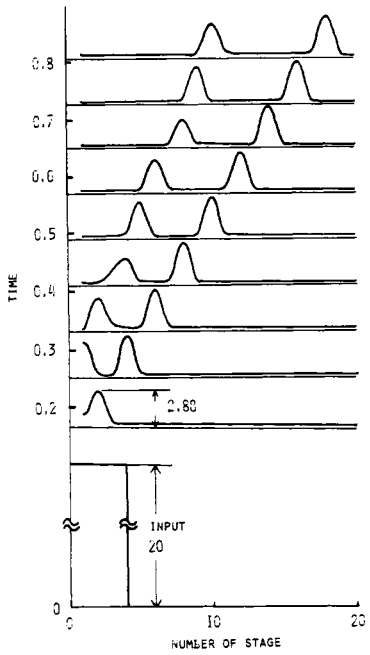

Fig. 3. Formation of solitary waves under the initial condition of rectangular input pulse.

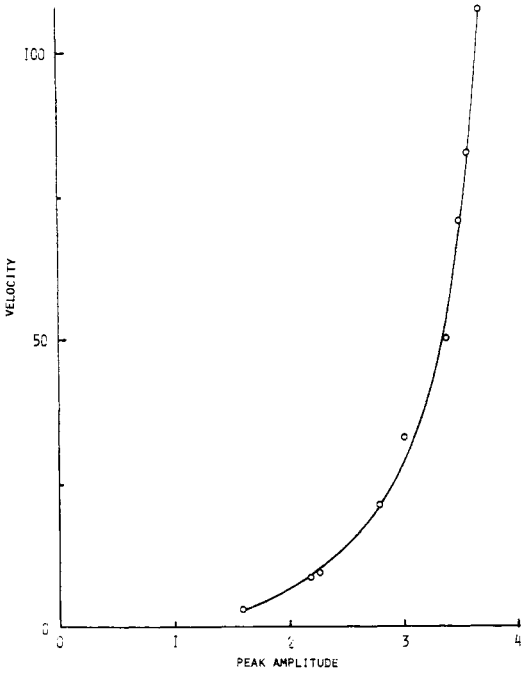

Fig. 4. Relation between the amplitude and the velocity of solitary waves.

reveal that solitary waves can propagate along the line showing soliton-like nature. On the other hand, a wave does not propagate on the nonlinear line if the parameters are chosen in such a way that the tank circuit is nonoscillatory, i.e., $G(V) > 0$. The results of computer experiments with respect to solitary waves are given in Fig. 3. The numerical results are obtained by solving (3), (4), (5), and (6) successively with the use of the Runge-Kutta Gill method. Here the reflections of the waves at the terminal of the nonlinear line are avoided by letting it be longer. The input rectangular pulse of the nonlinear transmission line decomposes into a train of solitary waves and each solitary wave propagates with its own velocity. The velocity is determined depending on the peak amplitude of the solitary wave, as is shown in Fig. 4. Fig. 5 shows the catching-up process of a large amplitude solitary wave with

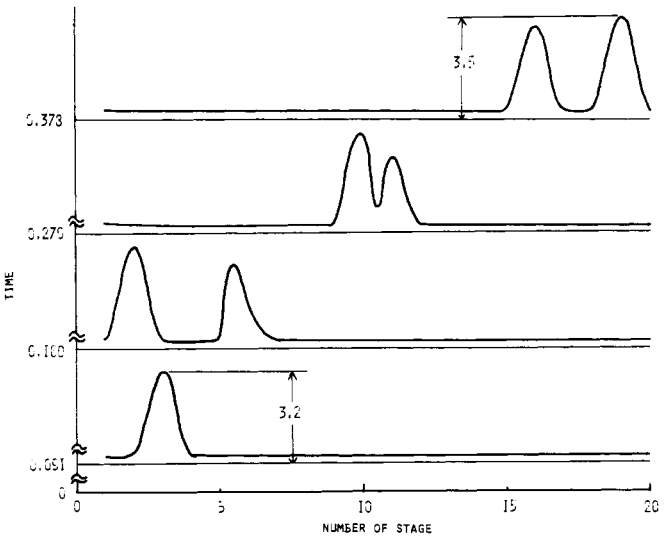

Fig. 5. A collision of the two solitary waves having different amplitudes traveling in the same direction.

