NEW MODERN CIRCUIT BLOCK CCTA AND SOME ITS APPLICATIONS

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The new device CCTA (Current Conveyor Transconductance Amplifier) was designed in CMOS technology and is presented in this paper. The CCTA is brought in as the new convenient element for current mode signal processing, which should be very convenient for several applications, e.g. sensor output signals processing. CCTA is supposed for usage mostly in current mode circuits but it is also good choice in case of voltage mode and/or hybrid (voltage-current) circuits (e.g. V/I converters). This modern active device is a newly designed type of analog block that was inspired by transimpedance amplifier (current feedback amplifier which is basically built from CCII conveyor followed by voltage buffer), but CCTA expects even much more versatility in circuit applications. Example of possible internal topologies is presented here as well as brief review of some of many suitable application connections.

Keywords: Current mode signal processing & applications, analog building block

1. INTRODUCTION

Current mode signal processing is very useful for several applications, e.g. sensor output signal processing. Using the current mode means, that the individual circuit elements should interact by means of currents, not voltages [1]. Choosing proper impedance levels, sufficiently small voltages can be achieved with the aim to eliminate the influence of Miller's capacitances and even other nonidealities.

The current amplifiers can be considered as a basic block for current signal processing and they are analogical to classical voltage amplifiers. They can have either a finite or infinite current gain KI. In case of infinite (ideal) gain we call the current operational amplifiers COA. The COA can be designed in several variants corresponding to number of inputs and outputs (e.g. single input double output SIDO etc). The detailed taxonomy is given in [2].

The well-known second generation current conveyor CCII [3] as well as the less known CCIII with grounded input "y" can be used as a circuit element with „pure current signals". In terms of input "x" and output "z" it can be utilized as current-controlled current source with a current gain of 1. By the similar connection the CCTA device based on CCIII conveyor input stage can be even used as the current amplifier with gain from zero to infinity, controlled by external resistors. Furthermore CCTA allows us to realize many other applications by one active device that cannot be easy reached by other devices, especially in current mode.

2. DESCRIPTION OF THE NEW CCTA DEVICE

The CCTA (Current Conveyor Transconductance Amplifier) is the newly designed type of analog block that was inspired by transimpedance amplifier (current feedback amplifier which is built from CCII conveyor followed by voltage buffer).

CCTA is designed for usage mostly in current mode circuits but it is also good choice in case of hybrid (voltage-current) circuits. Behavioral model of the CCTA is shown in Fig. 1. From its behavior the possible internal structure can be visible (Fig. 2). The CCTA consists from two basic blocks. The input is represented by the current conveyor CCIII that is followed by double output transconductance opamp (OTA).

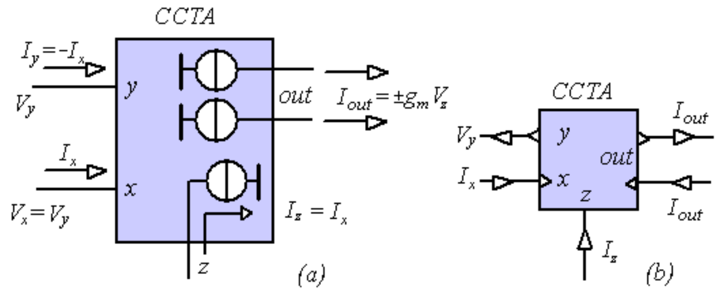


Figure 1: (a) Behavioral model of CCTA, (b) example of schematic symbol of CCTA

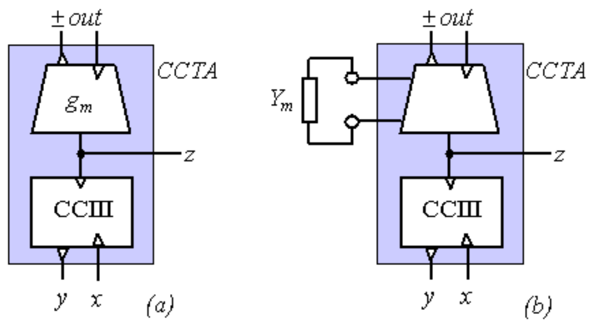


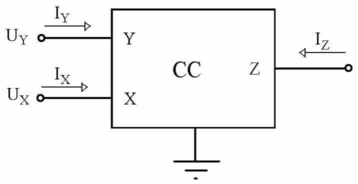
Figure 2: (a) CCTA element as a connection of CCIII and OTA element
(b) CCTA with possibility to choose „transconductance" by an outside two-pole

The input behavior is mostly given by properties of the CCIII conveyor that is described in paragraph 2.1. Conveyor output current flows out of the CCTA terminal "z" into an outside load. The voltage across the z-terminal is converted through a transconductance gm into a two output currents with opposite polarity. The transconductance can be either fixed or given by external component or controlled electronically from an auxiliary terminal as well. Some of possible microelectronics internal topologies are shown in [4,5].

