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Comment

Comment on "A new feedback control of a modified Chua's circuit system"

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Abstract

Errors in Hwang et al. (1996) are pointed out. The correct results are presented. To demonstrate the errors, computer simulation results are provided.

Keywords: Nonlinear control; Chaos; Chua's circuit

In [1], the authors presented a new feedback control scheme on Chua's circuit with cubic nonlinearity. While the computer simulation results seem to be promising, there exist some errors in [1]. We rewrite Eqs. (2) and (3) of [1] as follows:

$$\dot{x} = p(y + \tfrac{1}{7}(x - 2x^3)), \qquad \dot{y} = x - y + z, \qquad \dot{z} = -\tfrac{100}{7}y + u, \tag{1}$$

where

$$u = k(x - y + z) + qy + k_p(x_{\mathrm{ref}} - x). \tag{2}$$

Then the Jacobian and characteristic equation of the equilibrium manifold given by Eq. (5) in [1] is wrong, the correct one should be:

$$J = \begin{bmatrix} p(-(6x_{\mathrm{ref}}^2 - 1)/7) & p & 0 \\ 1 & -1 & 1 \\ k - k_p & -k & k \end{bmatrix} \tag{3}$$

and

$$|\lambda I - J| = \lambda^3 + \left(1 - k + p\frac{6x_{\mathrm{ref}}^2 - 1}{7}\right)\lambda^2 + p\left(\frac{6x_{\mathrm{ref}}^2 - 1}{7}(1 - k) - 1\right)\lambda + pk_p. \tag{4}$$

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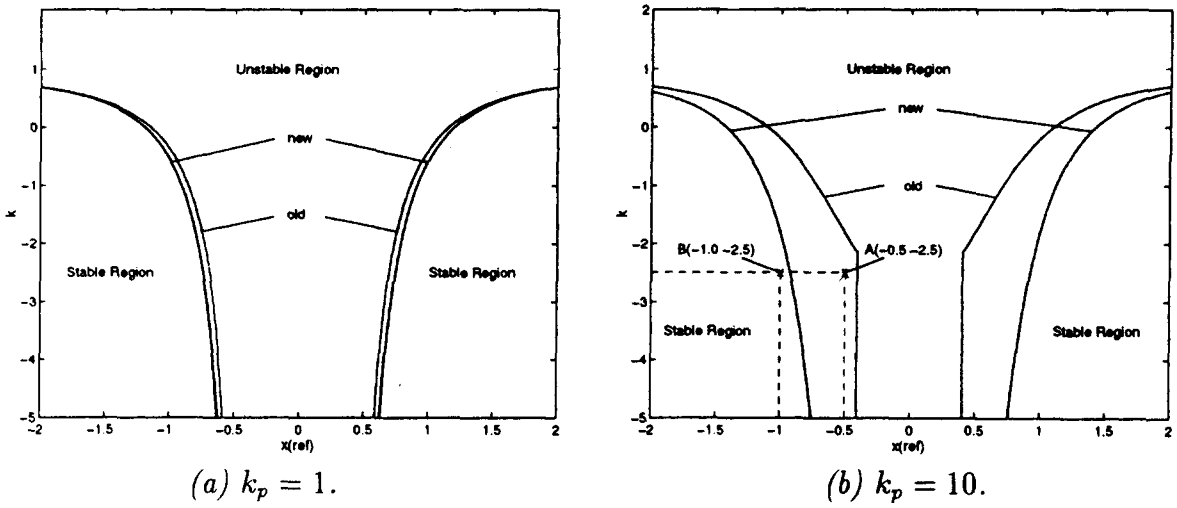


Fig. 1. The stability diagram in the x_{ref}–k plane with different k_p: (a) $k_p = 1$, (b) $k_p = 10$.

Let

$$F = \tfrac{1}{7}(6x_{\text{ref}}^2 - 1). \tag{5}$$

Applying the Routh–Hurwitz criterion to Eq. (4) we find that the boundaries between stable and unstable regions are given by

$$k = \frac{(pF^2 + 2F - 1) \pm \sqrt{(pF^2 + 2F - 1)^2 - 4F(pF^2 + F - 1 - pF - k_p)}}{2F}. \tag{6}$$

For comparison, the corresponding result of Eq. (5) in [1] is as follows:

Case 1. $k_p \neq p$:

