IMPEDANCE CONVERTERS★

L. GRIGORESCU

"Dunărea de Jos" University of Galați, Romania,
luiza.grigorescu@ugal.ro

Received September 26, 2006

From a lot of applications of current-conveyors, impedance converters put in evidence special performances obtained through replacement of conventional op-amps with current mode circuits.

Key words: Circuits, current-conveyors, impedance converters.

1. INTRODUCTION

The current-conveyor is a versatile analog device that is intended to be used with other circuit components to implement many analog signal-processing functions. It is an analog circuit building- block in much the same way as a voltage op-amp, but it presents an alternative method of implementing analog systems that traditionally have been based on voltage op-amps [1]. This alternative approach leads to new methods of implementing analog transfer functions, and in many cases the conveyor-based implementation offers improved performance to the voltage op-amp-based implementation in terms of accuracy, bandwidth and convenience. Circuits based on voltage op-amps are generally easy to design since the behavior of a voltage op-amp can by approximated by a few simple design rules. This is also true for current-conveyors, and once the appropriate design rules are understood, the application engineer is able to design conveyor based circuits just as easily.

2. CURRENT-MODE IMPEDANCE CONVERTERS

Using two or more of these CCII+ current conveyors, floating-impedance convertors can be realized. In this paper a floating-negative-impedance convertor and a floating-generalised-impedance convertor (GIC) are described. The floating-impedance convertors are based on the differential input/output transadmittance

★ Paper presented at the National Conference on Applied Physics, June 9–10, 2006, Galați, Romania

cell show in Fig. 1. OA_1 and OA_2 are conventional operational amplifiers and both act as high-input-impedance voltage-followers to the two voltage inputs V_A and V_B. The potential across the impedance Z is $V_A - V_B$, and this defines the current in the feedback path around each operational amplifier. This feedback current is sensed by the current-mirrors in the power supply leads to OA_1 and OA_2, providing the differential output currents shown on the diagram. If the circuit of Fig. 1 is modified by connecting the high-output-impedance nodes *C* and *D* to *A* and *B* respectively, then the circuit behaves as a floating negative impedance –*Z*.

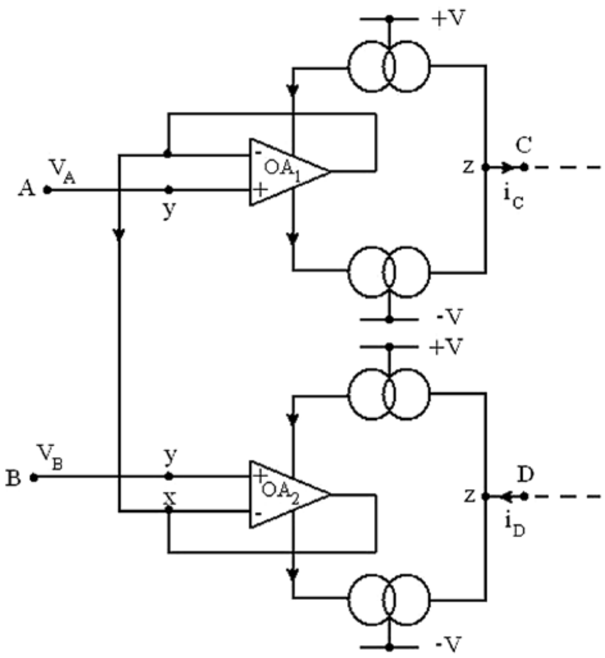

Fig. 1 – Differential input/output transadmittance cell.

As a test, a negative- resistance potential "divider" was constructed using 741-type operational amplifiers together with current-mirrors constructed from CA 3096 transistor arrays. The standard high-performance four-BJT current-mirror was used in all the circuits described here [3].

The voltage gain against frequency response of the " divider" is shown in Fig. 2.

The DC voltage transfer was set at –1, and it can be seen that the negative impedance remained constant at –1 kΩ up to a frequency of 100 KHz, which is principally determined by the unity-voltage-gain bandwidth of OA_1 and OA_2 [2].

