Research Article

Dynamic Systems Enhanced by Electronic Circuits on 7D

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Hybrid synchronization is one of the most significant aspects of a dynamic system. We achieve nonlinear control unit results to synchronize two comparable 7D structures in this study. Many dynamic systems are directly connected to health care and directly enhance health. We employed linearization and Lyapunov as analytical methods, and since the linearization method does not need updating the Lyapunov function, it is more successful in achieving synchronization phenomena with better outcomes than the Lyapunov method. The two methods were combined, and the result was a striking resemblance to the dynamic system's mistake. The mathematical system with control and error of the dynamic system was subjected to digital emulation. The digital good outcomes were comparable to the two methods previously stated. We compared the outcomes of three hybrid synchronizations based on Lyapunov and linearization methods. Finally, we used the existing system, presenting it in a new attractor and comparing the findings to those of other similar systems.

1. Introduction

Real-world turbulent dynamics are studied and analyzed with greater importance in many aspects of nonlinear dynamic systems. The Lorenz system, which includes only true variables and was uncovered in 1963, is the first physical and mathematical model of a chaotic system, opening new pathways to other chaos systems such as the Chen system, Liu system , Lu's system, and Pan system. In each system, there are 3D differential equations and a positive exponent of Lyapunov [1–5].

In the complete synchronization scheme, we focused on the nonlinear control strategy, and another method was suggested, namely, linearization; in addition, we used the Lyapunov method which is adopted in all previous works in order to compare and verify between the two methods. The results show that the linearization method is the best for achieving the synchronization; because the stability Lyapunov method needs, the Lyapunov exponent and the nonlinear dynamic system attractor are the base. Encryption [6–9], engineering [10–13], and nonlinear trunks [14] have generated greater interest in computer technology and other science applications. Safe networking is one of the leading engineering technologies. Messages made nuts by simple dysfunction mechanisms are not inherently stable. To solve this problem, the idea is higher dimensions, hyperchaotic systems, eradicate randomness, and unpredictability from the equation [15–17].

Rössler found the first 7D hyperchaotic system in 1979, containing real variables and two positive exponents for Lyapunov, as well as alternative 7D and 5D systems, with three positive exponents for Lyapunov [18]. Complex structures in higher dimensions are more efficient than low-dimensional systems [19–21].

Most papers deal with the contemporary hyperchaotic systems in higher dimensions (5D). The majority of experiments are focused on 7D and 5D systems and some studies are carried out in 6D nonlinear dynamic systems [20]. The equilibrium and equilibrium exponents from Lyapunov include the characteristics of 7D, which include ten operators with seven parameters and different functions. The exciting attractor is one of the latest dynamic systems with recent studies which differentiate between autonomous and secret types of attractors. In the following paragraphs, the results of this review are outlined.

(i) The coordination between related 7D hyperchaotic structures is therefore explored, and a computational engineering application is suggested to distinguish dynamics errors for each and their secure contact

(ii) Nonlinear control is based on Lyapunov stability techniques, and linearization creates a large number of controllers for various synchronization phenomena

(iii) The right controllers are calculated by comparing the effects of the Lyapunov and linearization processes

2. The Description of the Problem and Our Solution

This research provides the second Lyapunov approach and linearization methods in which it shows that Lyapunov serves as a specific building tool:

$$V(e) = \frac{1}{2} \sum_{i=1}^{n} e_i^2 = e^T P e,$$

$$P = \text{diag}\left(\frac{1}{2}, \frac{1}{2}, ..., \frac{1}{2}\right),$$

(1)

where P denotes a normal function and R denotes a random function.

Derivatives of the Lyapunov function:

$$\dot{V}(e) = \sum_{i=1}^{n} e_i \dot{e}_i = -e^T Q e.$$

(2)

This is clearly a negative result since Q is a positive matrix of the cube. In the case of negative Q matrix, however, the P matrix must be modified, in order to achieve the optimal Q matrix.

In the last two decades, extensive studies have been conducted on the properties of nonlinear dynamical systems. The most important characteristic of nonlinear dynamical systems is chaos. This phenomenon is an important topic in nonlinear sciences and has been extensively investigated in mathematics, physics, engineering sciences, and communications secrecy.