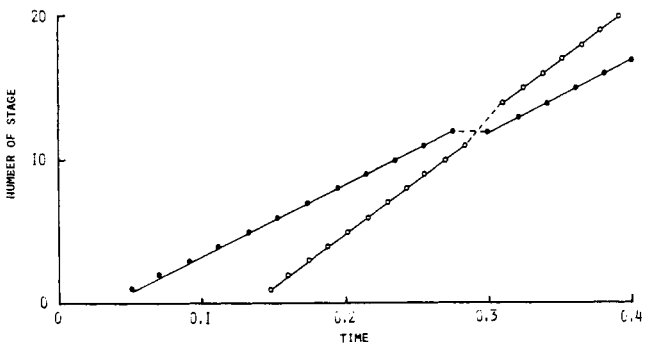

Fig. 6. Locus of the collision of the two solitary waves shown in Fig. 5.

a small one. Fig. 6 shows the orbit of the catching-up process as a function of time. The orbit of each solitary wave before collision becomes parallel with the orbit after collision.

The procedure to construct the soliton line developed here is widely applicable not only to nonconservative oscillatory systems showing limit cycle behavior, but also to conservative oscillatory systems [3], [4].

References

[1] E. Hofelich-Abate and F. Hofelich, "Time behavior of a laser with a saturable absorber as Q switch," *J. Appl. Phys.*, vol. 39, pp. 4823–4827, Sept. 1968.
[2] T. Takagahara, "Model analysis of undamped spiking," *Progr. Theor. Phys.*, vol. 53, pp. 589–590, Feb. 1974.
[3] K. E. Lonngren, in *Soliton in Action*, K. E. Lonngren and A. C. Scott, Eds. New York: Academic Press, 1978.
[4] M. Agu and T. Kinoshita, "Avalanche breakdown as a nonlinear wave," *Jap. J. Appl. Phys.*, vol. 16, pp. 835–839, May. 1977.

A Grounded Inductance Simulation Using the DVCCS/DVCVS

AHMED M. SOLIMAN

***Abstract*—A new economical active *RC* realization of a grounded inductance using the DVCCS/DVCVS as the active element is given. The circuit uses a single grounded capacitor which controls the magni-**

Manuscript received December 5, 1977; revised April 6, 1978.
The author is with the Electronics and Communications Engineering Department, Faculty of Engineering, Cairo University, Giza, Egypt.

0018-9219/78/0900-1089$00.75 © 1978 IEEE

tude of the inductor. Sensitivities to all passive and active circuit components are very low. Application of the simulated inductance in the realization of a canonic selective parallel resonator is discussed.

I. Introduction

Since the introduction of the integrated DVCCS/DVCVS which is a linear versatile active building block [1], several configurations for realizing different types of transfer functions have appeared in the technical literature [2]-[4]. It is well known that an ideal grounded inductor could be realized using two DVCCS/DVCVS (acting as a gyrator [2]) terminated by a grounded capacitor. In this letter a new active *RC* realization of a lossy grounded inductor using only a single DVCCS/DVCVS, a single grounded capacitor, and a resistor is introduced. The effect of the phase shift in the transconductance of the active element is studied in detail.

II. The Active Device

The DVCCS/DVCVS is basically a differential input, linear active element with two outputs, one of high impedance and the other of low impedance. Fig. 1 shows the device symbol [1] where

$$I_0 = G(V_+ - V_-). \tag{1}$$

This active device is now commercially available in integrated circuit form [1].

