing the last four keys, different waveform functions can be run to generate different waveforms; by pressing the first two keys, functions that change waveform frequency can be run to realize the addition or subtraction of

waveform frequency.

### 2.3.3 Waveform output main function

```
void main()
{
    LCD_init();
    LCD_send(1,0,"Type:Sin",8);
    LCD_send(2,0,"frequency:",10);
    LCD_send(2,11,fre,5);
    init();
    while(1)
    {
        keyscan();
        switch(Signal_chose)
        {
            case 0: {dataout=sin_tab[n]; break;} //
Sinusoidal wave
            case 1: {dataout=thr_tab[n]; break;} //
Triangular wave
            case 2: {dataout=squ_tab[n]; break;} //
Square wave
            case 3: {dataout=255-n;break;}
// Sawtooth wave
            default:{break;}
        }
    }
}
```

void main() is the main function of the waveform output, when the Signal chose=0, read the table that generated the sine wave; When the Signal chose=1, read the table that produced the triangular wave; When the Signal chose=2, read the table that generated the square wave; When the Signal chose=3, the program runs the equation that produces the sawtooth wave.

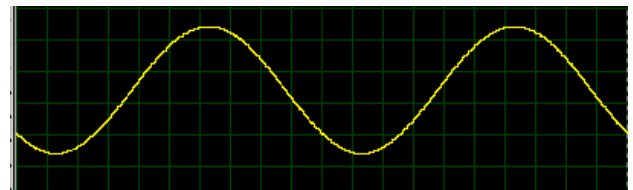
### 2.3.4 Waveform generation

The scheme uses P1.2 port to P1.5 port to select different waveforms and input them into the MCU program memory, adjusts the frequency of the signal by adjusting the number of key presses, and outputs the desired waveform according to the initial value of the signal.

#### 1、Sinusoidal wave

Sine wave generation principle: Each time the delay time output a database inside the data, this process forms a sine wave.

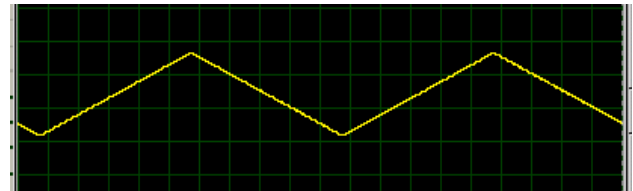
**Figure 9 Sine wave waveform**



#### 2、Triangular wave

Triangle wave generation principle: Input 00 H from port P3 to register A, DAC 0832 output data of A, the data in A each increase 1, after A delay time, the content of A is 0 FF, the content of A begins to reduce 1 each time, this process forms a triangle wave.

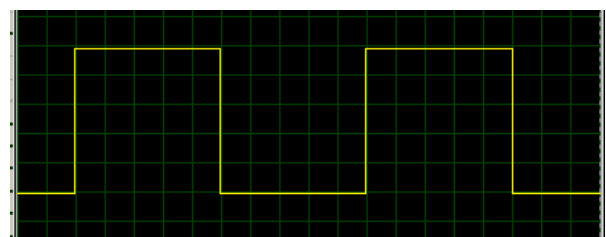
**Figure 10 Triangular wave shape**



#### 3、Square wave

The principle of square wave generation: The square wave is generated by input 00 H from port P3 to DAC 0808, output the corresponding analog value, then read out the state of port P3, and reverse process the state of port P3. When the delay time is up and FFH is output, the corresponding analog quantity is also output, and then delay processing is performed, and the above operations are repeated to obtain the square wave.

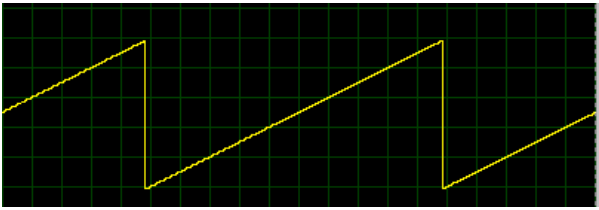
**Figure 11 square wave shape**



#### 4、Sawtooth wave

Sawtooth generation principle: After each delay time, the amplitude of the waveform decreases by n units, forming a sawtooth wave.