In a nutshell, this final point clarifies three key questions. Is the Lyapunov method always successful? Is the linearization method, on the contrary, superior? And, finally, how can we tell the difference between these two approaches? This paper establishes the preceding questions and, in the end, provides a clear answer to them.

3. System Portrayal

The Lorenz method is the most common 3D chaotic system and is widely applied. Using a linear feedback control system, the original architecture is converted into a 5D and 7D hyperchaotic configuration. The built 7D hyperchaotic frame is made up of $LE_1 = 0.94613$, $LE_2 = 0.28714$, $LE_3 = 0.0047625$, and $LE_5 = -0.19386$, $LE_6 = -0.79691$, and $LE_7 = -12.701$. The system is mathematically explained as follows:

$$\begin{cases} x = a(y - x) + u, \\ y = cx - xz + w - y + hs, \\ z = xy - bz, \\ u = -xz + hu - v, \\ v = qy - pv - rx, \\ w = rv + qs - px, \\ s = ry - qw. \end{cases}$$

(3)

The variables $x_1, x_2, x_3, x_4, x_5, x_6, x_7$, as well as the parameters a, b, c, h, p, q, and r, all have positive real values equal to (10, 8/3, 28, 1, 0.2, 8, 0.5), and this 7D device is filled with dynamical properties. Figures 1 and 2 depict the system's 3D attractor (3), while Figures 3 and 4 depict the structure's 2D attractor (3).

3.1. Lyapunov Exponents and Dimensions. A numerical emulation of $a = 10, b = 8/3, c = 28, h = 1, p = 0.2, q = 8$, and $r = 0.5$ was proved using MATLAB and Wolf algorithm. $LE_1 = 0.9461$, $LE_2 = 0.2871$, $LE_3 = 0.0048$, $LE_4 = 0.0007$, $LE_5 = -0.19386$, $LE_6 = -0.7969$, and $LE_7 = -12.702$, with three positive Lyapunov exponents, $LE_1 = 0.9461, LE_2 = 0.2871$, $LE_3 = 0.0048$, $LE_4 = 0.0007$, $LE_5 = -0.19386$, and $LE_6 = -0.7969, LE$.

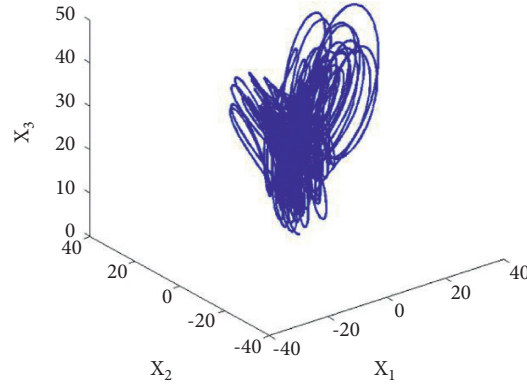Figure 5 depicts the exponents of the Lyapunov diagram. Lyapunov's proportions are as follows:

FIGURE 1: Three-dimensional attractor of system (3) in the (x_1, x_2, x_3) space.

$$D_{LE} = j + \frac{1}{\left|LE_{j+1}\right|} \sum_{i=1}^{j} LE_i = 6 + \frac{LE_1 + LE_2 + LE_3 + LE_4 + LE_5 + LE_6}{\left|LE_7\right|} = -0.012798. \tag{4}$$

3.2. Hybrid Synchronization.

Theoretically, this section establishes with its numerical emulation which is one of the main applications of protected information engineering. The first device (known as the drive system) thus represents the massage information to be communicated, while the second system displays the sound preceding this information to keep it from being violated. Suppose the computer (3) is a drive and the second method is written (called response system).

