Comment on a Driven Nonlinear Oscillator

In their recent Letter Testa, Pérez, and Jeffries[1] gave experimental evidence for universal chaotic behavior by using a driven nonlinear oscillator. The oscillator was composed of a generator driving a series *RLC* circuit where the capacitor, a varactor diode, is the nonlinear element. The diode conducts normally in the forward direction and its capacitance decreases with increasing reverse voltage. Their results were confirmed here with a different diode, an ordinary rectifier (1N1221) with a similar capacitance-voltage relation.

The purpose of this Comment is to point out that there is another property of the diode which, at least in our case, is responsible for the observed behavior. A junction diode continues to conduct for a time after the current is reversed. The reverse recovery time, the time for the minority carriers to recombine, increases with increasing forward current,[2] and is a significant fraction of the driving cycle in our case. That this is the major cause of the effects can easily be proved by using the parallel combination of a fast switching diode and the varactor diode biased such that it never conducts. This combination virtually eliminates any reverse-recovery-time effect while maintaining the conduction and nonlinear capacitance properties. No period doubling is observed.

Furthermore, very similar results are obtained when using a pure *RLC* circuit with the capacitor shunted by a simple transistor circuit simulating only the conducting and recovery properties of the diode. The circuit shown in Fig. 1 shows period doubling, chaotic behavior, and stable orbits of the chaotic regime. Transistor Q_1 acts as the diode to ground and provides a current to charge C_1 while Q_1 is conducting. After the conduction portion of the cycle C_1 discharges through Q_2 causing it to conduct for an additional portion of the cycle. The larger the current through Q_1, the longer Q_2 remains conducting. The nonlinear capacities associated with the transistor junctions are orders of magnitude smaller than the varactor diode used in the above experiments, and negligible compared with the 1-nF series capacitor. Therefore, the major cause of the period doubling and chaotic behavior is the reverse-recovery-time effect of the varactor diode rather than its nonlinear capacitance.

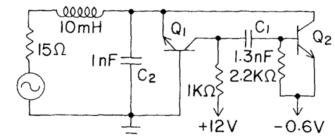

FIG. 1. A circuit that demonstrates the period-doubling route to chaotic behavior. The signal generator has a 50-Ω impedance and the transistors are 2N3393 or equivalent. None of the values of the components are critical.

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[1] J. Testa, J. Pérez, and C. Jeffries, Phys. Rev. Lett. 48, 714 (1982).

[2] J. Millman and C. Halkias, *Electronic Devices and Circuits* (McGraw-Hill, New York, 1967).