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Realisation of electronic circuit based on modified rossler system and its application in secure communication

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ABSTRACT

The present article described the design technique of hardware electronic circuit based on modified Rossler equations. The dynamical behaviour of the proposed system has been studied by computer simulation and in electronic experiment. The results of periodic and chaotic behaviour of the hardware circuit are reported. Next the synchronization between two such electronic circuits is experimentally verified and a secure scheme of communication is described using chaos masking technique. The hardware experimental results are incorporated in this article to support the design algorithm.

Introduction

Over the last two decades the field of chaotic synchronization [1] and its applications [2] have grown considerably due to the attractive properties of the chaotic systems like- sensitivity to initial conditions and parameter values. The synchronizationis important in diverse fields of study including communications [3], electronic circuit and systems [4], nano-oscillators [5] and biological systems [6]. There are several types of possible synchronization [7-10] namely feedback synchronization, phase synchronization, lag synchronization, generalized synchronization, anti-synchronization are studied due to their relevance in different field of application. But in the field of electronic application, the feedback synchronization is the simplest one, which can be achieved by unidirectional coupling between two identical chaotic systems. In this synchronization scheme the second system (slave or response) is dependent on the behaviour of the identical first system (master or driver) but the converse is not true. In this feedback system, as time elapses, the strength of feedback decreases and soon both the driver and response systems achieve complete synchronization by following the same trajectory and afterward the feedback strength becomes zero and identical synchronization persists.Chaotic synchronization is important in the field of electronic communication because it is secured and interference free.

In this article we have studied the dynamics of the modified Rössler system by solving its system equations using fourth order Runge-Kutta method in MATLAL simulation. Next we have implemented the system in an electronic circuit and its response has been observed and recorded with the help of digital storage oscilloscope. The unidirectional synchronization between two such identical systems is also demonstrated electronically and its possible applications using chaos masking technique is also included in this article.

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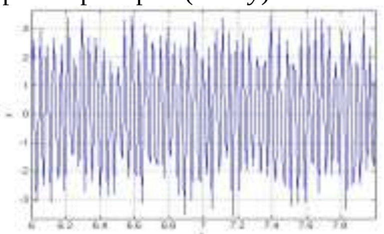
Therest of the paper is organizedas follows. In section 2 we have mention modified Rössler system equations and it mathematical simulation results in chaotic region. Next section 3 contains the electronic design approach for the system equation (1) and its output behaviour with parameter values. Section 4 contains the synchronization technique and its possible applications insecure communication. The article concludes in section 5.

System equation and simulation results

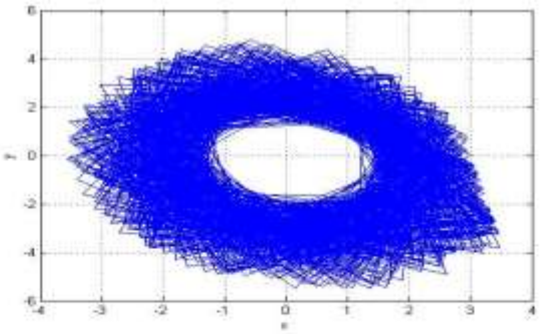
One multiplication term was present in the nonlinear system equation described by Rössler in 1976 [11]. But the system equations described here has no multiplication term. The equation contain only one nonlinear term $g(x)$, which is piecewise linear function of *x* and the system is given by [12]:

$$\left.\begin{aligned} \dot{x} &= -\alpha[\Gamma x + \beta y + \lambda z] \\ \dot{y} &= -\alpha[-x - \gamma y + 0.02z] \\ \dot{z} &= -\alpha[-g(x) + z] \end{aligned}\right\} \quad (1)$$

The function $g(x)$ is the only nonlinear component of the system and it is defined as $g(x) = 0$ for $x \le 3$ and $g(x) = \mu(x-3)$ for $x > 3$. In this equation, using the parameters $\alpha = 10^4 s^{-1}$, $\Gamma = 0.05$, $\beta = 0.5$, $\lambda = 1.0$, $\gamma = 0.13$, $\mu = 15$, we get the resulting behaviour of the system is chaotic. The equation (1) has been solved using fourth order Runge-Kutta method and the results for above parameter values are shown in Fig. 1. The time domain view of the chaotic response of the variable *x* is depicted in Fig. 1(a) and the corresponding phase space plot (*x* vs. *y*) is shown in Fig. 1(b).



