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CIRCUIT DESIGN AND REMOTE APP CONTROL OF THE SIGNAL GENERATOR IN THE CHAOTIC UNDERWATER ACOUSTIC POSITIONING SYSTEM

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Based on chaos theory and Chua's circuit, a chaotic signal generator for chaotic underwater acoustic positioning system is designed. Firstly, the classical Lorenz system of chaos is analyzed. Secondly, the principle of Chua's circuit is analyzed. Thirdly, hardware control circuit of chaotic signal generator system is designed by referring to Chua's circuit. Fourthly, corresponding control of mobile phone APP software is developed. Finally, the circuit simulation shows that the designed circuit can generate chaotic signal when the key parameters take some specific values, such as C = 100 nF, R= 1780 Ω, or C = 260 nF, R = 1440 Ω. It can provide a stable and adjustable chaotic signal for the research of chaotic underwater acoustic positioning system. And it can provides a reference for chaotic circuit design in other related research fields.

Keywords: chaotic underwater acoustic localization; Chua's circuit; chaotic circuit; signal generator; chaotic signal; circuit design; APP soft design

1. Introduction

In recent years, more and more attention has been paid to the field of marine resources exploration and rational utilization and development. Among them, the key technology of underwater resources scientific exploration and development is the accurate underwater acoustic positioning system. In the chaotic underwater acoustic location technology, it is mainly the transmission and reception of chaotic acoustic signals. Because there are a lot of characteristics of initial value sensitivity, strong autocorrelation, weak cross-correlation, strong anti-interference, non convergence, strong orthogonality, bounded, aperiodic, strange attractor, infinite self similar structure, Lyapunov exponent, continuous power spectrum and so on [1] for the chaotic signal, it can be obtained that the time delay difference between transmitted signal and received signal by using the strong autocorrelation of chaotic signal. And it can be realized the identification and ranging of acoustic signal transmission. The necessary condition of chaotic signal underwater acoustic

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localization is to generate chaotic signal first, and then send and receive the corresponding chaotic signal. Therefore, the basic and key research content is the development of a chaotic signal generator with simple circuit structure and easy control.

In the hardware circuit, in order to generate chaotic signals, specific electronic components with specific parameters need to be connected. Chua's circuit is a classical chaotic circuit [2-3]. There are characteristics of simple circuit structure, easy hardware implementation and simple mathematical mode for Chua's circuit. It has been favored by chaotic circuit researchers. Four equivalent Chua's memristor chaotic circuits through changing the component parameters of the hardware circuit is studied by Xu et al. [4] and the experimental results show that the circuit is easy to adjust and has good robustness. A single power Chua's oscillator is studied by Gao et al. [5] and the simulation results show that the Lissajous waveform of Chua's circuit is a double helix attractor under 1.8V single power supply. An inductor to Chua's circuit is added and Chua's diode is replaced with voltage controlled memristor by Lin et al. [6] and it is obtained a fifth order voltage controlled memristor Chua's chaotic circuit. The analysis shows that there is only one unstable zero equilibrium point under certain parameters. The Chua's circuits system is studied by Lu et al. [7], and some algebraic synchronization criteria is strictly proved. The delay dependent synchronization of Lévy noise coupled system is studied by Zhou et al. [8], and it is simulated in Chua's circuit.

The chaotic system of Chau's circuit is studied by Guo et al. [9] and the corresponding adaptive feedback control method is proposed. The characteristics of Lorenz optical isolation system is researched by Aluf [10]. An improved Chua's circuit is designed by Bao et al. [11] and there is the same mathematical model for the improved Chua's circuit and the classical Chua's circuit. Sene [12] proposed adaptive controls of Chua's circuits. Kamal et al. [13] studied an image encryption scheme based on chaotic circuit model. Ramakrishnan et al. [14] studied infinite attractors in a chaotic circuit and propose a nonlinear chaotic oscillator. Maamri et al. [15] proposed the Penguins Search Optimisation Algorithm (PeSOA), which can calculate the parameters of Chua's circuit to produce a stable chaotic oscillation. It can be seen that the related research mainly focuses on the characteristics of Chua's circuit, and there is little research on how to control the chaotic circuit to produce different chaotic signals. But it is very important to control the generators that can produce different chaotic signals for the research fields of chaotic underwater acoustic positioning technology and chaotic signal encryption so on.

Therefore, based on MATLAB, Multisim, Proteus, Keil uVision and eclipse, a chaotic signal generator with clear principle, simple operation and low cost is designed in this paper, which can provide a basic and stable chaotic signal for chaotic underwater acoustic positioning system and provide reference for chaotic signal encryption so on research fields.

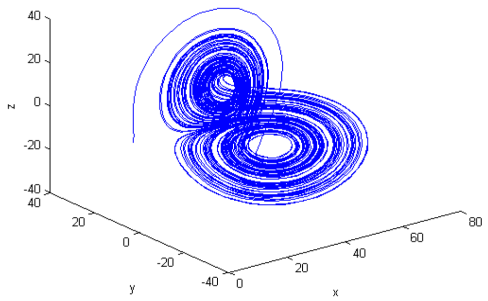
2. Principle

2.1 Lorenz system

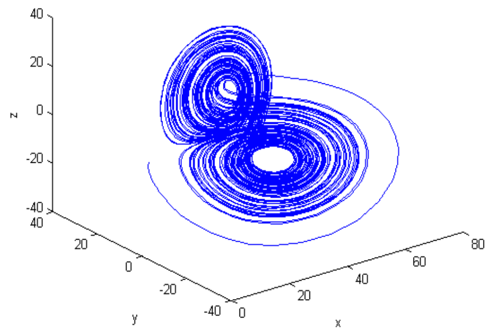
In order to design a tunable chaotic signal generator, it can be first understood the simplest and most classical Lorentz system. Understand the conditions that produce chaotic images and properties of chaotic system. Lorenz system is a classic chaotic phenomenon [16], which is mainly a three-dimensional differential equation system. It involves Prandtl constant σ , Rayleigh constant r and parameters b. The simplified differential equation is

$$\begin{cases} \dfrac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x), \\ \dfrac{\mathrm{d}y}{\mathrm{d}t} = rx - y - xz, \\ \dfrac{\mathrm{d}z}{\mathrm{d}t} = xy - bz. \end{cases} \tag{1}$$

