ISSN 2959-6157

Design and Implementation of Eight-Way Call System Based on Digital Integrated Circuits

Meiting Dong*

[1] School of Information and Control Engineering,Qingdao University of Technology, Qingdao, China
*Corresponding author: 201805650110@smail.xtu.edu.cn

Abstract:

This paper introduces the construction of an eight-channel call system using medical callers. The circuit enables the call signal to be sent to the 74HC148 priority encoder for encoding if any of the channels make a call. The encoded signal is processed by the 74LS283 and then output from the 74LS373 latch to the 4511BD decoding and driving circuit. The output of the decoding and driving circuit is displayed on the display circuit, showing the number of the channel that made the call. Meanwhile, the control signal triggers a monostable oscillator circuit composed of a 555 timer, which generates a temporary stable output signal with a pulse width of about 2s. The pulse signal drives a multivibrator circuit composed of a 555 timer, which causes the LED to work and output an alarm signal. The alarm state can be eliminated manually by pressing a key.

Keywords: 74HC148 priority encoder; 74LS373; 555 timer; monostable oscillator circuit; multivibrator circuit.

1. Introduction

The 8-way paging system, as a medical device, provides a quick way for patients or their family members to call doctors when a sudden change in their condition is detected. This helps prevent patients from missing the best treatment opportunity and ensures their life safety. The device uses a keypad located near the patient's bed to make the call. When the key is pressed, the alarm bell and indicator light in the nursing staff's duty room work simultaneously to alert the nursing staff of the patient's call. At this time, the nursing staff can accurately determine which bed the patient is in by looking at the digital display and immediately go to the patient for timely treatment. Meanwhile, the doctor can also press the key to turn off the 2s alarm bell and indicator light and clear the display.

This article introduces a circuit design method. If any signal from S1 to S8 is called, the call signal will be sent to the 74HC148 priority encoder for encoding, the encoded signal will be sent to the 4-bit binary super-advance ripple-carry adder 74LS283 for addition processing, and then the processed encoded signal will be sent to the 4511BD decoding driver circuit. The encoded signal is displayed through the display circuit. At the same time, the control signal triggers the monostable oscillator circuit composed of 555 timers, which generates a temporarily stable pulse signal with an output width of about 2s. This signal drives the multivibrator circuit composed of 555 timers, which makes the LED work and outputs the alarm signal. The alarm state can be manually cancelled by pressing a key.

The first chapter of the article is the introduction, which first introduces the research background, research significance, and application scenarios of the article; the second chapter is the design and analysis of the local and overall circuits, giving the working principles of the important components in the circuit, respectively introducing the composition and working process of the display circuit and the alarm circuit; the third chapter is the conclusion part, summarizing the entire circuit and looking forward to the application of the technology.

2. Circuit Analysis and Design

2.1 74HC148

The following figure 2-1 is the schematic diagram of the 8-line to 3-line priority encoder 74HC148 chip:

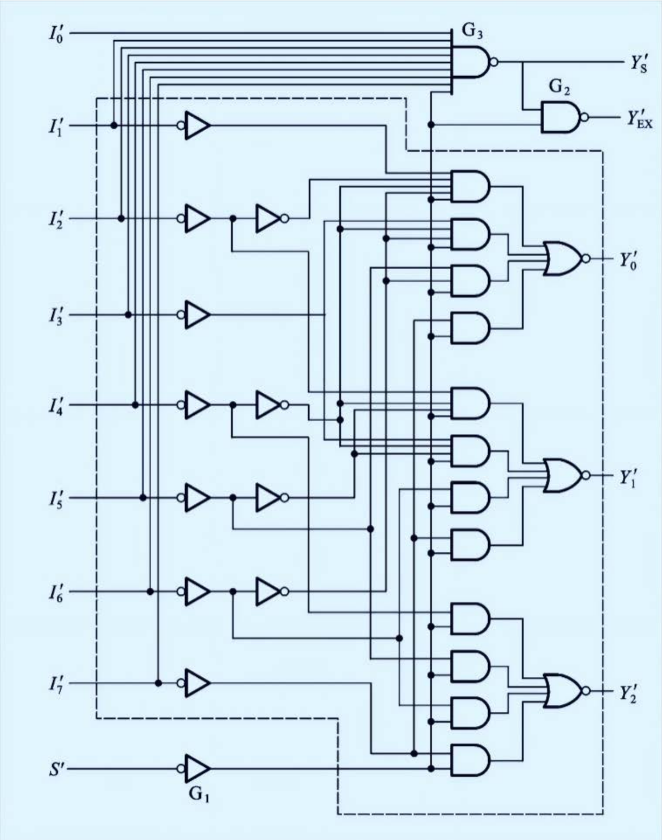

Fig.1 8-line to 3-line priority encoder 74HC148

As shown in Figure 1, G1, G2, and G3 are the control circuit parts composed of simple logic gates; S' is the enable input terminal, which is enabled at low voltage; Y's is the enable output terminal relative to S', and similarly, both are enabled at low voltage; I'0~I'7 are input terminals, with priority level 7 being the highest and decreasing in priority in descending order; similarly, Y'0~Y'2 are output terminals, both of which are effective at low voltage.

① The Boolean expression for the output end Y'2~Y'0 of the encoder is as follows:

$$Y_2' = [(I_7 + I_6 + I_5 + I_4)S]' \tag{1}$$

$$Y_1' = [(I_7 + I_6 + I_5 I_4' I_3' + I_2 I_4' I_5')S]' \tag{2}$$

$$Y_0' = [(I_7 + I_6' I_5 + I_3 I_4' I_6' + I_1 I_2 I_4' I_6')S]' \tag{3}$$

② The Boolean expressions for the enable output $\overline{Y_s}$ and expansion output $\overline{Y_{EX}}$ are as follows:

$$\overline{Y_s} = \overline{\overline{I_0}\cdot\overline{I_1}\cdot\overline{I_2}\cdot\overline{I_3}\cdot\overline{I_4}\cdot\overline{I_5}\cdot\overline{I_6}\cdot\overline{I_7}\cdot S} \tag{4}$$

$$\overline{Y_{EX}} = \overline{(I_0 + I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7)S} \tag{5}$$

It is worth noting that when $\overline{Y_s}$ is in the coding state, it requires $\overline{S} = 0$, meaning that if there is no input signal, $\overline{Y_s}$ should be 0, representing that the circuit is working but no coding signal is input. When $\overline{Y_{EX}}$ is in the coding state, it requires $\overline{S} = 0$, meaning that if there is an input signal, $\overline{Y_{EX}}$ should be 0, representing that the circuit is working but no coding signal is input. $\overline{S}$ is the enable input, and it is zero when coding is enabled, and one when coding is disabled (the output end is blocked at a high voltage level).

2.2 74LS283

The 74LS283 is a 4-bit binary carry-lookahead adder, whose schematic diagram is shown in Figure 2 [1].

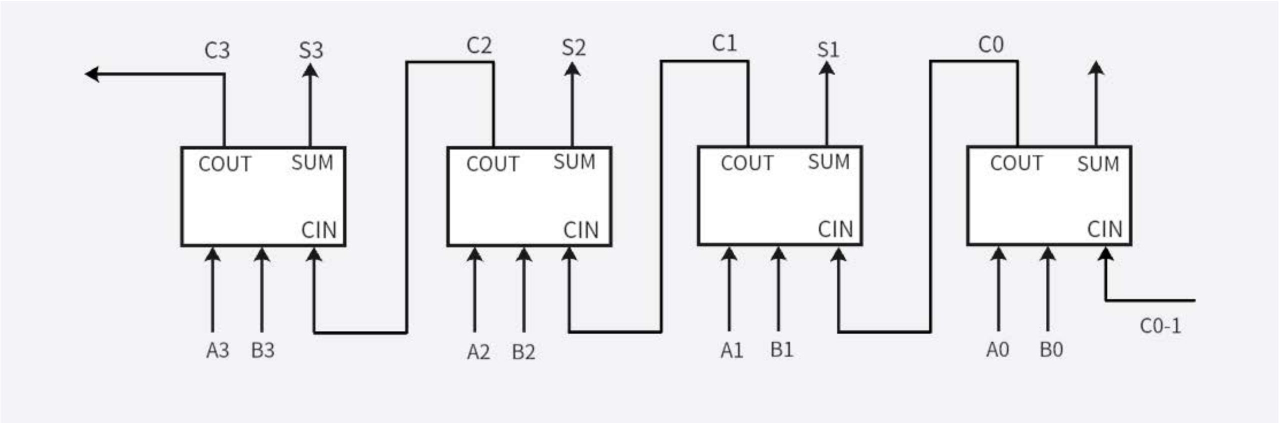

Fig.2 Circuit diagram of 74LS283

As shown in Figure 2, the 74LS283 is composed of four full adders, where the carry output from one full adder is connected to the input of the next full adder. The schematic diagram of a full adder is shown in Figure 3, and its truth table is given in Table 1 [2,3].