The CCTA may be reasonably useful, for example, in current sensing applications. In fact, if a current, at a generic point into a network, has to be sensed, the current "probe" should be able to make flow a current with very low series impedance while the sensed current can be further processed (amplified, filtered etc.). If the terminal "z" is not connected (high impedance) the CCTA with terminal "y" grounded can be also used as a COA (current operational amplifier). Also these two application connections are introduced in the chapter 3.

2.1 Description of the CCIII conveyor as the input stage of CCTA

To fully understand the functionality of the CCTA, the input stage CCIII (Current conveyor of the third generation) behavior must be described.



$$\begin{bmatrix} I_y \\ U_x \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} U_y \\ I_x \\ U_z \end{bmatrix}$$

Figure 3: Symbol of the general current conveyor and CCIII matrix description

The operation of this device is such that if a voltage is applied to input terminal "y", an equal potential will appear on the input terminal "x". In a similar fashion, an input current *I* being forced into terminal "x" will result in an opposite amount of current flowing into terminal "y". As well, the current *I* will be conveyed to output terminal "z" such that terminal "z" has the characteristics of a current source, of value *I*, with high output impedance. As can be seen, the potential of "x", being set by that of "y", is independent of the current being forced into port "x". Similarly, the current through input "y", being fixed by that of "x", is independent of the voltage applied at "y". Ideally the terminal "x" exhibits short circuit input. In mathematical terms, the input-output characteristics of CCIII can be described by the hybrid equation from Fig.3. Depending on the polarity of the current *Iz* we know CCIII+ and CCIII- conveyors [3].

3. CCTA APPLICATIONS

The new developed device CCTA is very versatile function block which can be used in many various circuit applications. CCTA allows to be used in many well-known applications instead of conventional devices in current as well as in voltage mode. Some of the different approaches of using this active block is shown here.

3.1 Current sensing and signal processing circuit using CCTA

Example of the connection is shown in Fig. 4. From this schematic is visible that the CCTA can be used as a curent sensing device even in between two resistors in resistor divider. If transconductance of the second stage of CCTA can be determined by external Ym, then the output current of the CCTA is given by the following equation:

$$I_{out} = \pm Z_z . Y_m . I_{sensed} \qquad (1)$$

Advantages of the solution with CCTA are obvious. The CCTA works as a through current sensor even at floating potential without affecting the measured circuit and at the same time the sensed signal is processed by only one active element. When assume the Ym and Zz as frequency dependent elements then the active filters can be designed by the same manner like with conventional opamps.

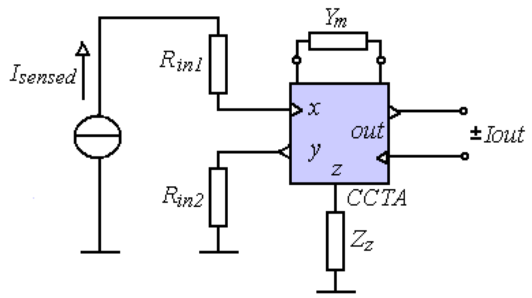


Figure 4: Current sensing and processing circuit using CCTA

3.2 Simple inverting current amplifier using CCTA with infinity gain

In case of the Zz= ∞ (external impedance is not connected) we get CCTA with infinity current gain. By such circuit the current gain can be determined by external components even in case of non-tunable gm. Possible connection is shown in Fig. 5.

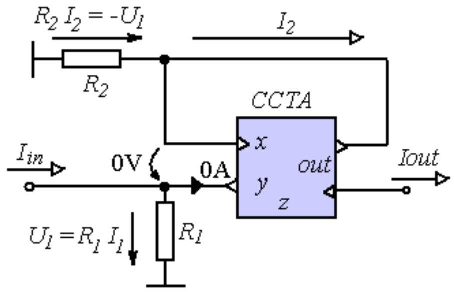


Figure 5: Simple inverting current amplifier with CCTA

The infinity current gain CCTA has similar signal relations at its input gate as the classical voltage feedback Opamp: zero difference voltage (due to the current conveyor on the input) and zero input currents (due to negative feedback and infinite current gain). However, the mechanisms inside these circuits are entirely different. The gain of such current amplifier can be set by the ratio of resistances R1 and R2:

$$I_{out} = -\frac{U_1}{R_2} = -\frac{R_1}{R_2} I_{in} \quad ; \qquad K_I = -\frac{R_1}{R_2} . \qquad (2)$$

3.3 Simple inverting current amplifier using CCTA as a COA

When terminal "y" of the device is grounded, terminal "x" is used as the low impedance current input and "z" is not connected (high impedance) then the CCTA behaves as a COA and the simple current mode inverting amplifier, adjointed to the classical voltage amplifier with opamp, can be simply connected. The advantage of this circuit in comparison with the previous one is really low input impedance at its current input. For proper function the output must be connected to the low impedance ground potential net. This condition can be easily satisfied when other similar circuit follows. Schematic of the amplifier is shown in Fig. 6. The gain of the circuit can be also described by equation 2.

