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A KIND OF NEW AMPLIFIER*

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Chaotic characteristics in the iteration of logistic map (one-dimensional discrete dynamic system) are simulated and analyzed. The circuit implementation of a kind of chaotic amplifier model is based on the chaotic characteristics that chaos is sensitively dependent on its initial conditions, and the circuit simulation result is given using simulation program with integrated circuit emphasis for personal computer (PSPICE), and is compared with linear amplifier. Advantages and disadvantages of such a model are indicated.

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Chaos is a relatively normal phenomenon in nonlinear system. Lots of researches on chaos have been done with mathematical analysis, experimental observation and computer simulation, and many instructive results have been obtained.[1,2] On the one hand, chaotic behaviors occurring in a real engineering system are often unfavorable and even harmful sometimes. Therefore, dynamic behaviors of a system are usually controlled to avoid chaos or get rid of it.[3−6] On the other hand, chaos is not disorderly and it has inherent characteristics and laws that can be followed. So chaos can be regarded as an advantageous factor to be used. In recent years, people have been paying much attention to the use of the results paralleled with the study of chaos theory. More and more stress has been laid on this trend by academic and engineering fields in many countries. In this paper, the feasibility of designing a nonlinear chaotic amplifier is discussed based on the facts that the chaotic motion is sensitively dependent on its initial value and this value is one-to-one correspondent with the chaotic trajectory.

Many researchers and engineers have discovered or observed chaotic phenomena in their research field respectively since Lorenz found the chaotic phenomenon in 1963. The mathematical models of the chaotic phenomena were generalized. Some models are simple enough to be implemented and applied. "Insect population" model or logistic mapping:[1]

$$x_{n+1} = T(x_n) = 4x_n(1 - x_n) \tag{1}$$

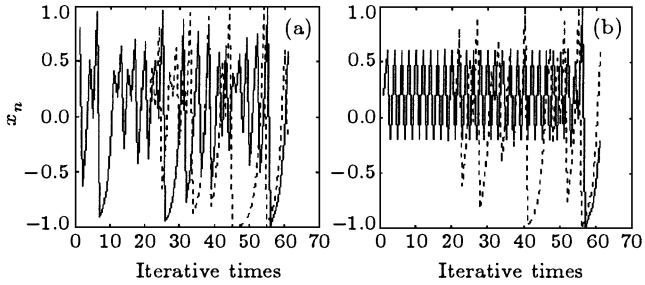


Fig.1. The sensitive dependence on initial conditions of logistic mapping.

is one of the simplest models that can generate chaos and can be simulated by circuit and implemented accurately. Figure 1 shows the iteration simulation when the initial conditions are 0.8111223 and 0.8111222 (Fig.1 (a), the solid line is the former, the dotted line is the latter) as well as 0.2 and 0.199999(Fig.1 (b), the solid line is the former, the dotted line is the latter). We can see that the simulation results are obviously different after limited iterations when the difference of the initial conditions is 10^{-6}. We can see that when there is a very small difference in initial conditions, the numerical value of logistic mapping is obviously different after limited iterations because of its chaotic property. We wonder whether the initial conditions can be distinguished by numerical values when there are many small differences in initial conditions. We get an affirmative answer from the basic theory of symbolic dynamics.

From the basic theory of symbolic dynamics we know that although chaotic system is sensitively dependent on initial conditions, each initial value has

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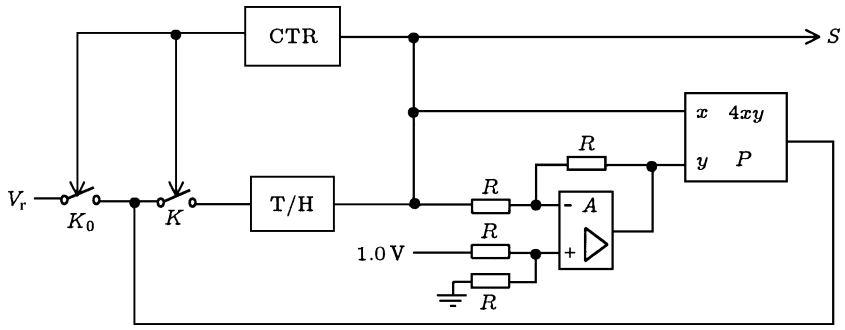