It can be seen that x, y and z change with time. When parameters σ, r and b are given special specific values, the chaotic pattern can be observed. For example, parameters $\sigma = 8$, $r = 38$, $b = \frac{5}{2}$, and initial value $x_0 = 0$, $y_0 = 3$, $z_0 = 0$, Fig. 1 (a) is obtained. The initial value $x_0 = 0$, $y_0 = -3$, $z_0 = 0$, Fig. 1 (b) is obtained.



(a)Initial value: $x_0 = 0, y_0 = 3, z_0 = 0$



(b)Initial value: $x_0 = 0, y_0 = -3, z_0 = 0$

Fig.1 Image of Lorenz system (1), when $\sigma = 8$, $r = 38$, $b = \frac{5}{2}$

It can be seen from Fig.1 that all the orbital lines are moving around two points, that is, the non-equilibrium solutions of Lorenz system eventually tend to the same complex set, and that is, Lorentz attractor. In addition, the comparison between (a) and (b) in Fig. 1 shows that the two graphs have folding symmetry because one of the initial values y_0 is 3 and the other is -3. Images of $x-t$ with different initial values is showed in Fig.2, when $\sigma=8, r=38$, $b=\frac{5}{2}$.

As can be seen from Fig. 2, when the initial value y_0 changes by 0.1, there is a large change between the red curve($x_0=0$, $y_0=3.1$) and the blue curve($x_0=0, y_0=3$). It shows that Lorenz chaotic system is sensitive to initial value.

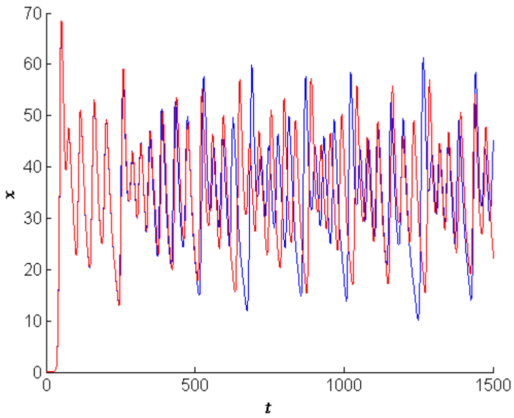


Fig.2 $x-t$ image of Lorenz system (1), when $\sigma=8$, $r=38, b=\frac{5}{2}$, initial value $x_0=0$,

$y_0=3$ (blue curve in image), $y_0=3.1$ (red curve in image)

2.2 Chua's circuit

According to Fig. 1 in Section 2.1, in order to get the chaotic image, a specific differential equation is needed to establish, and the key parameters take a specific value. It can be known that the chaotic system is sensitive to the initial value of circuit from Fig.2 in Section 2.1. And it can be seen from Fig.1 and Fig.2 in Section 2 that x, y and z all change with time. When designing chaotic circuits, we may choose electronic devices that can change voltage or current over time. In the hardware circuit, the electronic components related to the circuit state differential equation generally include: inductance components, capacitance components, nonlinear resistance components, etc. Therefore, the chaotic circuit usually includes inductors, capacitors and nonlinear resistors. The more classic is Chua's chaotic circuit [17], and it is shown in Fig.3. It consists of variable resistor

R, variable capacitor C, inductor L, capacitor C_1 and nonlinear resistor R_F. Assume that the current direction of each component is shown by the arrow in Fig.3. The current flowing through variable resistor R, variable capacitor C, inductor L, capacitor C_1 and non-linear resistor devices R_F is represented by i_R, i_C, i_L, i_{C_1} and i_{R_F} respectively. The potential of point A, point B and point E to ground are expressed by V_A, V_B and V_E respectively. It is obtained that

$$V_E = 0. \tag{2}$$

The voltage at both ends of the capacitor C_1 is

$$U_{C_1} = V_E - V_B = -V_B. \tag{3}$$

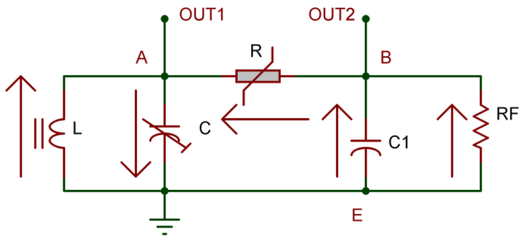


Fig.3 Simplified model of Chau's circuit

Capacitor C is

$$U_C = V_A - V_E = V_A. \tag{4}$$

Variable resistor R is

$$U_R = V_B - V_A. \tag{5}$$

Inductor L is

$$U_L = V_E - V_A = -V_A. \tag{6}$$

Non-linear resistance component R_F is

$$U_{R_F} = V_E - V_B = -V_B. \tag{7}$$

According to Kirchhoff's current law (KCL) [18], and it combined with the circuit in Fig.3, it can be obtained that