A positive floating GIC using current-conveyors is shown in Fig. 3 and an implementation using VOA supply current sensing is shown in Fig. 4. The

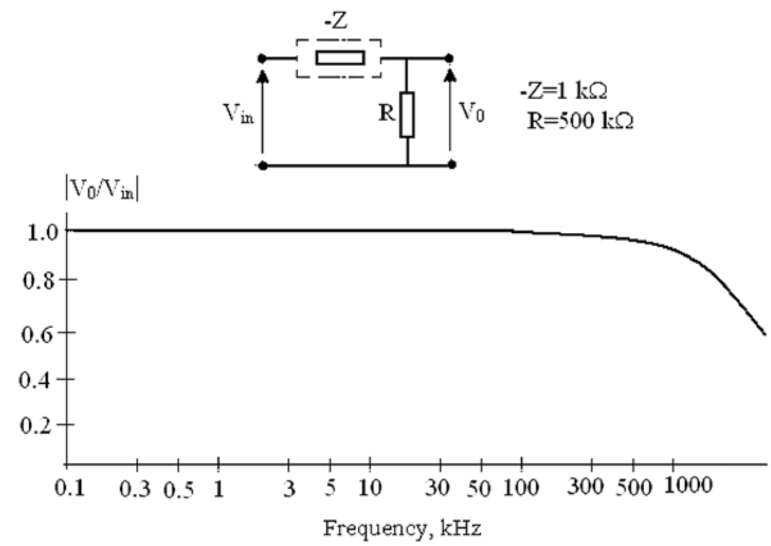

Fig. 2 – Potential divider frequency response.

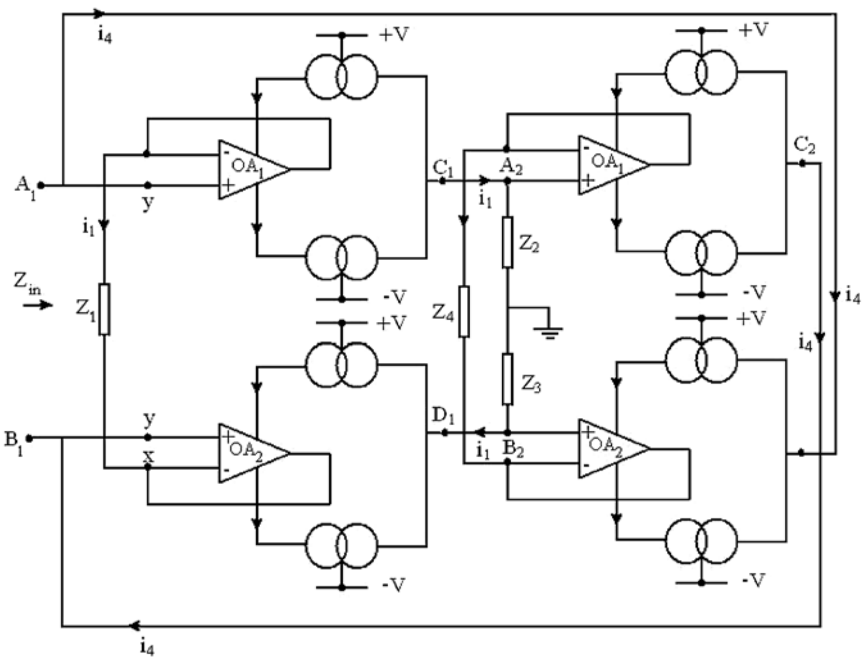

Fig. 3 – Floating GIC circuit using current-conveyors.

circuit comprises two of the basic cells of Fig. 1, the output current drives from the first cell being converted to voltage inputs for the second cell through impedance's Z_2 and Z_3.