III. The New Circuit

Fig. 2(a) represents the new inductance simulation circuit. By direct analysis assuming an ideal active device the input admittance to the network is given by

$$Y_{in} = \frac{1}{R_1} + \frac{G}{j\omega CR_1} \tag{2}$$

which is represented by the equivalent circuit shown in Fig. 2(b) where

$$R_{eq} = R_1, \quad L = \frac{CR_1}{G}. \tag{3}$$

The grounded capacitor controls the magnitude of L. The realization obtained which is a parallel RL impedance belongs to the type B as has been classified by Dutta Roy [5]. At this point it is worthwhile to compare the proposed realization with some of the well known inductance simulation circuits using only a single operational amplifier (op-amp) as the active element. With the op-amp used as the active element, at least two resistors are needed for the inductance simulation [5], whereas with the given realization only a single resistor is required, which may be an advantage from the noise point of view. Another point is that most of the active *RC* circuits simulating a grounded inductor using only a single op-amp require one or two cancellation constraints, thus imposing severe stability and tracking requirements on components with temperature and aging [6]. For example the Cheng and Lim realization [6] which is a single op-amp circuit simulating a series inductor-capacitor branch requires one cancellation. The Prescott type A realization [7] and the Berndt and Dutta Roy type A realization [8] both require one cancellation constraint. The Orchard and Willson attractive single op-amp inductor simulation circuit [9] requires two cancellation constraints. One of the few canonic circuits for inductance simulation using a single op-amp which requires no cancellation is the Ford and Girling type B circuit [10]. This is similar to the proposed circuit as both networks realize a type B circuit with no cancellation requirement. With finite op-amp gain, however, it is perhaps more appropriate to consider the Ford and Girling circuit as a type C realization [5].

The proposed network may also realize an ideal grounded inductor utilizing the phase shift in the transconductance of the DVCCS/DVCVS as illustrated next. Practically, the transconductance G is expressed as [1]

$$G = G_0 \cdot e^{-j\omega\tau} \tag{4}$$

where G_0 is the ideal value of the transconductance if the phase shift is neglected.

For the frequency range such that $\omega\tau \leqslant 1/3$, one can approximate the exponential function as [11]:

$$G \simeq G_0(1 - j\omega\tau). \tag{5}$$

Substitution of (5) into (2) yields

$$Y_{in} = \frac{1}{R_{eq}} + \frac{1}{j\omega L} \tag{6}$$

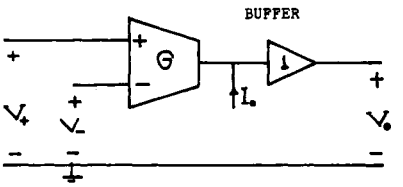

Fig. 1. Symbolic representation of the DVCCS/DVCVS.

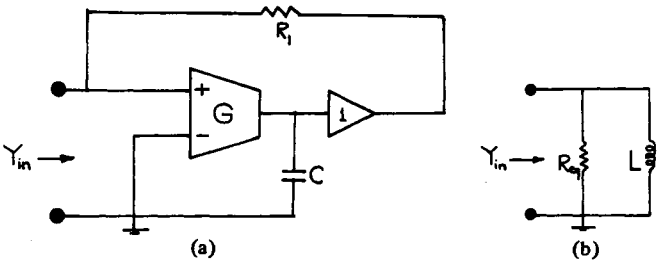

Fig. 2. (a) The new inductance simulation circuit. (b) The input admittance equivalent circuit.

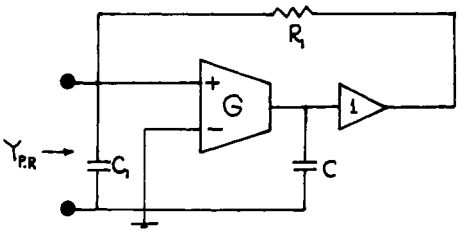

Fig. 3. A novel parallel resonator using a single DVCCS/DVCVS.

where

$$\left.\begin{aligned} \frac{1}{R_{eq}} &= \frac{1}{R_1}\left(1 - \frac{G_0\tau}{C}\right) \\ L &= \frac{CR_1}{G_0} \end{aligned}\right\}, \quad \text{for } \omega \leqslant \frac{1}{3\tau}. \tag{7}$$