$$i_R + i_L - i_C = 0, \tag{8}$$

$$i_{R_F} + i_{C_1} - i_R = 0. \tag{9}$$

According to Kirchhoff's law of voltage (KVL) [14], and it combined with the circuit in Fig.3, it can be obtained that

$$U_R + U_C + U_{C_1} = 0 . \tag{10}$$

For the inductance [19] L, there are

$$U_L = L\frac{\mathrm{d}i_L}{\mathrm{d}t} . \tag{11}$$

For capacitance [19] C, there are

$$i_C = C\frac{\mathrm{d}U_C}{\mathrm{d}t} . \tag{12}$$

For capacitance [19] C_1, there are

$$i_{C_1} = C_1\frac{\mathrm{d}U_{C_1}}{\mathrm{d}t} . \tag{13}$$

According to Ohm's law, the current flowing through the variable resistor R is

$$i_R = \frac{U_R}{R} . \tag{14}$$

For the current and voltage of non-linear resistance components, there is a mapping function

$$i_{R_F} = f^{-1}\left(U_{R_F}\right). \tag{15}$$

It becomes Ohm's law when equation (14) is linear. It is

$$U_{R_F} = R_F i_R . \tag{16}$$

The formula (13) is substituted into formula (9). And then it combined with formula (3), formula (5), formula (7), formula (14) and formula (15). Finally, it can be obtained that

$$-C_1\frac{\mathrm{d}V_{\mathrm{B}}}{\mathrm{d}t} = \frac{V_{\mathrm{B}} - V_{\mathrm{A}}}{R} - f^{-1}\left(-V_{\mathrm{B}}\right) . \tag{17}$$

By substituting formula (12) into formula (8), and combining formula (4), formula (5) and formula (14), it can be obtained that

$$C\frac{\mathrm{d}V_{\mathrm{A}}}{\mathrm{d}t} = \frac{V_{\mathrm{B}} - V_{\mathrm{A}}}{R} + i_L . \tag{18}$$

By substituting equation (6) into equation (11), it can be obtained that

$$L\frac{\mathrm{d}i_L}{\mathrm{d}t} = -V_{\mathrm{A}} . \tag{19}$$

By transforming equation (17), equation (18) and equation (19), it can be obtained that

$$\begin{cases} \frac{dV_B}{dt} = \frac{V_A}{RC_1} - \frac{V_B}{RC_1} + f^{-1}(-V_B), \\ \frac{dV_A}{dt} = \frac{V_B}{RC} - \frac{V_A}{RC} + \frac{i_L}{C}, \\ \frac{di_L}{dt} = -\frac{V_A}{L}. \end{cases} \tag{20}$$

By comparing differential equations (20) and differential equations (1), it can be found that there are many similarities for them. For example, V_B corresponds approximately to x, V_A corresponds approximately to y, and i_L corresponds approximately to z. It was proved in section 2.1 that only when relevant parameters are given special specific values, the chaotic pattern can be observed. Therefore, in this, only when the relevant parameters (for example, R, C, L, and so on) take a special specific value, the circuit can generate chaotic signals. In other words, different chaotic signals can be obtained by adjusting the values of R, C or L. The adjustable chaotic signal generator can be designed according to the generation principle of chaotic signal.

2.3 Generation of chaotic signal

According to the analysis of Fig.1, Fig.2 and Fig.3 in Section 2.1 and Section 2.2, it can be known that after the hardware circuit is established, to generate chaotic signal, specific values can be needed for the parameter. Therefore, in order to generate chaotic signal, firstly, it is necessary to set the value of capacitance C, then adjust the value of variable resistance R in small steps, connect the signal output to the oscilloscope, adjust the value of each variable resistance R, observe the change of the image in the oscilloscope until the chaotic image is obtained, and record the current value of capacitance C and variable resistance R. When chaotic signal is needed (for example, chaotic signal encryption), the chaotic signal output can be connected to the required circuit. The specific adjustment process is shown in Fig.4.

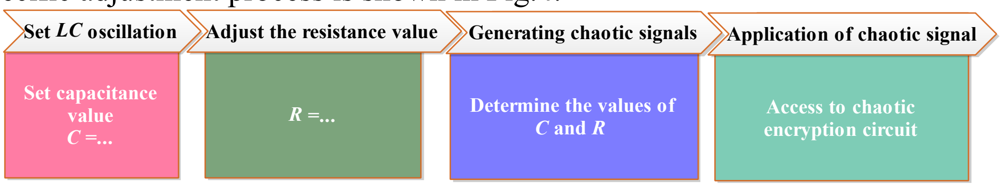


Fig. 4 General process of generating chaotic signal

3. Structure of chaotic system

The structure of the whole chaotic signal generator system is shown in Fig.

5, which mainly includes mobile phone, control circuit and oscilloscope. The operation steps are as follows: 1) connect the signal output end of the control circuit with the signal input end of the oscilloscope; 2) Power on the control circuit; 3) Open the app of mobile phone chaotic signal generator system; 4) Connect the WiFi between the mobile phone and the control circuit; 5) Click "R +" R - "C +" C - "in the mobile app to set the capacitance value and adjust the resistance value until the chaotic image is observed in the oscilloscope. In general, there are many advantages of simple structure, easy operation, low energy consumption, adjustable chaotic signal and fast application etc. for the chaotic signal generator.