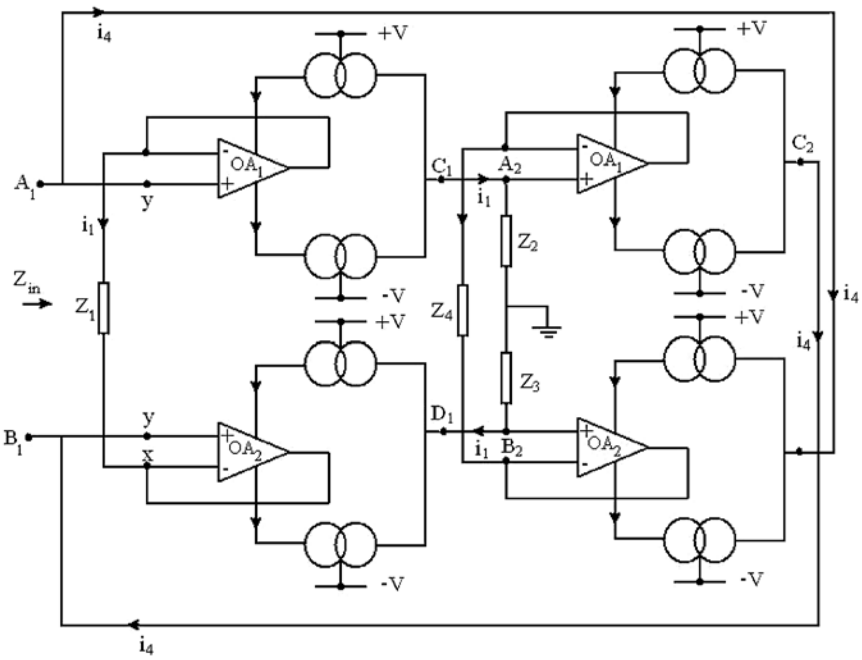

Fig. 4 – Practical Implementation of GIC using VOA supply current sensing.

The current feedback paths from the output of the second cell to the input terminals of the GIC are crosscoupled in order to achieve a net positive floating impedance between nodes A_1 and B_1. A negative GIC is readily configured by reversing this polarity.

The principal currents i_1 and i_4 shown in Fig. 4 are drawn assuming that $V_{A_1} - V_{B_1} > 0$, that the current-mirrors provide unity "reflection coefficients" and that the operational amplifiers are ideal.

By inspection,

$$i_4 Z_4 = i_1 \left(Z_2 + Z_3 \right) \tag{1}$$

and

$$i_1 Z_1 = V_{A_1} - V_{B_1} \tag{2}$$

then

$$Z_{IN} = \left(V_{A_1} - V_{B_1} \right) / i_4 = \frac{Z_1 Z_4}{\left(Z_2 + Z_3 \right)} \tag{3}$$

To test the validity of the design a floating inductance of 5 mH was realized using two equal-value capacitors of 10 nF for impedance's Z_2 and Z_3 and two 1 KΩ resistors for Z_1 and Z_4. The active components were the same type as those used in the negative-impedance converter. A second-order LCR bandpass filter was constructed using this simulated inductance.

Measurements showed that the simulated inductance of 5 mH held for frequencies up to 100 KHz, this frequency being determined by the unity-voltage-gain bandwidth of the operational amplifiers used.

From measurements the equivalent series resistance of the inductor was found to be less than 1 Ω.

3. CONCLUSION

Many other circuit functions, some quite unusual such as the positive frequency dependent negative resistor can be accurately realized from this GIC topology. However, in common with all circuits using active components, it is essential to limit the signal magnitude and frequency to within the operating constraints of the particular devices used.

REFERENCES

1. C. Toumazou, F. J. Lidgey, D. G. Haigh, *Analogue IC Design: the Current-Mode Approach*, *IEE Circuits and System* Series 2, Peter Peregrinus Ltd, 1990.
2. S. Pookaiyaudom, K. Samootrut, *Efficient Circuit Implementation of Current Conveyors, Negative Impedance Converters and Nonlinear Impedance Converters using Operational Transconductance Amplifier*, Int. J. Electronics, **64**, *6*, pp. 941–945, 1988.
3. CCII01– *Current Conveyor Amplifier Data Sheet*, LTP Electronics Ltd., 27 Park End Street, Oxford OX1 IHU, UK. tel/fax +44-865-200767.