(a)



(b)

Fig.1 Chaotic response of the modified Rössler system: (a) Time domain view of the variable *x* and (b) Phase space plot (*x* vs. *y*).

Electronic circuit realisation and experimental results

The hardware electronic circuit of the modified Rössler system has been design using commercially available operational amplifiers (Op-amp IC 741), *P-N* junction diode and passive electronic components like capacitors and resistors as shown in Fig. 2.According to circuit configuration the diode turns on when the voltage across it is greater than 3V and thus models the nonlinearityfunction $g(x)$. All the Op-amps are operated in their inverting modes to account for the negative term of each equation. The operational amplifiers OP-1, OP-2 and OP-3 act as integrators for the system with *x*, *y* and *z* as their outputs respectively. The resistors are connected in parallel with the capacitors to reduce the gain of the integrators. The term $\gamma = 10^4/_R$ is the control parameter of this system. The variable resistor *R* indicated in Fig. 2 is measured in KΩ. Here the constant$\alpha\Gamma$ is the time constant of the feedback element across OP-1. Similarly, 0.02α and α account for the feedback across OP-2 and OP-3 respectively. The gain of OP-4is denoteded by γ. The parameter β is represented as the voltage across the 200KΩ resistor at the input of OP-1.

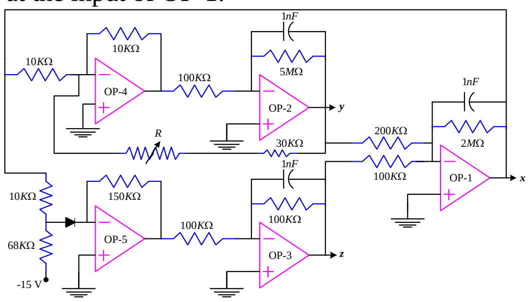


Fig. 2 Electronic circuit representation of the modified Rössler system [equation (1)

The electronic circuit represented in Fig. 2 is also simulated using circuit simulation software MULTISIM and the simulated result in the chaotic region is also shown in Fig. 3. To obtained hardware circuit results, the outputs *x* and *y* are connected to the channels 1 and 2 of a digital storage oscilloscope.

Simultaneously, the frequency response of the output *x* is recorded with the help of spectrum analyzer. The experimental results for the system, in terms of phase space, time series and spectrum of the isolated master system for different values of *R*are shown in Fig. 4. It shows fixed point for *R* > 141 and periodic behaviour for 141 ≤ R < 32.11 and chaotic behaviour for lower resistance values. We have also observedthe islands of stability within the chaotic region as described in the figures.

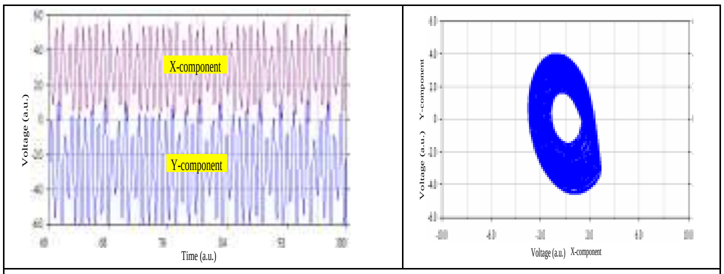
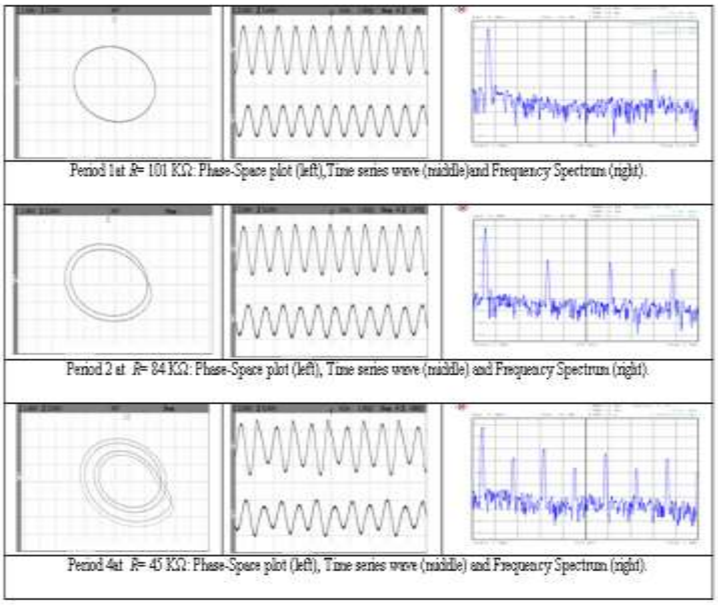


Fig. 3 Chaotic response of the circuit mention in Fig. 2 using MULTISIM simulation with *R* = 34 KΩ (time domain view and phase space plot).