Hybrid synchronization, where one part of the system is synchronized with another part of asynchrony so that full synchronization and asynchrony coexist in the system mathematically; the phenomenon of hybrid synchronization of the two systems is achieved when $\lim_{t \to \infty} Y - \alpha X = 0$, where Y and X are the state vectors of the drive-response system, respectively, and $(\alpha = \mp 1)$:

$$\begin{cases} x = a(y - x) + u, \\ y = cx - xz + w - y + hs, \\ z = xy - bz, \\ u = -xz + hu - v, \\ v = qy - pv - rx, \\ w = rv + qs - px, \\ s = ry - qw. \end{cases} \tag{5}$$

While the response system is as follows:

$$\begin{cases} x' = a(y' - x') + u' + u_1, \\ y' = cx' - x'z' + w' - y' + hs' + u_2, \\ z' = x'y' - bz' + u_3, \\ u' = -x'z' + hu' - v' + u_4, \\ v' = qy' - pv' - rx' + u_5, \\ w' = rv' + qs' - px' + u_6, \\ s' = ry' - qw' + u_7, \end{cases} \tag{6}$$

and let $U = [u_1, u_2, u_3, u_4, u_5, u_6, u_7]^T$ be the nonlinear controller to be designed.

The 7D hyperchaotic system (4) and system (5) synchronization error dynamics are known as

$$e_i = x' \pm \alpha_i x,$$
$$i = 1, 2, 3, 4, 5.6, 7, \tag{7}$$
$$\lim_{t \to \infty} e_i = 0.$$

Response system and hybrid synchronization are satisfied. The following is a description of the error's dynamics:

$$\begin{cases} \dot{e}_1 = ae_2 = ae_1 + e_4 - 2u + u_1, \\ \dot{e}_2 = ce_1 + 2cx - e_2 - x'e_3 + ze_1 = 2x'z + e_6 + he_7, \\ \dot{e}_3 = -be_3 + e_1e_2 - ye_1 + xe_2 - 2xy + u_3, \\ \dot{e}_4 = he_4 - x'e_3 + ze_1 - 2x'z - e_5 - 2v + u_4, \\ \dot{e}_5 = qe_2 - 2qy - pe_5 - ge_1 + u_5, \\ \dot{e}_6 = ge_5 + 2v - qe_7 + 2s + pe_1 + u_6, \\ \dot{e}_7 = -qe_6 - 2w + ge_2 - 2y + u_6. \end{cases} \tag{8}$$

System (7) of error dynamics is unpredictable based on linearization approach and legislation $|\lambda I_6 - J_{E_1}| = 0$.

$$-x^7 - \frac{193}{15}x^6 + \frac{3163}{10}x^5 + \frac{13661}{10}x^4 - \frac{505483}{30}x^3 - \frac{411241}{12}x^2 + \frac{816488}{15}x + 46576,$$

$$\begin{cases} \lambda_1 = -8, \\\\ \lambda_2 = -\dfrac{8}{3}, \\\\ \lambda_3 = 11.8983, \\\\ \lambda_4 = 7.8681, \\\\ \lambda_5 = 1.5246, \\\\ \lambda_6 = -0.6703, \\\\ \lambda_7 = -22.8207. \end{cases} \tag{9}$$

After many controller systems have been developed using Lyapunov and linearization approach, we can calculate the power of the error mechanism (6). The concern arises as to which of these two tactics is superior. Our questions are answered by the following theorems.

Theorem 1. *If the regulator U of structure (6) is the scheme as*

$$\begin{cases} u_1 = -ae_2 - e_4 + 2u, \\ u_2 = -ce_1 - 2cx + x'e_3 - ze_1 + 2x'z - e_6 - he_7 - 2s, \\ u_3 = -e_1 e_2 + ye_1 - xe_2 + 2xy, \\ u_4 = -2he_4 + x'e_3 - ze_1 + 2x'z + e_5 + 2v, \\ u_5 = -qe_2 + 2qy + ge_1, \\ u_6 = -ge_5 - +2v + qe_7 - 2s - pe_1 - e_6, \\ u_7 = qe_6 + 2w - ge_2 + 2y - e_7. \end{cases} \tag{10}$$

Machine (6) can then be monitored using two different methods (5).

