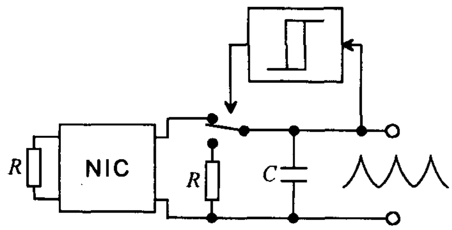

Fig. 2. Exponential signal generator based on Type 1 time reversal duality.

then its time reversal dual will be unstable, and vice versa. Though an unstable circuit may appear to be useless, this is not necessarily so: with a bounded input, the circuit's output will also be bounded *over a finite time interval.* This property has been put to use in the exponential signal generator shown in Fig. 2, which makes use of an NIC to emulate negative resistance for Type 1 duality. The output voltage alternately grows and decays between limits set by a hysteretic comparator.

D. Reversal of Energy Flow

In Type 1–2 time reversal duality, either current or voltage is negated, but not both. Power $p^{\#}$ in the dual circuit is given by

$$p^{\#}(t) = v^{\#}(t)i^{\#}(t) = -v(-t)i(-t) = -p(-t). \quad (8)$$

Because the power waveforms throughout the dual network are negated, the direction of energy flow is reversed. This is an important consideration for circuits in the field of power electronics, because it allows the synthesis of power converters with reversed or bidirectional energy flow. Such converters have many practical applications [5]–[7]. Type 1–2 duality can be applied, because ideal power converters are lossless, containing no dissipative R elements but only L, C and ideal switching devices. If an ideal power converter is considered realizable, then its Type 1–2 dual is also realizable.

To proceed further with such circuits, the theory of time reversal must be extended to include switches and diodes. Difficult philosophical questions arise with switches, because they are controlled devices and the direction of causality is reversed under time reversal. Work on clarifying this issue is currently in progress.

V. Conclusion

The time reversal dual of a network may be formed in four different ways. An important property of Type 1 and Type 2 duals is that the direction of energy flow is reversed. With extension to include switching devices, the theory of time reversal duality should find application in power electronics.

References

[1] M. Kobayashi, A. Takeuchi, A. Ochi, M. Yoneyama, and Y. Hamamoto, "Time-reversal nonlinear emphasis applied to analog HDVCR," *IEEE Trans. Consumer Electron.*, vol. 38, pp. 741–746, Nov. 1992.
[2] S. Ariyavisitakul, "A decision feedback equalizer with time-reversal structure," *IEEE J. Select. Areas Commun.*, vol. 10, pp. 599–613, Apr. 1992.
[3] A. Hiroi, H. Kamata, and Y. Ishida, "Linear phase IIR Hilbert transformers using time reversal techniques," *IEICE Trans. Fund. Electron., Commun. Comp. Sci.*, vol. E77-A, pp. 864–867, May 1994.
[4] L. O. Chua, *Introduction to Nonlinear Network Theory.* New York: McGraw-Hill, 1969.
[5] R. P. Severns and G. Bloom, *Modern dc-to-dc switchmode power converter circuits.* New York: Van Nostrand Reinhold, 1985.
[6] E. R. W. Meerman and H. J. N. Spruyt, "PWM converter topologies," in *Europ. Space Power Conf.*, Madrid, Spain, Oct. 1989, pp. 297–305.
[7] B. Ray, "Single-cycle resonant bidirectional dc/dc power conversion," in *Applied Power Electronics Conf.*, San Diego, CA, Mar. 1993, pp. 44–50.

Comment on "The Single CC II Biquads with High-Input Impedance"

Ahmed M. Soliman

In the above paper[1], two configurations for realizing second-order voltage transfer functions using a single current conveyor (CC II) were given. There is an error in the basic equation of the first configuration, which is (4). The correct form of (4) is:

$$\frac{V_1}{V_y} = \frac{y_2 y_5 - y_1 y_4}{y_5(y_2 + y_3 + y_4) + y_3 y_4}. \quad (4)$$

The sign error in (4) resulted in a series of sign errors in (9), (13) (first equation), (14), (15), and (19).

The filter networks obtained from the second configuration have one more resistor R_5 which has no effect on the filter transfer functions as seen from (16) and (17), thus taking $R_5 = 0$, the two networks described in 1 and 2 of Table III are identical to those obtained from configuration 1. The third network of Table III employs three capaitors to realize band- and high-pass responses with real axis poles, thus it is of no value.

Manuscript received March 20, 1995. This paper was recommended by Editor M. Hasler.
The author is with the Electronics and Communications Engineering Department, Cairo University, Giza, Egypt.
Publisher Item Identifier S 1057-7122(96)00723-4.

[1] S. I. Liu and H. W. Tsao, *IEEE Trans. Circuits Syst. — I*, vol. 38, pp. 456–461, 1991.