Thus to a first approximation, it is seen that magnitude of the realized inductance is not affected by the phase shift in the transconductance, whereas the shunt resistor R_{eq} is increased. This phase shift may be utilized to realize an ideal inductor. From (7), the condition for an ideal inductor is:

$$C = G_0 \cdot \tau. \tag{8}$$

IV. Sensitivities

From (7) the sensitivities of L to all circuit components are very low and are given by

$$S_C^L = 1, \quad S_{R_1}^L = 1, \quad S_{G_0}^L = -1. \tag{9}$$

V. A Novel Canonic Parallel Resonator

Fig. 3 represents a new second-order parallel resonator having two earthed capacitors. The ω_0 and the Q of the resonator are given by

$$\omega_0 = \sqrt{\frac{G_0}{CC_1R_{eq}}}, \quad Q = \sqrt{\frac{G_0R_{eq}C_1}{C}}. \tag{10}$$

The circuit may be tuned to realize a variable frequency oscillator (utilizing the phase shift in the transconductance) by adjusting the capacitor C to the value given by equation (8), and in this case the oscillation frequency is given by

$$f_0 = \frac{1}{2\pi\sqrt{C_1R_1\tau}}, \quad \text{for } \omega \leqslant \frac{1}{3\tau} \tag{11}$$

The output of this novel oscillator is obtained from the output of the buffer, and the frequency of oscillation is controlled by the capacitor C_1.

ACKNOWLEDGMENT

The author would like to thank the reviewer for his useful suggestions and comments.

REFERENCES

[1] M. Bialkow and R. W. Newcomb, "Generation of all finite linear circuits using the DVCCS," *IEEE Trans. Circuit Theory*, vol. CT-18, pp. 733-736, Nov. 1971.
[2] M. Bialkow, W. Sienko, and R. W. Newcomb, "Active synthesis using the DVCCS/DVCVS," *Int. J. Circuit Theory Appl.*, vol. 2, pp. 23-38, Mar. 1974.
[3] F. S. Atiya, A. M. Soliman, and T. N. Saadawi, "Active *RC* bandpass and lowpass filters using the DVCCS/DVCVS," *Electron. Lett.*, vol. 12, pp. 360-361, July 1976.
[4] ——, "Active RC nonminimum phase network using the DVCCS/DVCVS," *Proc. IEEE*, vol. 65, pp. 1606-1607, Nov. 1977.
[5] S. C. Dutta Roy, "On operational amplifier simulation of grounded inductance," *Archiv für Elektronik & Übertragungstechnik (AEÜ)*, vol. 29, pp. 107-115, Mar. 1975.
[6] R. H. Cheng and J. T. Lim, "Single op-amp networks for shunt arms in ladder filters," in *Proc. IEEE Symp. Circuits and Systems*, 1977, pp. 313-316.
[7] A. J. Prescott, "Loss-compensated active gyrator using differential-input operational amplifiers," *Electron. Lett.*, vol. 2, pp. 283-284, July 1966.
[8] D. Berndt and S. C. Dutta Roy, "Inductor simulation using a single unity gain amplifier," *IEEE J. Solid State Circuits*, vol. SC-4, pp. 161-162, June 1969.
[9] H. J. Orchard and A. N. Willson, "New active-gyrator circuit," *Electron. Lett.*, vol. 10, pp. 261-262, June 1974.
[10] R. L. Ford and F. E. J. Girling, "Active filters and oscillators using simulated inductance," *Electron. Lett.*, vol. 2, pp. 52, Feb. 1966.
[11] M. S. Ghausi, *Principles and Design of Linear Active Circuits*. New York: McGraw-Hill, 1965, p. 209.

A Perfect Positive Integrator Using Extremely Low Capacitance

ANUP KUMAR BANDYOPADHYAY

***Abstract*—A perfect positive integrator using a single grounded capacitor of extremely low value is described. A single resistance controlled (SRC) gain constant is another advantage of the circuit.**

A number of integrator circuits are available which use a single grounded capacitor [1], [2]. In this letter, a new configuration using a single grounded capacitor of extremely low value is presented.