**Figure 12 Zigzag wave shape**

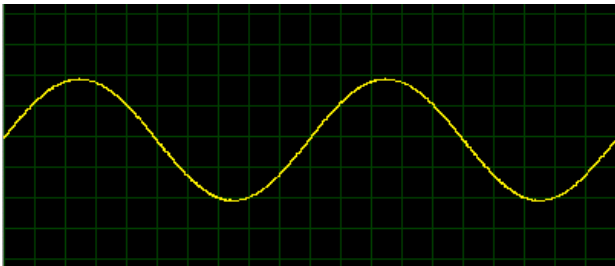


5. An increase in waveform frequency

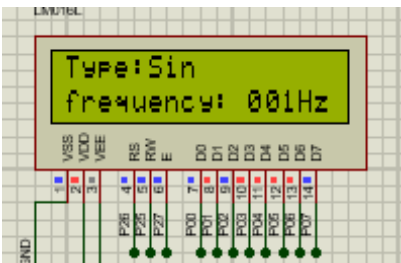
The principle of frequency increase: each time the key is pressed, div plus one, according to  $THHL=65526-3906/div$ , the cycle will become half of the original, that is, the frequency will become twice the original, the frequency limit is 100hz.

Before adding waveform and LCD display:

**Figure 13 Waveform before addition**

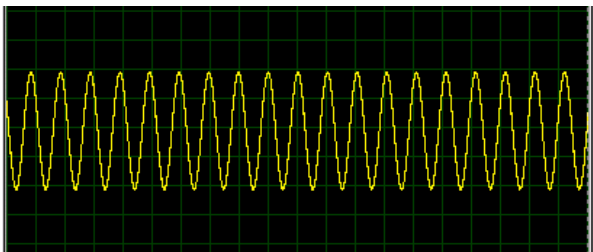


**Figure 14 LCD display before adding**

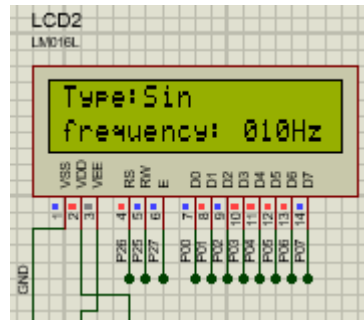


Added waveform and LCD display:

**Figure 15 Waveform after addition**



**Figure 16 Added LCD display**

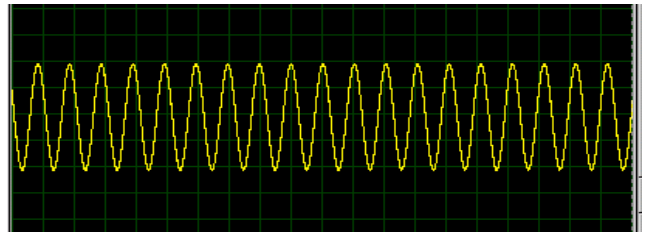


6. A reduction in waveform frequency

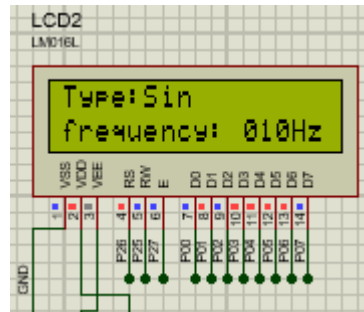
The principle of frequency reduction: each time the key is pressed, if div is greater than 1, div minus one, according to  $THHL=65526-3906/div$ , the cycle will become twice the original, that is, the frequency will become half of the original.