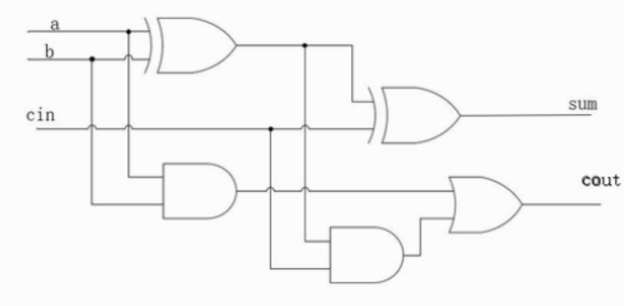

Fig.3 A schematic diagram of a full adder

Table 1. Truth table for a full adder

Inputs			Outputs	
Ai	Bi	Ci-1	Ci	Si
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

2.3 74LS373

The chip is composed of 8 independent D-type latches with D-type inputs, but they share a latch enable terminal LE and an output enable terminal OE. It is commonly used for data storage and allocation, with strong driving ability to make data transmission faster and more efficient. For the output enable terminal OE, when OE is at a low voltage, the latches will output the stored content; when OE is at a high voltage, the output terminal will enter a high-impedance state. The change in the OE terminal voltage will not affect the state or the locked content of the latches.

For the latch enable terminal LE, when the LE terminal voltage is at a high level, data is transmitted from the Dn input terminal to the latches, and at the same time, the latches enter a transparent mode in which the output corresponds to the input change; when the LE terminal voltage is at a low level, the input data is locked in the latches, and the output of the output terminal no longer depends on the input.

2.4 A Decoding Display Circuit Consisting of 4511BD and Common Cathode Digital Display Tubes

4511BD is a BCD-7 segment latch/decoder/driver that can latch or directly input and decode the BCD numerical values from four-wire input and output segment signals that can directly drive common cathode LED digit displays. The truth table for converting 4511BD to common cathode digital display is shown in Table 2.

Table 2. Truth table for converting 4511BD to common cathode 7-segment display

Inputs							Outputs							
LE	BI	LI	D	C	B	A	a	b	c	d	e	f	g	Displays
0	1	1	0	0	0	0	1	1	1	1	1	1	0	0
0	1	1	0	0	0	1	0	1	1	0	0	0	0	1
0	1	1	0	0	1	0	1	1	0	1	1	0	1	2
0	1	1	0	0	1	1	1	1	1	1	0	0	1	3
0	1	1	0	1	0	0	0	1	1	0	0	1	1	4
0	1	1	0	1	0	1	1	0	1	1	0	1	1	5
0	1	1	0	1	1	0	0	0	1	1	1	1	1	6
0	1	1	0	1	1	1	1	1	1	0	0	0	0	7
0	1	1	1	0	0	0	1	1	1	1	1	1	1	8
0	1	1	1	0	0	1	1	1	1	0	0	1	1	9

A specific Boolean expression can be written as:

$$\begin{cases} Y_a = A_3'A_2'A_1'A_0 + A_3A_1 + A_2A_0' \\ Y_b = A_3A_1 + A_2A_1A_0' + A_2A_1'A_0 \\ Y_c = A_3A_2 + A_2'A_1A_0' \\ Y_d = A_2A_1A_0 + A_2A_1'A_0' + A_2'A_1'A_0 \\ Y_e = A_2A_1' + A_0 \\ Y_f = A_3'A_2'A_0 + A_2'A_1 + A_1A_0 \\ Y_g = A_3'A_2'A_1' + A_2A_1A_0 \end{cases} \quad (6)$$

2.5 555 Timer

2.5.1 A Monostable Touch Circuit Composed of A 555 Timer

The monostable touch circuit composed of 555 timer is shown in Figure 4 [4,5].