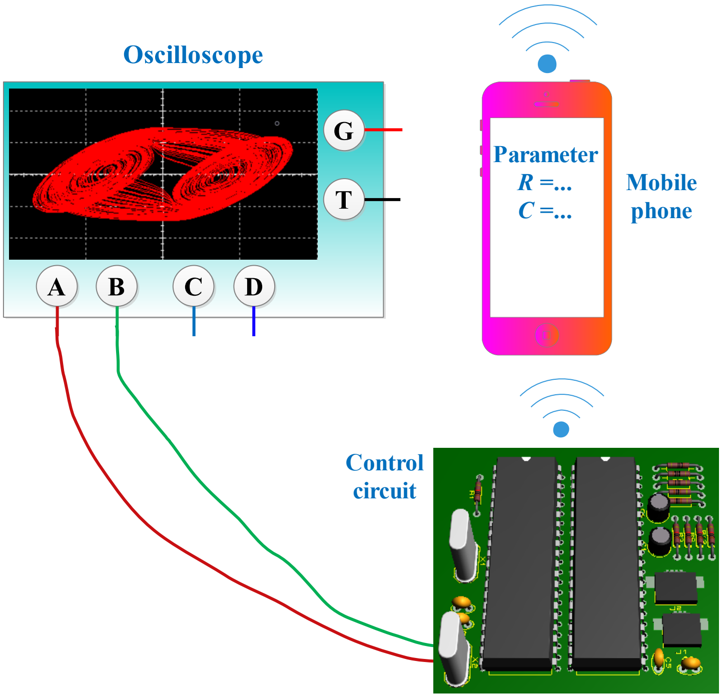


Fig. 5 Structure frame of chaotic signal generator

4. Hardware circuit design

The main control circuit of chaotic signal generator is shown in Fig.6. The design is mainly based on conditions for generating chaotic images in Fig.1 and Fig.2 and the chaos circuit in Fig. 3. And it is necessary to select nonlinear electronic components that can make voltage or current change with time and specific parameter values as the core of chaotic signal generation. U3A, U3B (U3A and U3B can be instead of TL062, TL082 and other chips), R1, R2, R3, R4, R5 and R6 constitute the nonlinear resistance devices R_F in Fig. 3. The capacitance C1 in Fig. 6 corresponds to the capacitance C_1 in Fig. 3. The inductance L1 in Fig. 6

corresponds to the inductance L in Fig. 3. The resistors R31, R32, R33, R34, R35, R36, R37 and R38 in Fig. 6 correspond to the variable resistors R in Fig. 3. The capacitors C2, C3, C4 and C5 in Fig. 6 correspond to the variable capacitors C in Fig. 3. In order to adjust the resistance and capacitance of the access circuit, the virtual switches U1, U2 and U3 (the virtual switch can use chips such as CD4066) are used to control the resistance R31, R32, R33, R34, R35, R36, R37, R38 and the capacitance C2, C3, C4, C5 respectively. In order to reduce the hardware cost, the central control uses 51 single chip microcomputers (STC89C51 or AT89S52, as shown in Fig. 6 U9). Because the working voltage of single-chip microcomputer 5V is different from that of virtual switch 10V, the optocoupler (such as U5A, U5B, U5C, U5D, U6A, U6B, U6C, U6D, U7A, U7B, U7C, U7D in Fig. 6. The optocoupler can use chips such as TLP521-4 etc.) can be connected between the virtual switch and single-chip microcomputer for isolation control. In order to improve the operation speed, another 51 single chip microcomputer (as shown in Fig. 6 of the U8) and WIFI module (WIFI module terminal as shown in Fig. 6 of the WIFI, WIFI module core chip using ESP8266) interactive communication, and then with mobile phone interactive communication. In order to display the total capacitance value of the variable capacitor and the total resistance value of the variable resistor, a total of 7 common anode digital tubes (U10, U11, U12, u13, U14, U15 and U16 shown in Fig. 6) are connected. Use seven triodes (Q1, Q2, Q3, Q4, Q5, Q6 and Q7 shown in Fig. 6) to drive and control seven nixie tubes. In the debugging stage, in order to check the running status of the program, two LED (LED1 and LED2 in Fig. 6) and four control switches (J3, J4, J5 and J6 in Fig. 6) are connected. Two 51 single chip microcomputers, U8 and U9, communicate with each other through virtual serial ports (Q12 and Q13 in Fig. 6). Considering that U9 can process the signals of four switches J3, J4, J5 and J6, in order to simplify the control program code, a new U9 signal input interface is not added. MCU U8 directly through four switch triodes (Q8, Q9, Q10, Q11 in Fig. 6) to simulate the input switch signal. Compared with some chaotic circuits with fixed parameters[20], the adjustability of the circuit in this study makes the application better. And compared with using Arduino Mega 2560 R3 microcontroller to realize chaotic circuit [21], the cost of the circuit in this study is relatively low. On the whole, the circuit cost is low, and the structure principle is clear and simple.

Circuit operation process:

1) MCU U8 communicates with the mobile phone through WIFI module when the power is turned on.

2) Corresponding operation signal is sent to the U8 through the WIFI module, and the data communication between the U8 and U9 is carried out through the virtual serial port or the virtual switches Q8, Q9, Q10 and Q11 when operating the mobile app.

3) U9 receives the signal from U8 and performs corresponding operations,

such as displaying the current total capacitance value and total resistance value on the nixie tube.

4) Through optocoupler and virtual switch, the total capacitance C and total resistance R of the control access circuit can be adjusted directly by U8.

5) The value of total capacitance and total resistance is sent to the mobile phone through the WIFI module when the chaotic signal is generated.

6) The data received is processed and displayed accordingly by the mobile phone.

