Research and Simulation of High Precision Signal Generator Based on Single Chip Microcomputer

Jiaxin Yue¹, Aimin Pu¹, Jingzhe Zhao²

¹Sichuan Film and Television University, Chengdu, Sichuan, 611331, China
²College of Electrical Engineering and Information, Sichuan University, Chengdu, Sichuan, 610035, China

*Corresponding author’s e-mail: 153766460@qq.com

Abstract: The function signal generator uses the integrated circuit IC8038 for signal generation. After filtering, signal amplification, relay network signal strobe, and resistor divider, it outputs square wave, triangle wave and sine wave with adjustable amplitude ranging from 0V to 10V and adjustable frequency ranging from 100Hz to 20KHz. The relay network is controlled by the single-chip STC12C5A60S2, and the signal selection and output are controlled by the single-chip microcomputer, too. The function signal generator can generate triangular, square and sinusoidal signals from 100HZ to 20KHZ. It has the characteristics such as low cost, good signal quality and easy operation, thus improving the intelligence level of the signal generator.

1. Instruction
As a signal source, the signal generator has the frequency which can be up to hundreds of megahertz. In the high frequency range, it has great frequency stability and adjustability[1-2]. Most of the signal generators used today are composed of analog circuits. When it is used to output frequency signal, a particularly large resistor value is required, and the parameter accuracy is hard to ensure[3]. In order to improve the accuracy and intelligence level of the signal generator, it is necessary to design a signal generator with large functions, simple operation, low cost and high precision[4-5].

2. Scheme design of function signal generator
The solution has the advantages of good signal quality, low cost and easy development. Therefore, this design adopts the integrated circuit ICL8038 to generate sine wave, triangle wave and square wave[6-7]. The system structure is shown in Figure 1:
3. Circuit design of function signal generator

3.1 Power module design
The stability of the power supply in the circuit design is the basis for the stable operation of the whole system[8]. The input power supply adopts an external separate power adapter to convert the 220V single-phase AC mains into 10V DC input and adopts the TL082C dual-power op amp chip, which is powered by TEL2426CDR. Its power structure diagram is shown in Figure 2:

Figure 2.Power structure diagram.

3.2 ICL8038 Signal generator circuit design
The quality of the original signal directly affects the performance of the entire function signal generator. ICL8038 is selected as the function signal generator. The ICL8038 is composed of a fine-vibration integrated circuit that outputs a variety of waveforms[9-10]. The external components of the variable portion can generate pulse signals of various shape waves with a low distortion rate from 0.001Hz to 300KHz. The chip has an FM signal input that can be used to frequency decompose low frequency signals. The signal generation module circuit is shown in Figure 3:
In Figure 3, the external capacitor \( C \) is charged and discharged by two constant currents, and the constant current source 1 continuously charges the capacitor \( C \), thereby increasing the capacitor voltage, changing the input level of the comparator, and changing the state of the comparator. The flipping of the trigger can be driven to continuously control. When the constant current source 2 is in the off state and the capacitor voltage reaches \( 2/3 \) times the principle value of the comparator 1 input voltage, the condition of the comparator 1 changes at this time, and the state of the trigger operation also changes, connecting the analog switch \( K \) from point B to point A. When the capacitor is in a discharging state, the voltage will drop to the linear capacitor terminal in unit time, when \( 1/3 \) times the capacitor voltage drops to the specified voltage, the voltage is input to the comparator 2, and when the comparator 2 changes state, the trigger is flipped to the start state, and it completes the entire oscillation process through this periodic cycle.

The signals of these three functions are easily connected to the circuit on the basis of the above. If the capacitors are the same, and the time constants of the charging and discharging processes are the same at this time, then, a triangular wave function that satisfies the condition is formed, and a triangular wave signal is obtained. Since the operating condition of the trigger changes with time, the whole process is realized by charging and discharging with capacitance and voltage, so the state of the trigger is changed, thereby generating a function signal of the square wave. Selecting all the ranges in the frequency and duty cycle scheduled by square wave that the RA, RB, RC can reach, in the asymmetrical state, the two constant current sources can be arbitrarily selected and mobilized from small to large, and the sawtooth function signal can be obtained. The sinusoidal function signal obtains a triangular wave signal by nonlinear transformation. Since the characteristics of the diode are non-linear, the resulting triangular wave signal has a low and continuous slope close to the sine wave. The calculation principle of the oscillation frequency is shown in Equation 1:

\[
 f = \frac{1}{t_1 + t_2} = \frac{1}{0.66 \times \frac{R_A C}{R_B}} + \frac{1}{2R_A - R_B} \tag{Formula 1}
\]