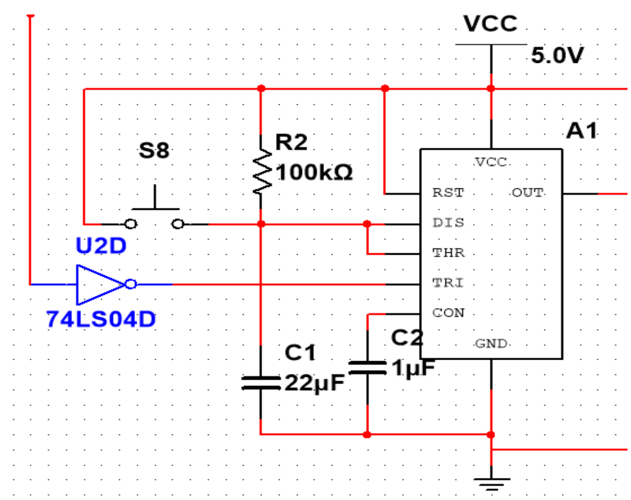

Fig.4 Single-stable oscillator circuit using the 555 timer

When the circuit is in a steady state, the output terminal OUT corresponds to a low output, i.e., when the input signal terminal TRI is at a high voltage, the circuit is in a stable state, and the OUT terminal outputs a low voltage. When a negative pulse is input to the TRI terminal, the low-voltage triggering end reaches a voltage lower than $\frac{1}{3}V_{cc}$, the trigger signal causes the OUT terminal to output a high voltage, the discharge tube VT is in a cut-off state, and the circuit enters a transient state, the timing starts. During the transient state of the circuit, there is a process from Vcc to the resistor R, then to the capacitor C1, and finally to ground, which charges the capacitor, the charging time constant t=rc, the voltage on both ends of the capacitor rises exponentially, and when the voltage rises to $\frac{2}{3}V_{cc}$, the output terminal OUT becomes low, the discharge tube VT is in a conductive state, the charging of the timing capacitor C1 ends, i.e., the transient state process ends. The circuit regains its steady-state output, with the output terminal OUT outputting a low voltage state. When the next trigger pulse arrives, the process will be repeated.

In Figure 4, due to the addition of the preceding inverter, a positive pulse is input to the inverter before it, a positive pulse waveform with a certain width can be obtained as the output, the width of the pulse tw depends on the time required for the capacitor to charge from a voltage of 0 to $\frac{2}{3}V_{cc}$, i.e.

$$t_w \approx 1.1RC \tag{7}$$

According to the parameter $R_2 = 470k\Omega, C_1 = 22uF, C_2 = 1uF$ in Figure 4, we can substitute $C = 1uF, R = 470k\Omega$ into the above formula to calculate the result.

2.5.2 A Multi-oscillator Circuit Using a 555 Timer

The astable multivibrator circuit composed of 555 timer is shown in Figure 5 [6].

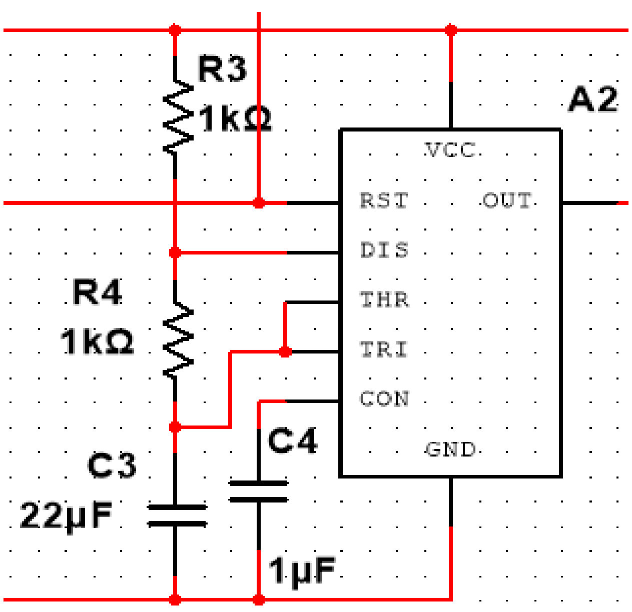

Fig. 5 Astable multivibrator using a 555 timer

The circuit shown above is charged by Vcc through R3 and R4 after the power supply is turned on. However, at the instant the circuit is turned on, C3 has not had time to charge, so Uc=0V, and the output state of the 555 timer is 1, with the output terminal OUT corresponding to a high voltage [7]. Meanwhile, the conductive tube VT is in the off state, and Vcc charges C3, causing Uc to gradually increase, and the circuit enters the transient state I at this time.