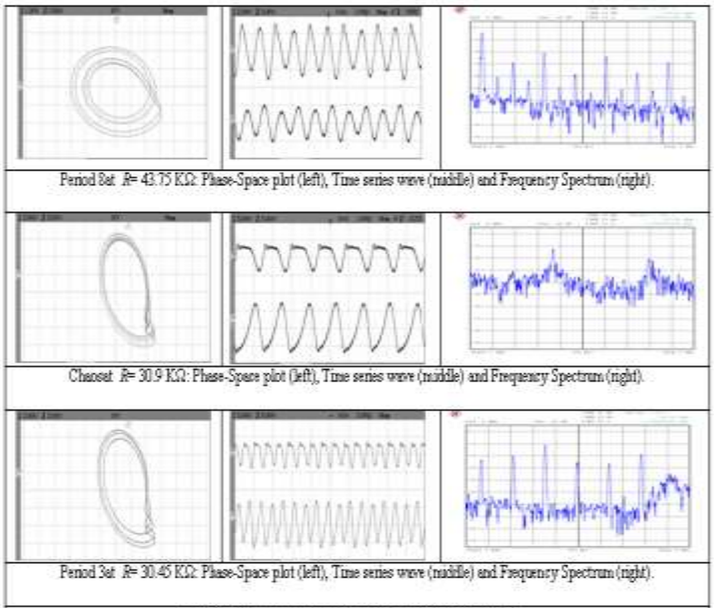


Fig. 3 Hardware experimental results for different values of R

Synchronization and application

The synchronization between two modified Rössler systems has been described in Fig. 4. The synchronization has been achieved by forcing the slave system by the *y*- output voltage of the master system. As a result, the slave system is forced to follow a specific function of the dynamics of the master. The control parameter *R* of the master circuit is changed to observe the synchronized performance of the coupled system in the periodic region and as well as in chaotic region. There is no synchronization between master and slave when the electrical connection (dashed line) is removed between master-slave system and unsynchronized results are shown in Fig. 5. The time domain and phase space plot of the *x*- output of the isolated master and slave system under unsynchronized operation is shown in Fig. 5(a) and Fig. 5(b) respectively. However, when the master and slave circuits are coupled electrically by the *y* output of the master system, the slave system becomes synchronized with respect to the master system. This is depicted by the straight-line inclined at an angle of 45^0 and passing through the origin in Fig. 6(b). The time domain view (*x*- output of the both system) under this condition is shown in Fig. 6(a). Thus, these results confirmed the existence of in-phase synchronization between the two subsystems.

In case of application of chaos, we have used the popular chaos masking technique for communication of data from transmitter to the receiver side as depicted in Fig. 7. The original massage signal, $m(t)$ at the transmitter end is masked with the chaotic output *x* of the master system using simple adder circuit. The chaos masking signal $m(t) + x$ and the *y* output of the master system are transmitted towards the receiver. The *y* signal is used to synchronized the slave system and we recovered massage signal $m(t)$ at the receiver end by subtracting *x*- output of slave from the signal $m(t) + x$. This is possible only because the master and slave subsystems were completely synchronized and hence, the *x*- output of the slave system is exactly same as the *x*- output by the master. The experimental results for implementing this communication scheme in small scale in the laboratory setup using continuous signal of frequency 1 KHz has been reported in Fig. 8. The output chaotic signal (channel 1: yellow colour) and chaos masking signal (channel 2: sky blue colour) are shown in Fig. 8(a). The transmitted massage signal (channel 1: yellow colour) and recover massage signal (channel 2: sky blue colour) are shown in Fig. 8(b). These results proved the validity of the secure communication using chaos masking technique.

