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The Research of Programmable Equivalent Capacitor Circuit

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Abstract: To meet the requirements of scientific research personnel on wide range and high-precision variable capacitor. The new digital capacitor is based on the impedance converting circuit. The new active impedance converting circuit is formed by integration operational amplifiers, a small amount of resistance and capacitance. Through control of the switching circuit part line, thus producing the equivalent pure capacitance.

Keywords: Programmable; Digital capacitor; impedance transformation

1 Introduction

In this paper, the circuit of equivalent capacitor is pure equivalent capacitance, so this will bring great convenience for many electronic circuit experiments and debugging, especially when the capacitance value is bigger. In this case. The same volume of the equivalent circuit can improve the integration of electronic circuits. It can possibly make some new devices. On the other hand, in this paper, the equivalent capacitance can be achieved by adjusting its value digitally, so it is easy to use microcontroller to adjust the capacitance value[1]-[5].

2 Impedance Generator Principle

2.1 Impedance generator principle

The impedance converting circuit is formed by operational amplifiers and shown in Figure 1.

Let Figure 1 for the ideal op amp, e1, e2, e3, e4, e5 is no devoltages. In figure 1, according to the op amp current knowledge and Kirchhoff's law, and then obtain the following equations:

$$e_1 = e_3 = e_5 \qquad (1)$$

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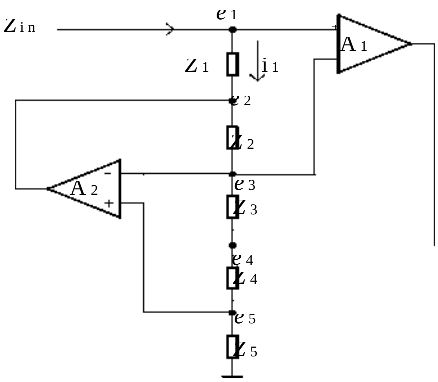

Fig. 1. Impedance converting circuit

$$\frac{e_1 - e_2}{Z_1} = i_1 \qquad (2)$$

$$\frac{e_3 - e_2}{Z_2} = \frac{e_4 - e_3}{Z_3} \qquad (3)$$

$$\frac{e_4 - e_5}{Z_4} = \frac{e_5}{Z_5} \qquad (4)$$

According to (1) ~ (4) equations, figure 1 is expressed as the equivalent impedance, Z_{in} :

$$Z_{in} = \frac{e_1}{i_1} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4} \qquad (5)$$

By (1) to (4) can also be educed

$$e_4 = e_1\left(1 + \frac{Z_4}{Z_5}\right) \qquad (6)$$

From (1), (3), (6) can get (7) equation

$$e_2 = e_1\left(1 - \frac{Z_2 Z_4}{Z_3 Z_5}\right) \quad (7)$$

According to the equation (5) ~ (7), we can know that Zin is proportional to Z_1,Z_3 and Z_5, and inversely proportional to Z_2 and Z_4. Phase and amplitude changes of e_1 is limited by e_2 , e_4 and Z_2~Z_5. In order to work in the op-amp dynamic range, e_4 and e_2 respectively work in op amps' (A_1 and A_2) maximum output voltage range. So, Z_2~Z_5 determine the op-amp output voltage of the dynamic range andZ_1determines the dynamic range of input current (i_1).

In the equation (5), impedance characteristics of Z_1~Z_5can be free to choose. But they actually must meet certain conditions, op-amp must form a DC loop and negative feedback loop of the phase change can cause oscillation. For example, when Z_1~Z_5 are capacitances in the circuit, circuit are does not work. Because there is no negative feedback loop formed.

From the formula ($Z_{in} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}$) analysis knowable, when $Z_1 = R_1$, $Z_2 = R_2$, $Z_3 = R_3$, $Z_4 = R_4$ and $Z_5 = \frac{1}{jwC_5}$, the formula represents impedance of a capacitor. The equivalent capacitance is $C_E = C_5 \frac{R_2 R_4}{R_1 R_3}$.

Considering that equivalent capacitance is easy to achieve in the circuit,
we choose C_5,R_1,R_2,R_3 for fixed capacitance or resistance,and changing the equivalent circuit depend on regulating R_4.

2.2 Digital capacitor circuit

Digital capacitor circuit is shown in Figure 2.In figure 2, A3 and A4 are buffers. When equivalent capacitance works in the high frequency range, they increase the op-amp output current. Digital potentiometer-X9110 was used instead of the resistance . The resistance value of the adjustment range is from 0Ω to 100kΩ. By adjusting the X9110 can realize the different capacitance values.

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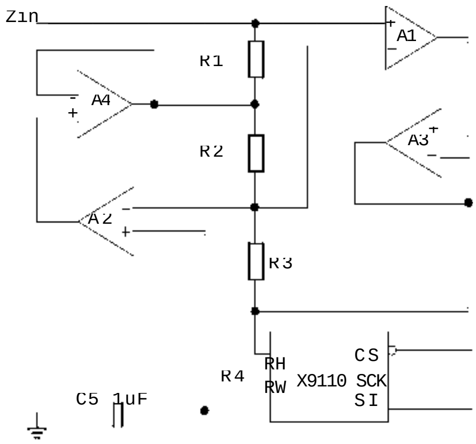

Fig. 2. Digital Capacitor Equivalent Circuit

The expression of equivalent capacitance is $C_E=DC_5$. In this expression D can be considered for (0-999) any number within.For example,C_5=1pF, within the scope of C_E in 0 ~ 999 pf is adjustable.C_5=1nF, within the scope of CE in 0 ~ 999 nf is adjustable.The unit of C_E can be changed by C_5.Also can choose different C_5 which is controled by analog switch to achieve the goal of changing the capacitor units.

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