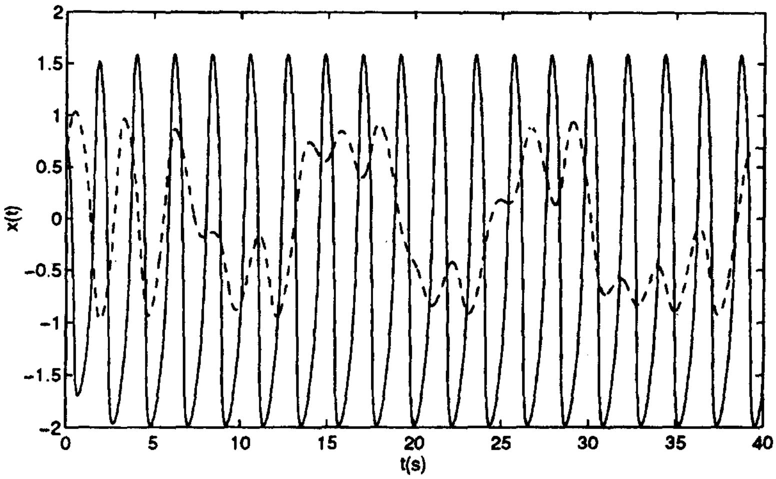
$$k' = \frac{(pF^2 + 2F - 1 + k_p/p) \pm \sqrt{(pF^2 + 2F - 1 + k_p/p)^2 - 4F(pF^2 + F - 1 - pF + k_p/p)}}{2F}. \tag{7}$$

Case 2. $k_p = p$:

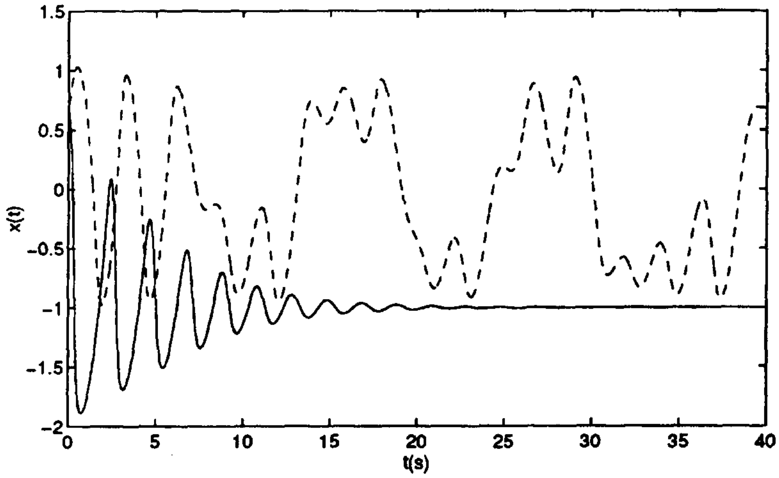
$$k' = \tfrac{1}{2}\left(pF + 2 \pm \sqrt{p^2F^2 + 4p}\right), \qquad F = 0. \tag{8}$$

Comparing Eq. (6) with Eqs. (7) and (8), one can see that there exist significant differences. In Fig. 1, the old and new boundaries are plotted in the x_{ref}–k plane under different k_p values. Based on Eqs. (7) and (8) the authors of [1] chaimed that "It is found that by increasing k_p the stability region has been enlarged". But based on Eq. (6) we find that by increasing k_p the stability region is shrunk. One can verify this by comparing the curves in Fig. 1.

To demonstrate this, in Fig. 1(b) we choose the point $A = (x_{\text{ref}}, k) = (-0.5, -2.5)$, which is in the stable region given in [1], the simulation result is shown in Fig. 2(a). One can see that this point is really not stable. Also the point $B = (x_{\text{ref}}, k) = (-1.0, -2.5)$, which is in the stable region given by Eq. (4) in this paper, gives the stable result as shown in Fig. 2(b). In our simulations, the fourth-order Runge–Kutta with step size 0.01 is used. The initial condition of Chua's circuit is $(x(0), y(0), z(0)) = (0.65, 0, 0)$ and the parameter $k_p = 10$.



(a) The periodic output of the controller given by point A in Fig.1(b).



(b) The stable output of the controller given by point B in Fig.1(b).

Fig. 2. (a) The periodic output of the controller given by point A in Fig. 1(b). (b) The stable output of the controller given by point B in Fig. 1(b). The solid line shows $x(t)$ with control and the dashed line shows $x(t)$ without control.

Reference

[1] C.C. Hwang, H.Y. Chow and Y.K. Wang, Physica D 92 (1996) 95–100.