When Uc increases to $\frac{2}{3}V_{cc}$, the output terminal OUT corresponds to a low voltage output, and at this time, the conductive tube VT is in the conducting state, and C3 discharges, causing Uc to gradually decrease, and the circuit enters the transient state II at this time.

After that, the circuit generates periodic output pulses in a cyclic manner.

Regarding Figure 5, the calculation of the charging time of the capacitor T_1. When the capacitor is charged, the time constant $\tau_1 = (R_3 + R_4)C_3$, the initial value $V_c\left(0^+\right) = \frac{1}{3}V_{cc}$, and the final value $V_c(\infty) = V_{cc}$, the transition value $V_c(T_1) = \frac{2}{3}V_{cc}$, and the transition process calculation formula is used for calculation, the calculation formula is:

$$T_1 = \tau_1 ln\frac{V_c(\infty) - V_c\left(0^+\right)}{V_c(\infty) - V_c(T1)} = \tau_1 ln\frac{V_{cc} - \frac{1}{3}V_{cc}}{V_{cc} - \frac{2}{3}V_{cc}} = \tau_1 ln2 \tag{8}$$
$$= 0.7(R_3 + R_4)C_3$$

The calculation of the discharge time T_2 of the capacitor. The discharge time constant of the capacitor $\tau_2 = R_4 C_3$, the initial value $V_c\left(0^+\right) = \frac{2}{3}V_{cc}$, the final value $V_c(\infty) = 0$, and the transition value $V_c(T_2) = \frac{1}{3}V_{cc}$. Substitute the RC transition process calculation formula into the calculation, the calculation formula is:

$$T_2 = 0.7R_4C_3 \tag{9}$$

The oscillation period T of the circuit can be calculated using the following formula:

$$T = T_1 + T_2 = 0.7(R_3 + 2R_4)C_3 \tag{10}$$

2.6 Display Circuit

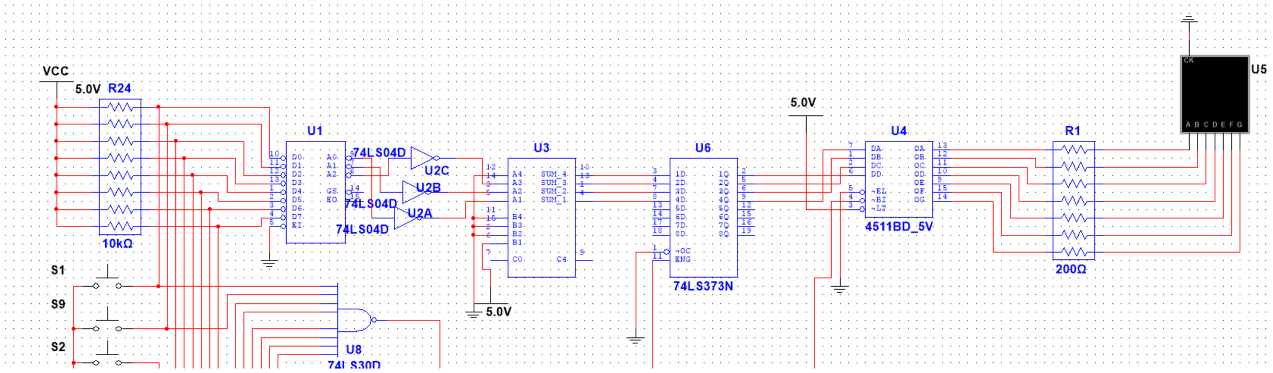

Fig.6 Shows the circuit

From Figure 6, the circuit consists of a keypad, a 8-3 line priority encoder 74HC148, an eight-D latch 74LS373 with a tri-state output, inverters 74LS04, drivers 4511BD, seven-segment displays, and protective resistors [8].