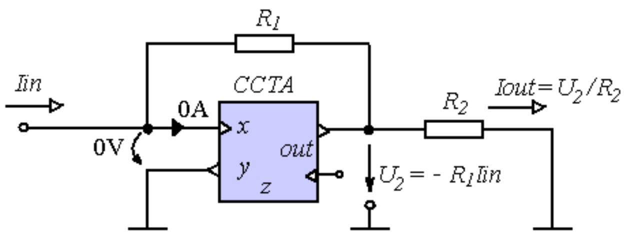


Figure 6: Inverting current amplifier using CCTA as a COA

3.4 Biquadratic active band-pass filter with CCTA

By virtue of the two complementary current outputs is the CCTA with grounded "y" terminal and infinity gain (COA behaviour) fully corresponding to conventional opamp in voltage mode. Thanks to that, in current mode we are able to realize by CCTA almost every known circuit with opamp in voltage mode, by simple adjoint transformation [6]. As an example the biquadratic active Huelsman band-pass filter can be taken. The traditional opamp filter and adjointed current mode filter with CCTA are shown in Fig. 7 and circuit functions are also introduced below.

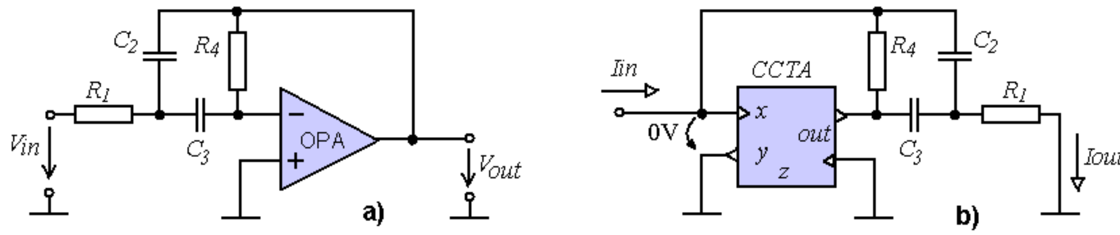


Figure 7: Biquadratic active low-pass filter
a) voltage mode opamp filter
b) current mode filter using CCTA

Adjoint transformation keeps the symbolic circuit functions unchanged and they stays the same for both circuits from Fig. 7. The transfer function, pass band gain, resonant frequency and quality are given in Eq. 3-6.

$$K(p) = \frac{-pR_4C_3}{p^2R_1R_4C_2C_3 + p(R_1C_2 + R_1C_3) + 1} \qquad (3)$$

$$K_0 = \frac{R_4C_3}{R_1(C_2 + C_3)} \qquad (4)$$

$$\omega_0 = \frac{1}{\sqrt{R_1R_4C_2C_3}} \qquad (5)$$

$$Q = \frac{\sqrt{R_1R_4C_2C_3}}{R_1C_2 + R_1C_3} \qquad (6)$$

4. CONCLUSION

The new device CCTA (based on CCIII input) represents, thanks to its high versatility, the new way in current signal processing. Some simple connections with CCTA were introduced here, but many further applications are possible as amplifiers, filters, oscillators, rectifiers in current as well as voltage mode. By the two current outputs is the device predetermined to be one of the best possibilities to design current mode circuits from the classical opamp ones using adjoint transformation. The gain of CCTA can be easy tunable by external admittance Z_z, that can be realized for example by switched net of resistors, voltage driven admittances (MOST), diodes and any other two-terminal passive device.

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5. REFERENCES

[1] Tomazou, C., Lidgey, F.J., Haigh, D.G.: *Analogue IC design: the current-mode approach*. (Peter Peregrinus Ltd, 1990).

[2] Mucha, I.: *Towards a true current operational amplifier*. ISCAS'94, London, May 30-June 2, Vol. 5, 1994, 389-392.

[3] Kumar, U.: *Current Conveyors: A review of the State of the Art*. IEEE Circuits and Systems Magazine, Vol. 3, No. 1, pp. 10-13.

[4] Prokop, R., Musil, V.: *Modular approach to design of modern circuit blocks for current signal processing and new device CCTA*, In Proc. IASTED Signal and image processing , Hawaii, Honolulu, ISBN:0-88986-516-7, 2005, 494-499.

[5] Prokop, R., Musil. V.: *CCTA – a new modern circuit block and its internal realization*, In Electronic Devices and Systems 05-Proceedings. The 12th Electronic Devices and Systems Conference, Brno, 2005.

[6] Fabre, A., Saaid, O. and Barthelemy, H.: *On the frequency limitations of the circuits based on second generation current conveyors*, Analog Intergated Circuits & Signal Processing (AICSP), Special issue on current processing and current mode circuits, 1995

[7] Biolek D., Gubek, T.: New Circuit Elements for Current-Mode Signal Processing, www.elektrorevue.cz