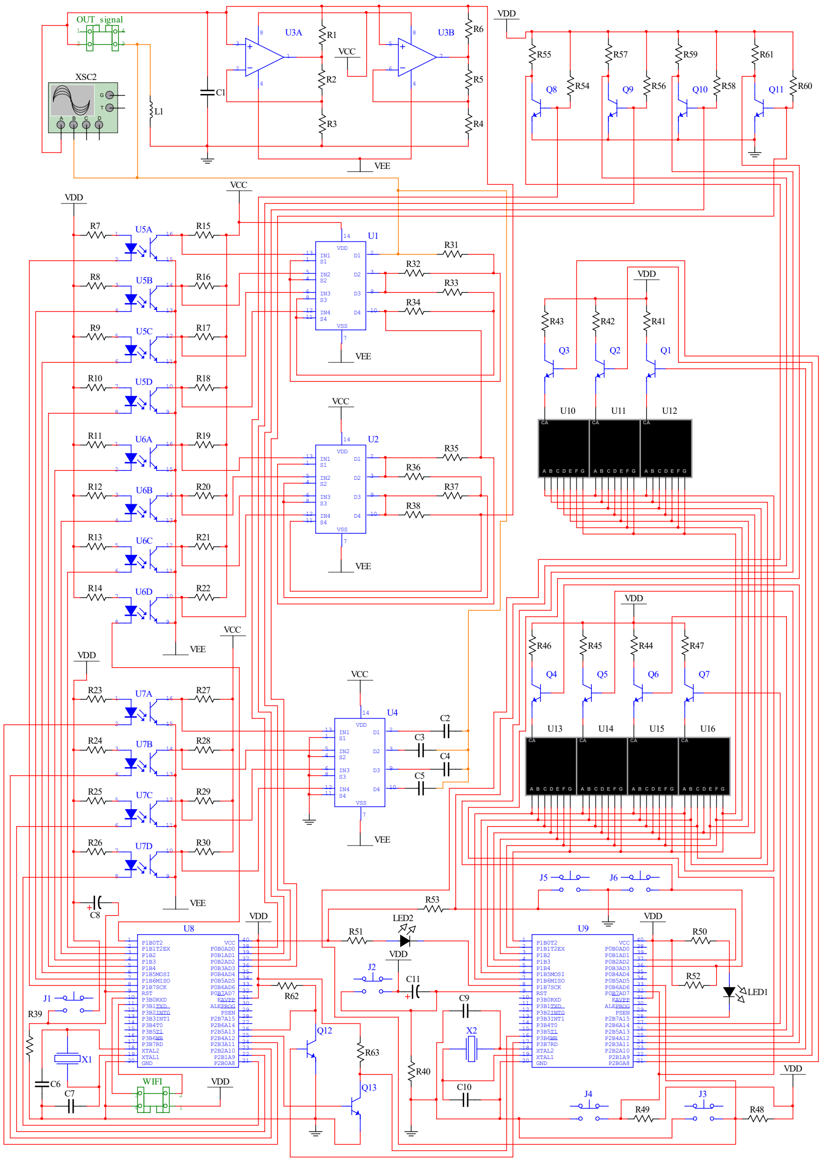


Fig. 6 Main control circuit of chaotic signal generator system

5. Program and software design

5.1 MCU program

5.1.1 Digital tube display

Digital tube display is mainly “**void** digit_led**(int** ID_digit**,int** num_digit**)**” function. For example, the code to display the number "4" is:

```
1)  if(num_digit==4) //display 4
2)  { a_digit=1;
3)  b_digit=0;
4)   c_digit=0;
5)  d_digit=1;
6)  e_digit=1;
7)   f_digit=0;
8)   g_digit=0; }
```

Bit selection is necessary because the number of digits of the value is different when displaying different resistance and capacitance values. For example, the highest bit program code of digital tube bit selection resistance is:

```
1)  if(ID_digit==6) // The highest position of nixie tube position selection resistor
2)  {       digit_C0=0;// Digital tube position selection, the lowest capacitance
3)          digit_C1=0;// Nixie tube position selection, the second low
4)          digit_C2=0;// Digital tube position selection, the highest capacitance, the third
5)        digit_R0=0;// Nixie tube position selection, the lowest resistance
6)         digit_R1=0;// Nixie tube position selection, the second low
7)         digit_R2=0;// Nixie tube position selection, resistance third
8)        digit_R3=1; }// Nixie tube position selection, the highest resistance, the fourth
```

If the resistance is greater than or equal to 1000, execute the following code to display.

```
1)num_0_9=R_data/1000;// The highest position of resistance is 1000 bits. Three resistance bits,
  // four resistance bits, ten resistance bits, five resistance bits, and six resistance bits
2)if (num_0_9>0)    // Resistance up to 1000 digits
3) { digit_led(6,num_0_9);
4)  num_0_9=(R_data/100)%10;// Resistance, 100 bit
5)   digit_led(5,num_0_9);
6)  num_0_9=(R_data/10)%10;// Resistance, 10 bit
```

7) digit_led**(**4**,**num_0_9**);**
8) num_0_9=R_data**%**10**;***// Resistance, one bit*
9) digit_led**(**3**,**num_0_9**); }**

5.1.2 Resistance value adjustment

The adjustment program of the total resistance R value of the access circuit mainly uses to directly convert the resistance value into 0-1 potential value, and then assign the value to the IO port pin of the corresponding MCU. The main program functions are as follows:

1)**void** R_data_IN **(void)** *// Circuit access resistance value control, step size 10 ohm*
2) **{unsigned int** R_HL=R_data/10**;**
3) R10=1**-(**R_HL**%**2**);***//P1^0 potential, control whether 10 ohm is connected or not*
4) R20=1**-((**R_HL/2**)%**2**);***//P1^1 Potential, control whether 20 ohm is connected or not*
5) R40=1**-((**R_HL/4**)%**2**);***//P1^2 Potential, control whether 40 ohm is connected or not*
6) R80=1**-((**R_HL/8**)%**2**);***//P1^3 Potential, control whether 80 ohm is connected or not*
7) R160=1**-((**R_HL/16**)%**2**);***//P1^4 Potential, control whether 160 ohm is connected or not*
8) R320=1**-((**R_HL/32**)%**2**);** *//P1^5 Potential, control whether 320 ohm is connected or not*
9) R640=1**-((**R_HL/64**)%**2**);***//P1^6 Potential, control whether 640 ohm is connected or not*
10) R1280=1**-((**R_HL/128**)%**2**); }***//P1^7 Potential, control whether 1280 ohm is connected or not*

5.1.3 Capacitance adjustment

The adjustment program of the total capacitance C value of the access circuit can be similar to the adjustment program of the resistance value. The capacitance value is directly converted into 0-1 potential value, and then assigned to the IO port pin of the corresponding MCU. The main program functions are as follows:

1) **void** C_data_IN **(void)***// Circuit access capacitance value control, step size 20 nF*
2) **{ unsigned int** C_HL=C_data/20**;**
3) C20=1**-(**C_HL**%**2**);***//P2^0 Potential,control whether 20 nF is connected or not*
4) C40=1**-((**C_HL/2**)%**2**);***//P2^1 Potential,control whether 40 nF is connected or not*

5) C80=1-((C_HL/4)%2);*//P2^2 Potential,control whether 80 nF is connected or not*

6) C160=1-((C_HL/8)%2); }*//P2^3 Potential,control whether 160 nF is connected or not*

Of course, considering that the capacitance range is 0-300 nF and the step size is 20 nF, there are 16 possibilities in total. The "if" statement can be used to write out all the possibilities and control them directly. For example, the main program codes of 120 nF and 140 nF capacitors are as follows:

```
1) if(C_data==120) // Connecting 120 nF capacitor
2) { C20=1;
3)    C40=0;
4)    C80=0;
5)    C160=1; }
6)    else
7)    {if(C_data==140) // Connected to 140 nF capacitor
8)      {C20=0;
9)       C40=0;
10)      C80=0;
11)      C160=1; }
```

5.1.3 WIFI data

Operate the app software of the mobile phone, and the mobile phone sends the corresponding operation data code to the MCU U8 through WIFI. Single chip microcomputer U8 needs to process the received data. That is, if the instruction to increase the capacitance is received and the current capacitance value does not reach the maximum value of 300 nF, the capacitance value will be increased by 20 nF on the original basis. If the instruction to reduce the capacitance is received and the current capacitance value does not reach the minimum value of 0 nF, the capacitance value will be reduced by 20 nF from the original value. If the command to increase the resistance is received and the current resistance value does not reach the maximum value of 2550 Ω, the resistance value will be increased by 10 Ω from the original value. If the instruction to reduce the resistance is received and the current resistance value does not reach the minimum value of 0 Ω, the resistance value will be reduced by 10 Ω on the original basis. Finally, the MCU U8 will receive the corresponding operation signal of the mobile phone through the virtual switch or virtual serial port to the MCU U9. The main program codes are as follows:

```
1)      if( Recwifi_data[0]=='0'&&R_data<2550  )//  Increase the resistance by 10 ohm key
2)      {   R_data+=10;
3)          R_add=1;   // Virtual switch control
4)          delayms(1);
5)          R_add=0;   // Virtual switch control
```

6) R_data_IN ( ); } // The minimum value of circuit access resistance is 10 ohm
7) if(Recwifi_data[0]=='1'&&R_data>0) // Press the button that reduces the resistance by 10 ohm
8) { R_data-=10;
9) R_sub=1; // Virtual switch control
10) delayms(1);
11) R_sub=0; // Virtual switch control
12) R_data_IN ( ); } // Circuit access resistance value control, step size 10 ohm
13) if(Recwifi_data[0]=='2'&&C_data<300) //Press the button to increase the capacitance by 20nF
14) { C_data+=20;
15) C_add=1; // Virtual switch control
16) delayms(1);
17) C_add=0; // Virtual switch control
18) C_data_IN ( ); } // The circuit is controlled by the value of capacitor, and the step size is 20nF
19) if(Recwifi_data[0]=='3'&&C_data>0) // Press the button to reduce the capacitance by 20nF
20) { C_data-=20;// Virtual switch control
21) C_sub=1;
22) delayms(2);
23) C_sub=0; // Virtual switch control
24) C_data_IN ( );}// Circuit is controlled by the value of capacitor, and the step size is 20nF