Fig. 1 shows the circuit diagram of the proposed configuration. The transfer function of the circuit is

$$V_0/V_i = \beta/[(2-\beta) + \text{SRC}\{2 + (2n+1)(R+R_0)/R_0\}]$$
$$= 1/(a + TS) \quad \ldots \text{(say)}$$

where

$$a = (2-\beta)/\beta$$

and

$$T = RC\{2 + (2n+1)(R+R_0)/R_0\}/\beta.$$

With $\beta = 2$, one gets

$$V_0/V_i = \beta/[\text{SRC}\{2 + (2n+1)(1+R/R_0)\}] = 1/TS.$$

This shows that the circuit is a perfect integrator for $\beta = 2$. The expressions for the sensitivities of T to the variations of β, n and R_0 are

$$S_\beta^T = 1$$
$$S_n^T = 2n(R/R_0)/[2 + (2n+1)(R/R_0)] \approx 1,$$
for $R/R_0 >> 1$, $n >> 1$
$$S_{R_0}^T = -(2n+1)(R/R_0)/[2 + (2n+1)(R/R_0)] \approx -1,$$
for $R/R_0 >> 1$.

Manuscript received March 9, 1978; revised April 11, 1978.
The author is with the Electronics and Telecommunication Engineering Department, Jadavpur University, Calcutta 700032, India.

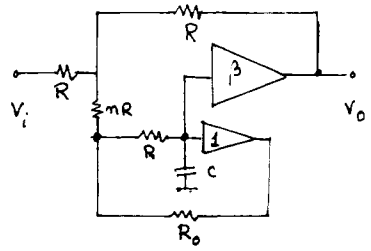

Fig. 1.

From the expression of a one finds that a critical adjustment of β would be necessary which is true for all positive integrators [1], [2]. However, β would be determined by the ratio of two resistances and, therefore, can be made temperature independent.

When the resistance R_0 is the output impedance of the unity gain amplifier one gets a very large value of R/R_0. A voltage follower with an output resistance of 1 Ω and gain 0.9995 is available [3]. $R = 1$ kΩ, $nR = 10$ kΩ, and $C = 100$ pF would therefore realize an integrator with $T = 1$ ms. Since the voltage follower has a very large input impedance, (10 000 MΩ) the positive feedback in this amplifier will not deteriorate the Q of the capacitor C. From the above example one finds that a very small capacitance can be used in this realization—a desirable feature in monolithic IC implementation. The gain constant of the circuit can, however, be controlled by controlling the resistance nR.

ACKNOWLEDGMENT

The author is indebted to Professor J. S. Chatterjee for his kind interest in this work. The author also wish to thank the reviewer of this letter for some comments which helped to refine the final write-up.

REFERENCES

[1] A. K. Bandyopadhyay and R. Nandi, "True noninverting integrators with single grounded capacitor," *Proc. IEEE*, vol. 66, pp. 596-597, May 1978.
[2] G. J. Deboo, "A novel integrator," *Electron Des.*, no. 110, p. 90, June 1967.
[3] "A fast integrated voltage follower with low input current," in *Linear Applications*, Vol. 1, National Semiconductor, p. AN5-1.

Programmable CTD Filters Using Pulse Duration Modulation

FRED J. TAYLOR AND VARADARAJ SHENOY

***Abstract*—A CTD filter is synthesized using a simple programmable coefficient policy. This policy is suitable for on-line operation and possesses a simple hardware realization. Experimental results are presented to demonstrate the potential of the proposed method.**

I. INTRODUCTION

The MOS bucket-brigade devices (BBD) and charge coupled devices (CCD) belong to a class of electronic systems called charge transfer devices (CTD). The basic operation and performance limitations of these devices are now reasonably well understood [1]. Charge transfer devices are now commercially available as delay lines, tapped delay lines, split-electrode transversal filters (e.g., the CZT filter), memory systems, and image sensors. This work will concentrate on the problem of using CTD's to mechanize programmable filters. In particular, a coefficient (or scaling) policy will be proposed and tested in this work.

II. THE CTD FILTER

In general, a normalized shift invariant single-input/single-output discrete filter is given by

$$y(n) = \sum_{i=1}^{N} a_i y(n-i) + \sum_{j=0}^{M} b_j x(n-j); \; |a_i| \leq 1, \; |b_j| \leq 1 \qquad (1)$$

Manuscript received February 21, 1978; revised March 23, 1978.
The authors are with the Electrical and Computer Engineering Department, University of Cincinnati, Cincinnati, OH 45221.

0018-9219/78/0900-1091$00.75 © 1978 IEEE