The characteristic equation and eigenvalues are, respectively, as

Proof. If we replace the error dynamics (6) mechanism with control,

$$\begin{cases} \dot{e}_1 = -ae_1, \\ \dot{e}_2 = -e_2, \\ \dot{e}_3 = -be_3, \\ \dot{e}_4 = -he_4, \\ \dot{e}_5 = -pe_5, \\ \dot{e}_6 = -e_6, \\ \dot{e}_7 = -e_7, \end{cases} \tag{11}$$

positively defined Lyapunovs are successfully built and elected, depending on the rules of Lyapunov method:

$$V(e) = e^T P e = \frac{1}{2}e_1^2 + \frac{1}{2}e_2^2 + \frac{1}{2}e_3^2 + \frac{1}{2}e_4^2 + \frac{1}{2}e_5^2 + \frac{1}{2}e_6^2 + \frac{1}{2}e_7^2, \tag{12}$$

where P is defined in formula (1); the derivative function of Lyapunov V(e) is related to time:

$$\begin{aligned} \dot{V} &= e_1\dot{e}_1 + e_2\dot{e}_2 + e_3\dot{e}_3 + e_4\dot{e}_4 + e_5\dot{e}_5 + e_6\dot{e}_6 + e_7\dot{e}_7, \\ \dot{V} &= e_1(-ae_1) + e_2(-e_2) + e_3(-be_3) + e_4(-he_4) + e_5(-pe_5) + e_6(-e_6) + e_7(-e_7), \\ \dot{V} &= -ae_1^2 - e_2^2 - be_3^2 - he_4^2 - pe_5^2 - e_6^2 - e_7^2 = -e^T Q e, \end{aligned} \tag{13}$$
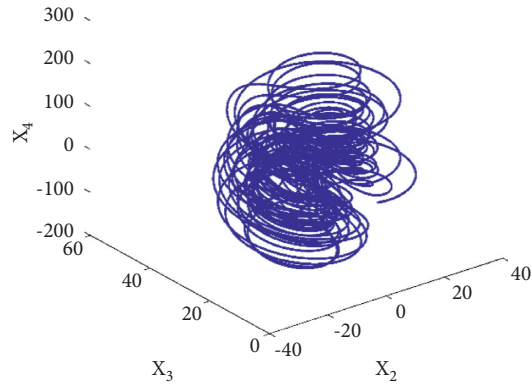
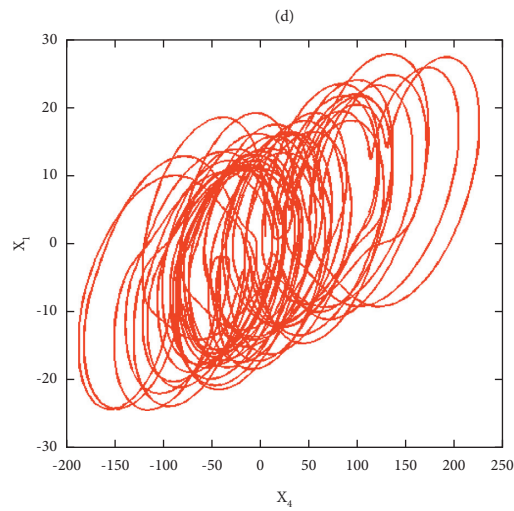FIGURE 2: Three-dimensional attractor of system (3) in the (x_2, x_3, x_4) space.

FIGURE 3: Two-dimensional attractor of system (3) in the (x_4, x_1) plane.

where $Q = \text{diag}(a, 1, b, h, p, 1, 1)$, so $Q > 0$. Consequently, $\dot{V}(e_i)$ is negative definite on R^4. The nonlinear controller works and eventually the syncing is complete.

In the second method (linearization method), the law $|\lambda I_6 - J_{E_1}| = 0$ on system (11) is applied; then, the given equations and eigenvalues are shown as follows:

$$x^7 + \frac{253}{15}x^6 + \frac{260}{3}x^5 + \frac{610}{3}x^4 + 249x^3 + \frac{485}{3}x^2 + \frac{758}{15}x^1 + \frac{16}{3},$$

$$\begin{cases} \lambda_1 = -1, \\ \lambda_2 = -1, \\ \lambda_3 = -1, \\ \lambda_4 = -1, \\ \lambda_5 = -10, \\ \lambda_6 = -1/5, \\ \lambda_7 = -8/5. \end{cases} \tag{14}$$
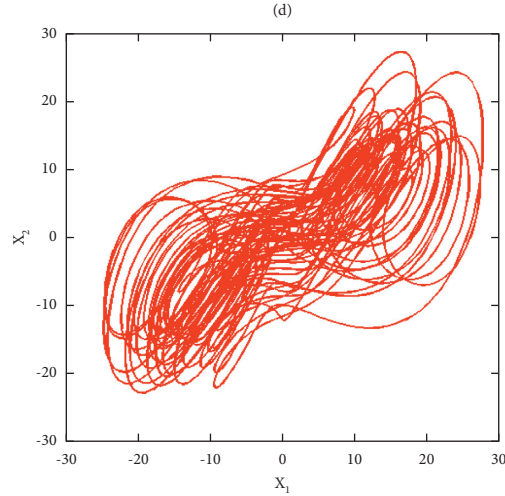
FIGURE 4: Two-dimensional attractor of system (3) in the (x_1, x_2) plane.