### 3.3 Signal filter circuit

The ICL8038 circuit generates standard rectangular waves and triangular waves, but the sinusoidal distortion produced by it is more serious. It is necessary to generate a sine wave from the triangular wave through the RC filter circuit which is composed of resistors and capacitors and divided into two types, namely RC low-pass circuit and RC high-pass circuit. When the output of the ICL8086 circuit is a waveform containing a DC component, the DC component of the signal is first filtered by the RC high-pass filter circuit, and then the signal is shaped by a multi-stage RC low-pass filter circuit. Its circuit diagram is shown in Figure 4:
After the signal is filtered, the triangular wave, square wave, and sine wave can be output, but the signals are relatively weak, so the signal should be amplified by the operational amplifier. The filter amplitude frequency curve is shown in Figure 5:

![Figure 5. Filter circuit amplitude frequency curve.](image)

Due to the high signal quality requirements of the function signal generator, the op amp TL082 of high performance must be used for signal amplification. The TL082 is a general-purpose J-FET dual op amp with low input bias voltage and offset current, short-circuit protection at the output, and high input impedance at the input stage. The chip has built-in frequency compensation circuit, wide common mode and differential circuit. It has a high slew rate and is typically 16V/us. The circuit diagram of the positive feedback voltage amplification is shown in Figure 6:

![Figure 6. Signal amplification circuit.](image)

### 3.4 Relay control circuit

For the convenient use of the function signal generator, the single output port can output different waveforms, and the signals need to be connected to the output port according to different requirements. The transmission of analog signal selects the way of transmitting analog signal by relay array, the structure diagram of the relay network is shown in Figure 7:

![Figure 7. Relay network architecture.](image)

The five-volt voltage driven relay is selected. The pull-in current is about 100mA and it is driven by a triode S8050. A Schottky reverse freewheeling diode is added outside the coil to prevent transistor damage and voltage surge caused by the reverse induced current generated when the relay is turned off. The relay control circuit is shown in Figure 8:
3.5 Signal amplitude adjustment circuit

The function signal is a fixed voltage output after amplification in the previous stage, and the output voltage adjustment is required when the function signal is output to the outside, so a signal amplitude adjustment circuit is necessary. Since the incoming signal has a full-bias voltage before entering the amplitude adjustment circuit, the amplitude adjustment circuit only needs to lower the voltage. Using the method of resistor divider, the formula for adjusting the voltage divider value is shown in Equation 2:

\[
U_0 = \frac{U_i R_A}{R_A + R_B} \quad \text{(Formula 2)}
\]

According to the principle of Formula 2, the impedance of the output voltage is high, which is not applied in practical applications. Therefore, it is necessary to add an impedance conversion circuit in the latter stage of the voltage output, and the impedance conversion circuit uses the operational amplifier TL082 as a voltage follower.

4. Circuit simulation

Circuit simulation with EWB’s multisim10 version covers circuit simulation and PCB design. Through the EWB circuit simulation, the output waveform of the circuit can be seen as follows: the sine wave, square wave and triangular wave are shown in Figure 9, Figure 10 and Figure 11 respectively:
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References
[1] Yu Meng, Wang Chao. (2015) Design of function signal generator system based on single chip microcomputer. J. Electronic Production., 1: 13-14.
[2] Su Qinjiang, Shen Bin. (2014) Design of signal generator based on single chip microcomputer. J. Petroleum and Chemical Equipment, 1: 19-22.
[3] Li Dong. (2015) Design of Signal Generation System Based on Single Chip Microcomputer. J. Graduate School of Sun Yat-Sen University., 1: 83-99.
[4] Yang Jianhua, Yu Xiaoning, Lang Baohua. (2014) Application of DDS technology and FPGA in multi-function signal source. J. Journal of Xi'an Technological University., 4.
[5] Wang Jiarong. (2015) Design of signal generator based on DDS technology. D. Changchun: Jilin University.
[6] Ren Xiaoqing. (2014) Design of low frequency signal generator based on single chip microcomputer. J. Modern Electronic Technology., 37(16): 14-17.
[7] Wan Fujun, Pan Songfeng, Liu Fang et al. (2014) Principles, system design and application of mcs-51 single-chip microcomputer. Tsinghua University Press, Beijing.
[8]] Li Kaili, Liu Pan, Cheng Huixiang et al. (2018) Design of Signal Generator Based on Single Chip Microcomputer. J. China New Communications., v.20(9): 239-240.
[9] RenYingjie, Huang Jianqing, Guo Kai, et al. (2018) Design of simple function signal generator based on STC89C51 single chip microcomputer. J. Electronic Design Engineering., v.26; No.388(14):97-100+112.
[10] Wang Xinxin, Hu Jiacheng, Jiang Xueping, et al. (2017) Development of standard signal generator for medical motion plate calibration device. J. China Test., 43(10):74-79.