Before reducing waveform and LCD display:

**Figure 17 Waveform before reduction**



**Figure 18 LCD display before reduction**



Reduced waveform and LCD display:



Figure 19 Waveform after reduction

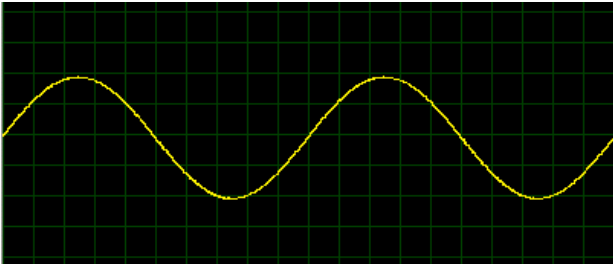
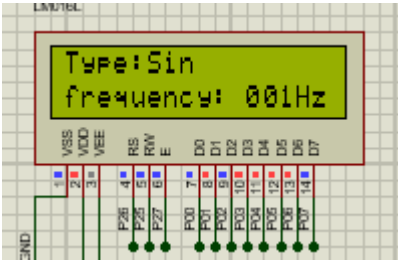


Figure 19 Waveform after reduction



### 3 SYSTEM PERFORMANCE TEST AND ANALYSIS

#### 3.1 Software debugging

This design uses C language for programming, the reason why choose C language rather than assembly language, because it is process-oriented, and assembly is processor-oriented, the former is an abstract design language, the latter is a specific low-level language, and assembly language to complete a simple job, requires a lot of code, and is prone to errors. C language is more flexible than assembly language, more operators, more data types, good portability, strong expression, so choose C language rather than assembly to program.

In order to simulate the program written in C language, Keil uvision5 is selected as the software debugging tool. Keil is a U.S.-German company acquired by ARM in 2005, and the latest Keil  $\mu$ Vision5 was released in 2013. Keil software can be compatible with MCU C language, and its integrated development environment includes library management, macro assembly, C compiler, linker, simulation debugger and other tools, which is of great help to this design simulation debugging. Unfortunately, there is no Chinese version of Keil software, and commercial activities in China have been handled by several ARM partners.

#### 3.2 Hardware debugging

This design uses Proteus 8 Professional for hardware simulation. Proteus is an EDA tool software developed by a British company that integrates printed circuit board design, circuit simulation and

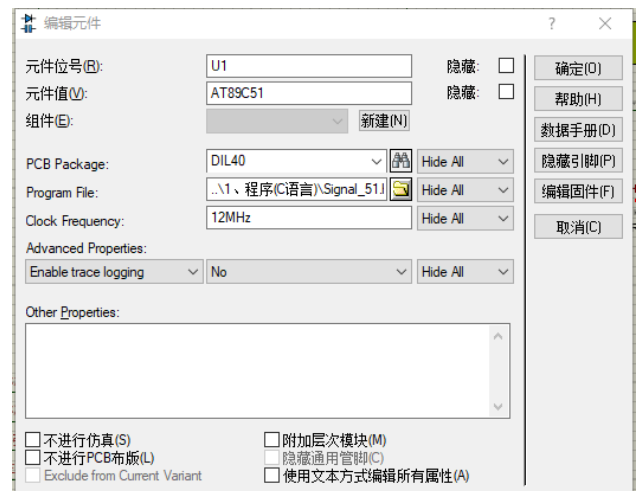
virtual simulation. Proteus has the functions of other EDA tools, such as principle wiring, PCB manual or automatic wiring. In contrast, Proteus also has features that other EDA tools do not have, such as interactive circuit simulation and the ability to simulate the functions of single-chip computers and peripheral devices. Based on these advantages, Proteus is loved by a large number of microcontroller users, so it is a very good simulation software.

In the simulation, firstly select the single chip microcomputer and various peripheral devices to be used in Component Mode, then select the ground wire and power cord to be used in Terminals Mode, and finally select the oscilloscope in Instruments. When all the devices are selected, they can be connected in order, and then the written program is downloaded to the single chip computer, so that you can use Proteus to simulate the digital waveform generator.

#### 4 Final report

Because of the simulation experiment, the program is directly brought into the MCU AT89C52. Double-click the single chip microcomputer to find Program File in all option boxes, because the single chip microcomputer can directly identify the HEX file, so find the HEX file of the corresponding program in the document and pull it into the box, so that the compiled file is stored in the single chip microcomputer AT89C51.

Figure 21 Program download diagram



After installing the program, you can start the simulation by powering it on.

From the output waveform, we can see that the shape of these waveforms is relatively complete, and there is no incomplete waveform, which shows that there is no particularly big problem in the writing of the program or the connection between various hardware, and the simulation part is relatively successful. Then it

can be used on the real thing to test its performance in the real world.

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