Naturally, linearization is done with unit (5) to machine hybrid synchronization (6).

Of course, in all roots with negative real components, the linearization process successfully synchronizes system (6) and system (5). Figure 6 shows the numerical inspections of those steps. Figure 7 contains the eigenvalues during the response of driving processes and drive systems for controlling the convergence of the system. □

4. Circuit Experiment

Utilizing Kirchhoff's law, the corresponding circuit equations can be written as

$$
\begin{cases}
\dot{X} = \dfrac{1}{C_1 R_1}(X) + \dfrac{1}{C_1 R_2}\dfrac{R_5}{R_4}(-Y) + \dfrac{1}{C_1 R_2}\dfrac{R_7}{R_6}(-U), \\[2mm]
\dot{Y} = \dfrac{1}{C_2 R_{10}}\dfrac{R_9}{R_8}(-X) + \dfrac{1}{C_2 R_{11}}(X*Z) + \dfrac{1}{C_2 R_{12}}\dfrac{R_{16}}{R_{15}}(-W) + \dfrac{1}{C_2 R_{13}}(Y) + \dfrac{1}{C_2 R_{14}}\dfrac{R_7}{R_6}(-S), \\[2mm]
\dot{Z} = \dfrac{1}{C_3 R_{21}}\dfrac{R_{22}}{R_{21}}(-X*Y) + \dfrac{1}{C_3 R_{24}}(Z), \\[2mm]
\dot{U} = \dfrac{1}{C_4 R_{27}}(X*Z) + \dfrac{1}{C_4 R_{28}}\dfrac{R_{31}}{R_{30}}(-U) + \dfrac{1}{C_4 R_{29}}(V), \\[2mm]
\dot{V} = \dfrac{1}{C_5 R_{34}}\dfrac{R_{33}}{R_{32}}(-Y) + \dfrac{1}{C_5 R_{35}}(V) + \dfrac{1}{C_5 R_{36}}(X), \\[2mm]
\dot{W} = \dfrac{1}{C_6 R_{39}}\dfrac{R_{38}}{R_{37}}(-V) + \dfrac{1}{C_6 R_{40}}\dfrac{R_{43}}{R_{42}}(-S) + \dfrac{1}{C_6 R_{41}}(X), \\[2mm]
\dot{S} = \dfrac{1}{C_7 R_{46}}\dfrac{R_{45}}{R_{44}}(-Y) + \dfrac{1}{C_7 R_{47}}(X),
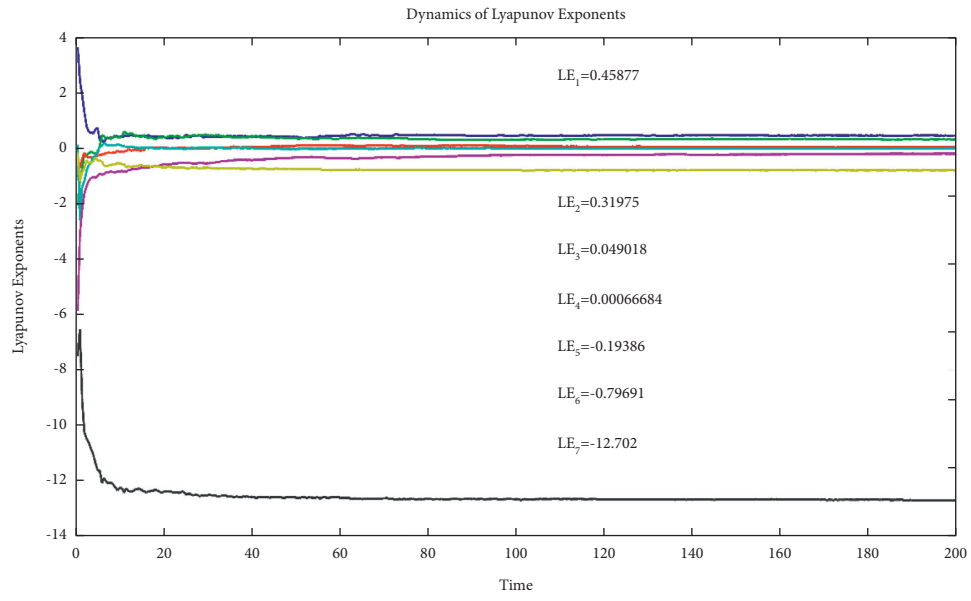\end{cases}
\tag{15}
$$