Fig.2. Simple circuit implementation of chaotic amplifier.

a one-to-one correspondence with the dynamic trajectory. Therefore, as to the logistic mapping, if we set the value less than zero to be zero, the value larger than zero to be one, then for each initial value x_0, there is a one-to-one correspondence sequence $(s_1 s_2 s_3 \cdots s_n \cdots)$ consisting of zero and one. We know that we can only use the first several finite terms to meet a certain required accuracy.[2]

Figure 2 presents the schematic diagram of logistic-mapping-based amplifier, and also the circuit schematic diagram. It can reflect the tiny variations of the input V_r through the output S squarewave sequences, which is equivalent to the amplification of the tiny signals. Thus nonlinear chaotic amplifier is feasible. The working process of nonlinear chaotic amplifier based on logistic mapping is: set the voltage which is needed to measure across V_r, the first pulse of the counter CTR makes the switch K_0 close and open (the switch K is always close in the course of iterations), the nonlinear amplifier A and multiplier P realize the first iteration of logistic mapping; then the computed voltage value of the first is sent to the holder T/H. The second iteration is the same as the first, so do the later iterations. The switch K will open when the computing times meet our demand. At the same time, the iterations are over. In Fig.2, the output of S is the correspondence of squarewave sequence of the input value of each V_r. Figure 3 shows the S squarewave

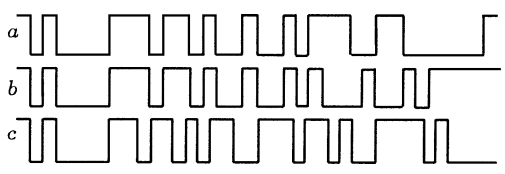


Fig.3. S squarewave sequences of circuit simulation.

sequence, which is correspondent to the different V_r values by circuit simulation (the V_r values of squarewave sequences of a, b, c are 0.5112221, 0.51112222, 0.5112223, respectively, 40 iterations). It is clear that the minute variance of V_r can be distinguished by S squarewave sequence.

A model of nonlinear chaotic amplifier is proposed in this paper, which is implemented by logistic mapping. The basic principle is that the minute variance of the measurement will be directly shown by the large difference between trajectories if the initial value of chaos system is the parameter variance, which we want to measure with a sensor. Chaotic amplifier has some advantages over the linear amplifier: 1) The magnitude of linear amplifier is a constant and it cannot realize very large magnitude because of the limitation of the linear working range of the system, otherwise it will exceed the linear range. While chaotic amplifier can amplify a small signal until it is observable by doing finite iterations repeatedly within the bounded range and it is not limited by the linear range. 2) The linear amplifier has a high demand of sampling accuracy of signals, otherwise it will linearly amplify the error so that the measuring accuracy degrades; while chaotic amplifier can find a one-to-one correspondent dynamic trajectory to each initial value so that the requirement of sampling accuracy of signals can be reduced and the error caused by measurement can be decreased largely. Chaotic amplifier also has some disadvantages against linear amplifier: 1) The difference of measured values can be indicated obviously and directly by linear amplifier, whereas it cannot by chaotic amplifier. 2) Because a chaotic amplifier realizes amplification by multiple iteration, the disturbance of electrical parameters will result in accumulated error of iteration computation in a real system. This is the main factor that affects the accuracy of a chaotic amplifier.

In conclusion, a chaotic amplifier has high sensitivity and resolution so that extensive applications can be expected in the fields of metal defect detection that demands high accuracy, the measurement of

minute crack in mechanical instruments and system identification. Meanwhile, chaotic amplifier will greatly affect and accelerate the study and development of control and measuring techniques. Although chaotic amplifier has some disadvantages compared with linear amplifier, these disadvantages will be overcome with the development of technology and the profound study of chaos theory.

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