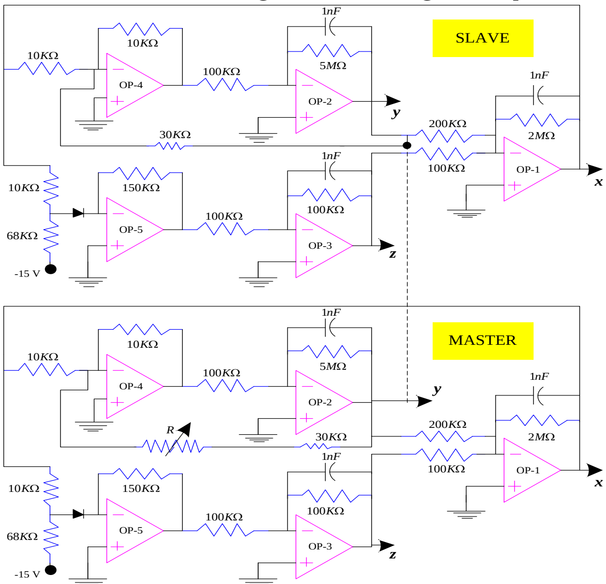


Fig. 4 Coupled master-slave system for chaos synchronization.

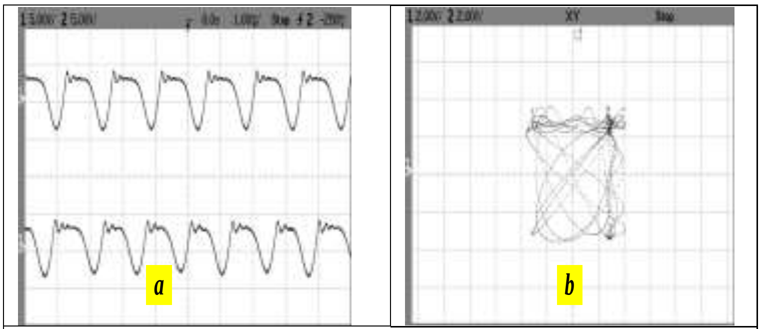


Fig. 5 Unsynchronized output from the master and slave circuit: (a) time domain view of *x* output, (b) phase space plot of *x* output of the master and slave system.

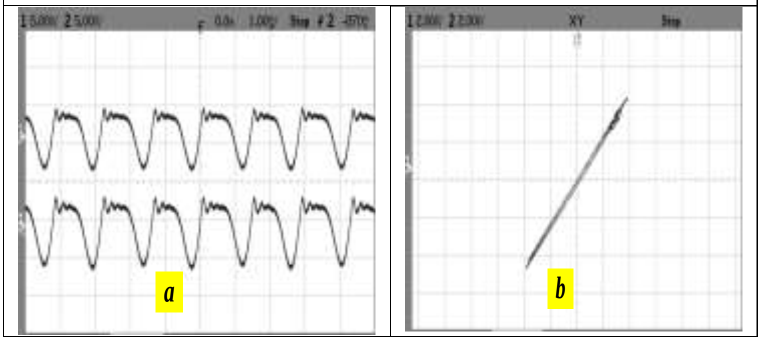


Fig. 6 Synchronized output from the master and slave circuit: (a) time domain view of *x* output, (b) phase space plot of *x* output of the master and slave system.

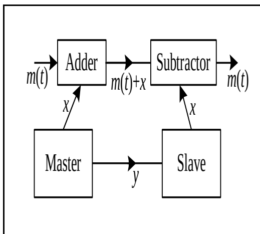


Fig. 7 Basic block diagram for Secure communication using chaos masking.

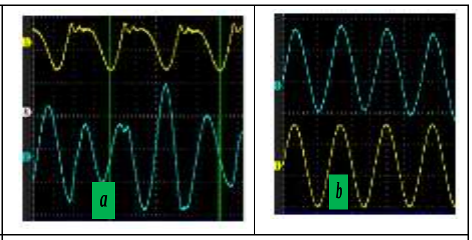


Fig. 8 Experimental results of secure communication: (a) Channel-1Chaotic signal *x* (yellow), Channel-2 chaos masking signal *x* + *m*(*t*) (sky blue); (b) Channel-1 transmitted information signal *m*(*t*) (yellow), Channel-2 regenerated information signal (sky blue). Vertical axis: 5V/div., Horizontal axis: 500μs/div.

Conclusion

The present article describe how chaotic equations have been modelled by simple electronic circuit, and how its output characteristic can be varied from chaotic to periodic to steady state behaviour by using simple resistor. This work also shows the synchronization of the Rössler type system with an equivalent system, and how this scheme can be utilized for attaining secure communication. Hence, we conclude this article by pointing out that chaotic communication systems offer increased security in transmission because of the high sensitivity of chaotic signals to parameter and initial condition perturbation. This method can be improved to attain stronger coupling between the subsystems, so that it can be implemented in the large scale commercially. Thus, chaotic masking of information will become an efficient tool in communication engineering for sending and receiving confidential information.

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