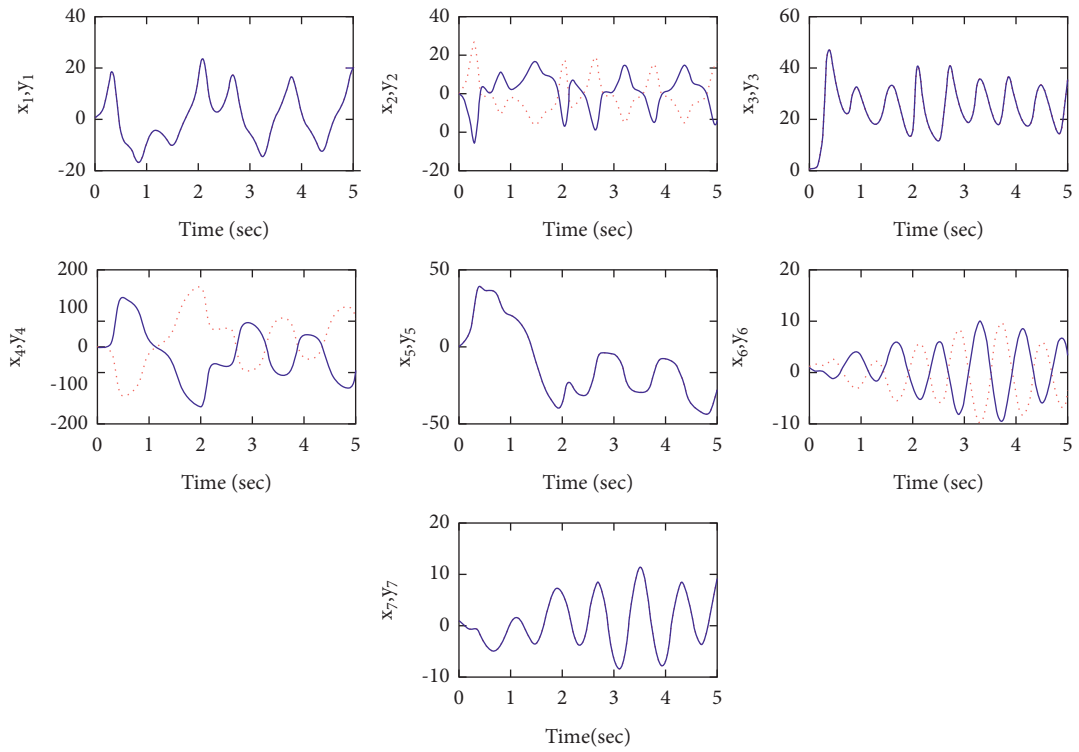FIGURE 5: Seven-dimensional hyperchaotic system exponents of Lyapunov.