5.2 Mobile APP soft design

5.2.1 APP soft window

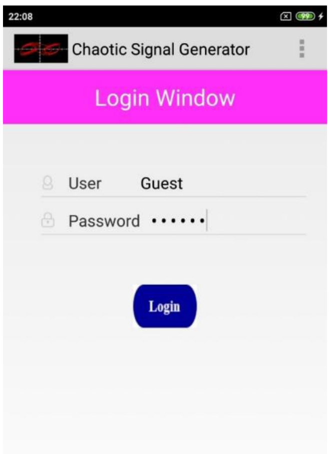


Fig.7 Login window

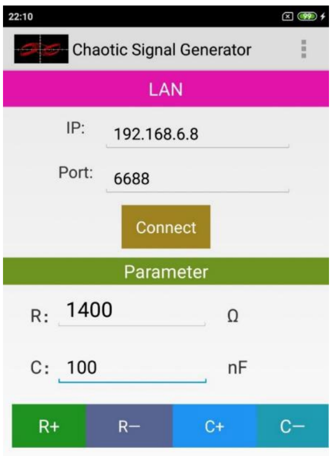


Fig.8 Setting window

The login window of mobile app software is shown in Fig.7. The whole landing window is simple, including the logo of chaotic signal generator software, user name input, login password input and login button. The specific operation window of circuit control and parameter setting is shown in Fig.8. It mainly includes the part of WIFI communication with MCU, which needs to input IP address and port number. Display of current resistance value. Display of current capacitance value. Add resistance button (as shown in Fig.8 R +). Reduce the resistance button (as shown in Fig.8 R -). Add capacitance button (as shown in Fig.8 c +). Reduce the capacitance button (C - in Fig.8).

5.2.2 Main procedures of APP soft

The main program of login interface needs to judge the user name and password, and the default user name of login window is "guest". If the user name and password are correct, jump to the test page, otherwise, prompt "user name or password error, please enter the correct user name and password." This function program only needs if statement. The program of detection interface mainly realizes the connection with control circuit board through WIFI, parameter setting, display of resistance value and capacitance value, etc. WIFI connection needs to input IP address and port number to establish service connection. The default IP address is "192.168.6.8", the port number is "6688", and the resistance and capacitance values are displayed with "EditText". The main program code is

```
1)    IP=(EditText)findViewById(R.id.editIp);
2)    IP.setText("192.168.6.8");// Default IP address
3)    PORT=(EditText)findViewById(R.id.editport);
4)    PORT.setText("6688");// Default port address
5)    R_num=(EditText)findViewById(R.id.edittemp);
// Display resistance value, the default resistance value is 1400
6)    C_num=(EditText)findViewById(R.id.edithumi);
// Display capacitance value, the default capacitance value is 100
```

The increase and decrease of resistance and capacitance are realized by sending different information codes to MCU. For example, send "0" to increase 10 Ω resistance, send "1" to decrease 10 Ω resistance, send "2" to increase 20nF capacitance, and send "3" to decrease 20nF capacitance. Their program function codes are similar. The following is the main program code to increase the value of 20nF capacitance.

```
1)      public class sendC_ADDclick implements OnClickListener
// Define the function of increasing the capacitance
2)      {@Override
3)         public void onClick(View arg0) {
4)              if(C_data<300)
5)              {C_data+=20;}// Add 20nF capacitor
```

6) C_num.setText(String.*valueOf*(*C_data*));// Capacitance value
7) **if**(socket!=**null**)
8) {**try** {
9) OutputStream outputstream = socket.getOutputStream();
10) **byte** buf[]=**new byte**[1];// Open up a memory space
11) buf[0]='2';// Press the increase 20nF capacitance key
12) outputstream.write(buf);
13) outputstream.flush();//Clear send data
14) Toast.*makeText*(tcpActivity.**this**," Data sent successfully！ " , 0).show();
15) } **catch** (IOException e) {
16) e.printStackTrace();} }
17) **else**
18)Toast.*makeText*(tcpActivity.**this**," WiFi connection error, please check ", 0). show();}}

MCU sends the resistance value and capacitance value back to the mobile phone through WIFI, using fixed data length, 9-bit data coding form, as shown in Fig.9. For example, "4 1860 3 100" means that the resistance is 4 digits, the resistance is 1860 Ω, the capacitance is 3 digits, and the capacitance is 100 nF. The main program code of mobile phone receiving data for display is as follows:

1)String result = msg.getData().get("msg").toString();
//9-bit data, 0-bit resistance data, 1-bit resistance highest and first,
//2-bit resistance second, 3-bit resistance low, 4-bit resistance fourth
//9-bit data, 5-bit capacitance data, 6-bit capacitance highest and first,
//7-bit capacitance second, 8-bit capacitance low three
2)a=result.substring(0, 0);
3)b=result.substring(5, 5);
4)**if**(a=="1")// Resistance 1 digit
5) {*R_data*=Integer.*valueOf*(result.substring(4, 4));
6) R_num.setText(String.*valueOf*(*R_data*)); }// Resistance value
7) **if**(a=="2")// Resistance 2 digits
8) { *R_data*=Integer.*valueOf*(result.substring(3, 4));
9) R_num.setText(String.*valueOf*(*R_data*)); }// Resistance value
10) **if**(a=="3")// Resistance 3 digits
11) { *R_data*=Integer.*valueOf*(result.substring(2, 4));
12) R_num.setText(String.*valueOf*(*R_data*)); }// Resistance value
13) **if**(a=="4")// Resistance 4 digits

```
{ R_data=Integer.valueOf(result.substring(1, 4));
  R_num.setText(String.valueOf(R_data)); }// Resistance value
if(b=="1")// Capacitance 1 digit
{C_data=Integer.valueOf(result.substring(8, 8));
 C_num.setText(String.valueOf(C_data)); }// Capacitance value
if(b=="2")// Capacitance 2 digits
  { C_data=Integer.valueOf(result.substring(7, 8));
    C_num.setText(String.valueOf(C_data)); }// Capacitance value
if(b=="3")// Capacitance 3 digits
  { C_data=Integer.valueOf(result.substring(6, 8));
    C_num.setText(String.valueOf(C_data)); }// Capacitance value
```