When one of the S1 to S8 keys is pressed, there is a call on that line. There is corresponding encoding output at the output end of 74LS148. The latched data is then stored in the 74LS373 latch and finally input to the 4511BD decoder to drive the seven-segment display to display the corresponding key number.

2.7 Alarm Circuit

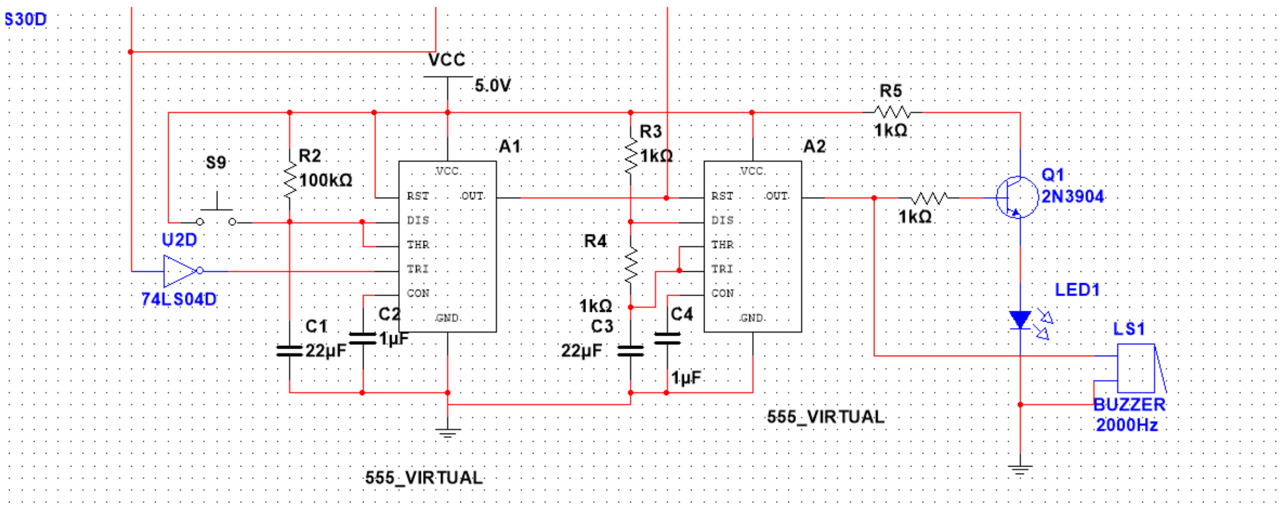

Fig.7 Alarm circuit

From Figure 7, the circuit consists of a keypad, an 8 NOR gate 74LS30, a monostable circuit, a multivibrator, a buzzer, six inverters 74LS04, a transistor, an LED light-emitting diode, and protective resistors [9,10].

When one of the S1 to S8 keys is pressed, it indicates that there is a call on that line. The 74LS30 outputs a high voltage, which is inverted by an inverter to produce a low voltage that triggers the monostable circuit to produce a high voltage delay. The inverted output triggers the multivibrator to oscillate, thereby controlling the operation of the LED and buzzer to generate an alarm. The manual alarm elimination circuit is composed of a latch 74LS373 and an NOR gate 74LS00, which can manually set the RST pin of the multivibrator to a low voltage within 2 seconds to eliminate the alarm. The LED lamp is a simplified and rudimentary alarm device. When a low voltage input is inverted by an inverter, the LED lamp turns off.

2.8 Alarm Circuit

The overall circuit design is as follows:

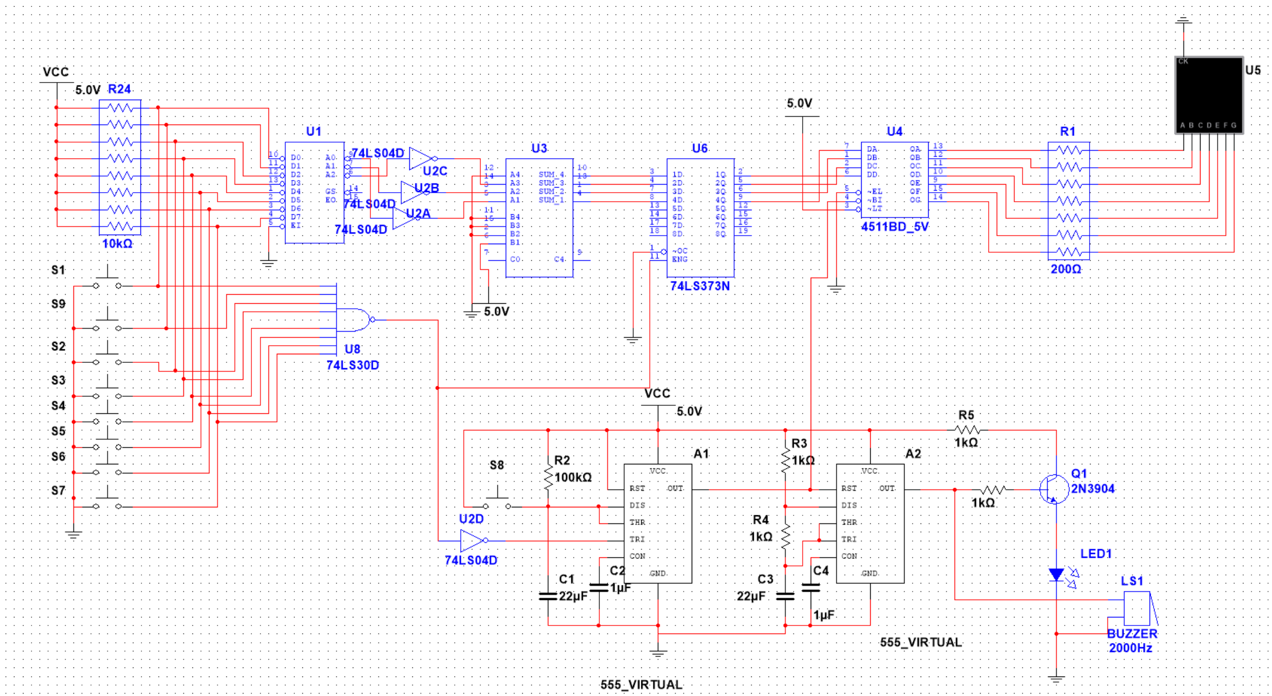

Fig.8 Overall circuit

Figure 8 shows the overall circuit, which integrates the display circuit and the alarm circuit, using the signal from the display circuit to control the oscillation of the alarm circuit.