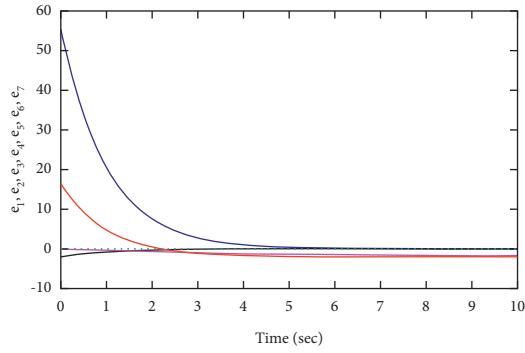FIGURE 6: Hybrid synchronization between systems (6) and (5) with control (7).
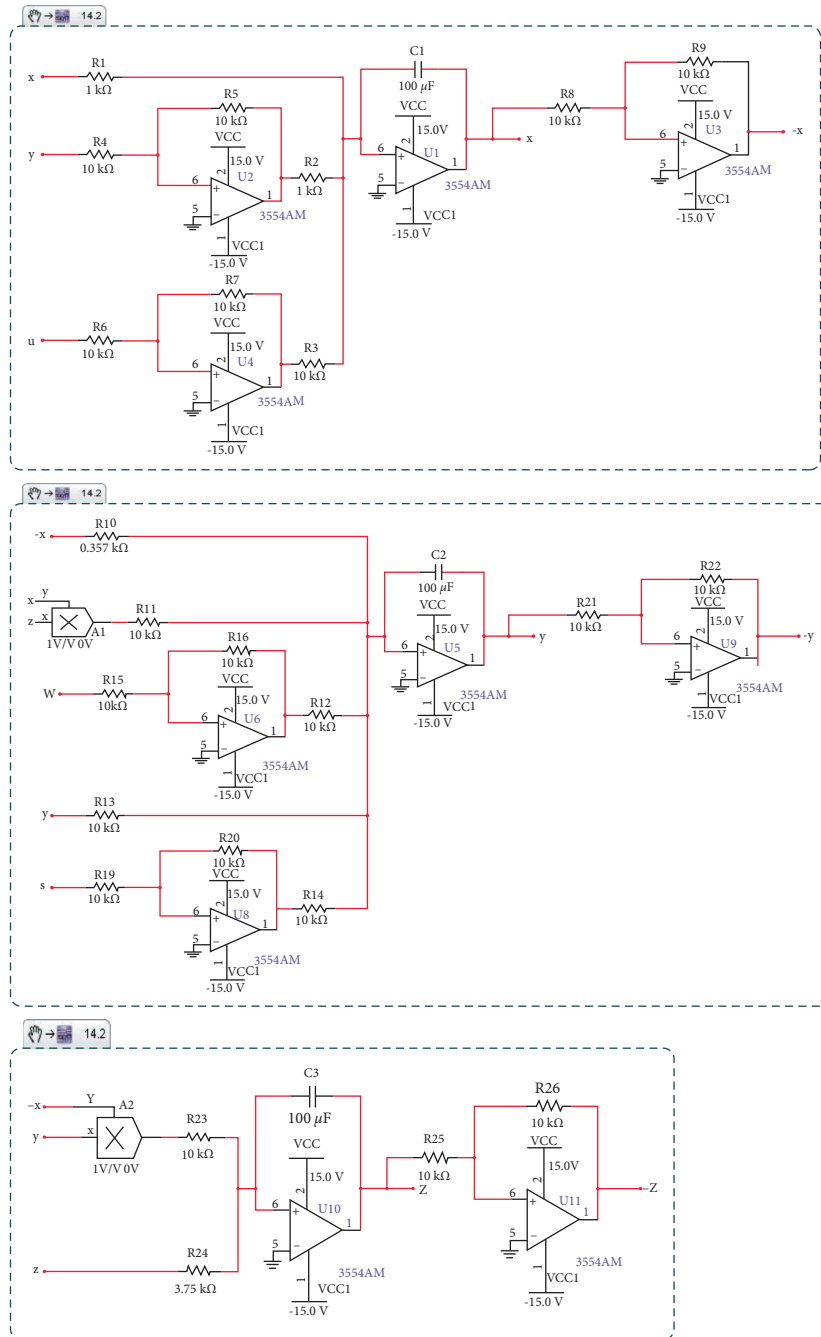
FIGURE 7: The convergence of system (8) with controller (7).
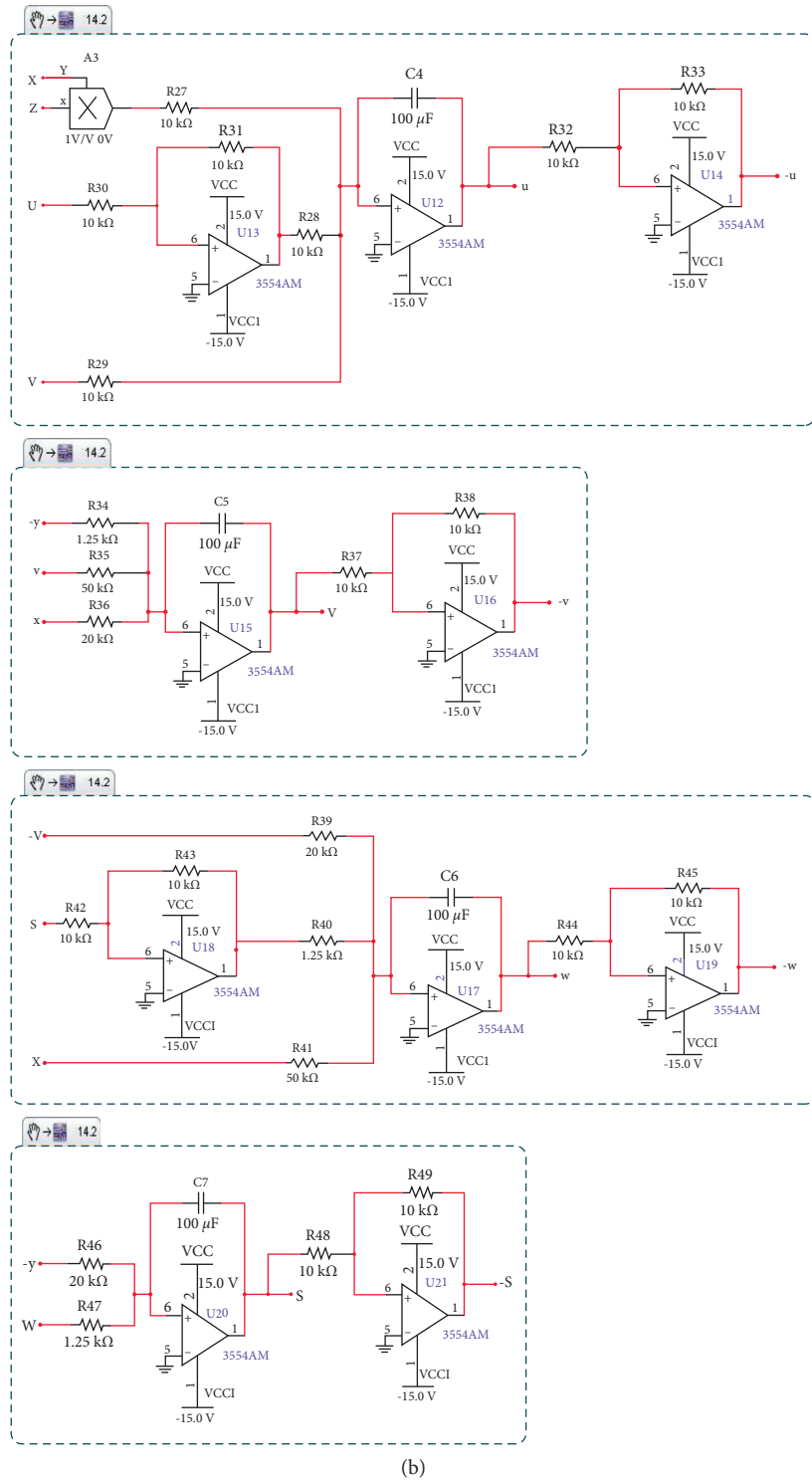

(a)

FIGURE 8: Continued.

(b)

Figure 8: Circuit diagram of system (1).

where x', y', z', u', v', w', and s' represent voltages on capacitors C_1, C_2, C_3, C_4, C_5, C_6, and C_7, respectively. The implement circuit is shown in Figure 8.

5. Conclusions

By Lyapunov and linearization techniques, we have been attempting to comprehend the inconsistencies in each step and how to achieve synchronization. To achieve hybrid synchronization, two identical 7D hyperchaotic systems are employed in this article. What is the most effective method? This study uses the linearization technique to answer such problems based on the outcomes and comparisons conducted between the two processes. It is important to note that the Lyapunov method should not be changed or constructed as a supporting function. The linearization method is superior to the Lyapunov way. The same results were explained using a computer simulation.

Data Availability

The data underlying the results presented in the study are available within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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