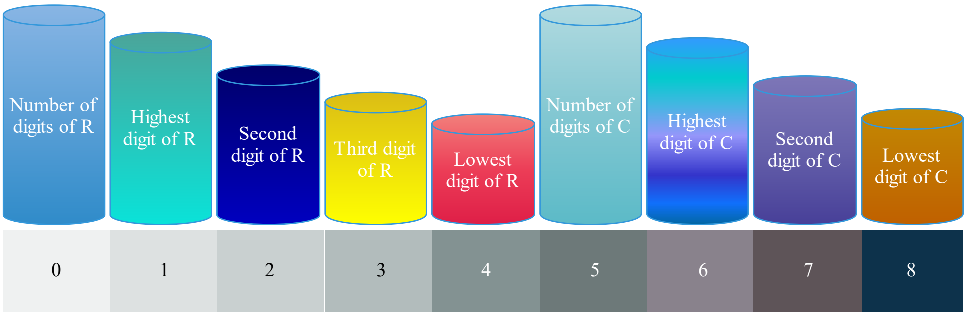


Fig.9 Meaning coding of 9-bit data transmission

6. Simulation results

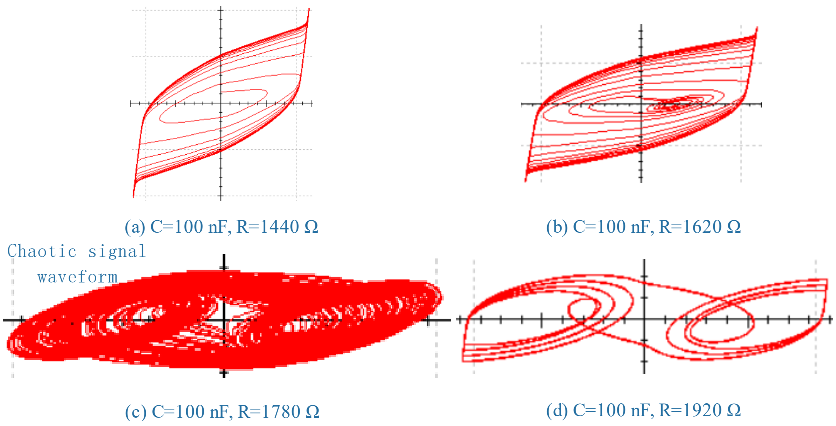


Fig.10 Waveform of different analog resistance values when analog capacitance C

In order to verify that the designed control circuit can generate chaotic signals, Multisim is used for simulation. The parameters of some key components in the circuit principle of Fig.3 are: resistance R1 = 20 kΩ, R2 = 20 kΩ, R3 = 1 kΩ, R4 = 2 kΩ, R5 = 210 Ω, R6 = 210 Ω, capacitance C1 = 12 nF, inductance L1 = 20 mH, operational amplifier U3A, U3B TL062, positive power VCC = 10 V, negative power VEE = - 10 V. Fig.10 shows signal waveform of different analog resistance values 1440-1920 Ω when analog capacitance C = 100 nF. And the signal waveform of analog resistance values 1280-1510 Ω when analog capacitance C = 260 nF are shown in Fig.11. According to the waveform changes in Fig.10 and Fig.11, different signal waveforms can be obtained by changing the value of capacitance C or resistance R. under specific parameter values, chaotic signal waveforms can be obtained, such as C = 100 nF, R = 1780 Ω, or C = 260 nF, R = 1440 Ω.

= 100 nF

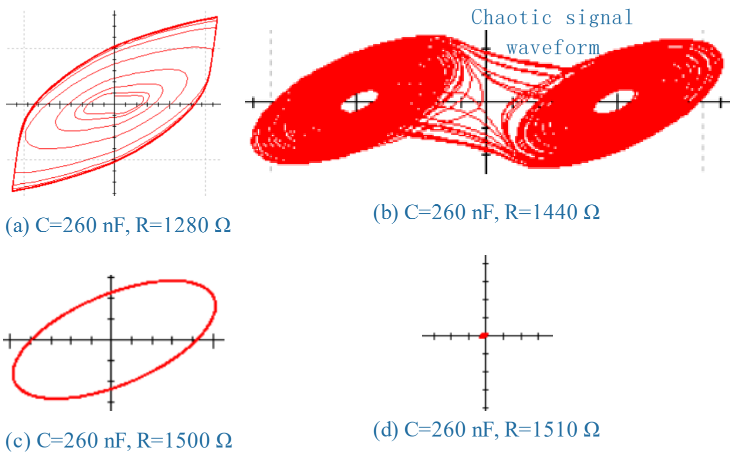


Fig.11 Waveform of different analog resistance values when analog capacitance C = 260 nF

7. Conclusion

A low-cost, clear structure, simple operation and adjustable chaotic signal generator is designed, which can provide signal source for chaotic underwater acoustic positioning system and provide reference for the research of chaotic signal. The theory of chaos and the classical Chua's circuit are analyzed and it shows that it is feasible to design chaotic signal generator. The control circuit of chaotic signal generator system based on C51 MCU and the mobile app controlled by WIFI communication are developed. They can provide a reference for the development of other related control APP and the single chip microcomputer control circuit and program. Of course, there are still many places to be further studied and improved for the chaotic signal generator. For example, optimize the program, further improve the efficiency of program execution, reduce system power consumption.

Add system functions, for example, add the function of displaying the current signal waveform on the mobile phone app, and store the generated chaotic signal by 0-1 binary processing for standby. Further optimize the circuit, and strengthen the stability of the circuit. The applicability of the chaotic signal generator in the research of chaotic underwater acoustic positioning system is further improved by enlarging the working environment temperature of the chaotic signal generator.

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