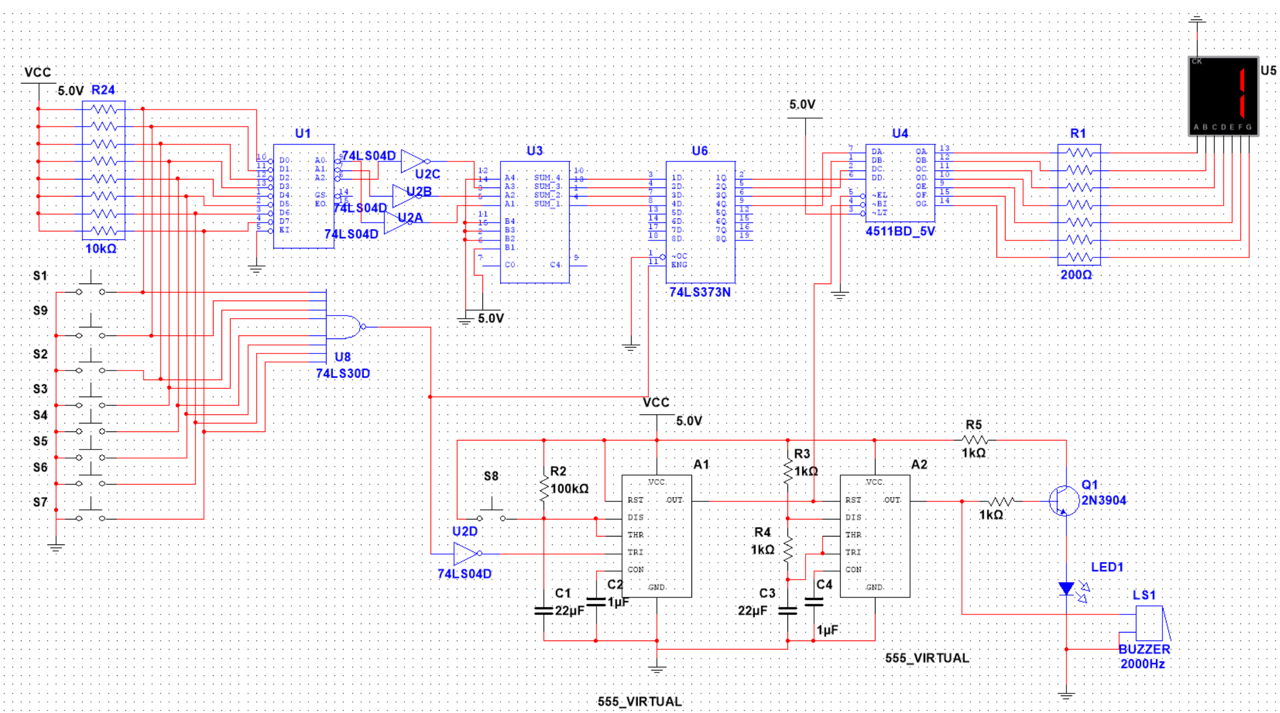

Fig.9 Circuit after the alarm display

Figure 9 shows that when S1 is pressed after the entire circuit is set up, it represents that a call has been made on Line 1. At this time, the LED light-emitting diode displays the digit “1”, the buzzer sounds an alarm, the LED conducts and lights up.

3. Summary

The circuit can simulate the operation of any one of the

S1~S8 buttons being pressed, i.e. any one of the eight call circuits making a call request will display the corresponding call circuit number, the buzzer will emit a 2S buzzing sound, and the diode will also light up in response.

The circuit can be changed as follows: The circuit is not limited to 8 circuits, but only one common cathode LED display can display 0~9 circuits, i.e. a total of 10 circuits, allowing multiple common cathode LED displays to display the call circuit encoding together. When the total number of common cathode LED displays is N, the number of call circuits that can be displayed can be increased to 10^N.

In addition, the previous circuit also needs to be changed. The 74LS283 is limited to the addition of four-bit binary numbers, and a cascade of full adders can be used to perform addition of multiple binary numbers. If there are M full adders, the condition $2^{M-1} < 10^N \leqslant 2^M$ must be satisfied to make the multi-bit adder compatible with the display device. Other components can be connected in parallel on other call paths.

This circuit can not only be used in the medical field, but also in competitions, where athletes press a button after completing a task to answer questions or start the clock; of course, it can also be used in the fire protection system, but the button operation method is changed, and the smoke alarm replaces the button. When the smoke alarm detects smoke with a concentration exceeding a certain level, it is equivalent to the button being pressed. Other parts of the circuit work in a similar principle. It can be seen that when the switching method is changed, the circuit can be used for detection and alarm in different scenarios, which is beneficial for timely maintenance and prevention of safety accidents.

References

[1] Balasubramanian P ,Maskell L D .Monotonic Asynchronous Two-Bit Full Adder[J].Electronics,2024.

[2] S S S ,G M .CMOS full adder cells based on modified full swing restored complementary pass transistor logic for energy efficient high speed arithmetic applications[J].Integration,2024.

[3] Samane A ,Reza M R ,Erfan S F .Energy-efficient and fast IMPLY-based approximate full adder applying NAND gates for image processing[J].Computers and Electrical Engineering,2024.

[4] Selvam K .Design of Function Circuits with 555 Timer Integrated Circuit[M].CRC Press:2022.

[5] Solar tracking system using pic16f84a , stepper motor and 555 timer[J].International Journal of Latest Trends in Engineering and Technology,2017.

[6] Bhat K A S .Zero-Voltage Switching of Thyristors Using 555 Timer[J].IETE Journal of Research,2015,25(10):436-437.

[7] Rathore S T .Timer 555 with Dual Supply[J].IETE Journal of Education,2015,34(2):85-90.

[8] Global LED Digital Tube Industry[J].M2 Presswire,2016,

[9] Silver W H .Experiment #161: Transistor Subtleties[J]. QST,2016,100(6):65-66.

[10] Yuki H ,Syafiq M A ,Aisyah S A , et al.Time-dependent characteristic of negative feedback optical amplifier at bit rates 10-Gbit/s based on an optical triode[J].Kinki Univ. (Japan);Brno Univ. of Technology (Czech Republic);Comenius Univ. in Bratislava (Slovakia);Czech Technical Univ. in Prague (Czech Republic),2015.