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CMOS Current Controlled Current Conveyor Transconductance Amplifier (CCCCTA)

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***Abstract*: Current conveyors are unity gain active building block having high linearity, wide dynamic range and provide higher gain-bandwidth product. The current conveyors operate at low voltage supplies and consume less power. It has high input impedance, low output impedance, high CMRR and high slew rate. The current mode circuits such as Current conveyors (CCs) have emerged as an important class of circuits in the field of analog electronics. It has excellent properties that enable them to rival their voltage-mode counter Since the gain-bandwidth product of Op-Amp is finite; thus higher the gain it realizes; the less bandwidth it possesses. In the project we are going to design novel CCCCTA, developed in CMOS technology. The new structured CCCCTA the balanced differential-pair structure is used instead of the trans-linear structure as in the original CCCCTA. The major difference between the original CCCCTA and our proposed block are the requirements of bias current which is used to control the parasitic resistance at the input current port and the number of MOSFETs.**

***Keywords*: current controlled current conveyor trans-conductance amplifier (CCCCTA).**

1. Introduction

The introduction of integrated circuits, the operational amplifier (op-amp) has been the basic analog building block in circuit design, it has been evolved by introducing new analog integrated circuit applications and by changing the analog circuit requirements. Early high-gain amplifiers were implemented using discrete thermionic valves which were inherently voltage-controlled devices with controlled voltage output al-lowed stages to be easily cascaded. Then the resulting voltage op-amp architectures were translated to silicon with the development of integrated circuit technologies, and this device become ubiquitous to the area of analog signal processing [1]. The op-amp has several attractive features, such as the differential pair input stage that is very good in rejecting common-mode signals. Moreover, this device only requires a single-ended output to provide a negative feedback and to drive a load, and its implementation is simpler than a fully differential or balanced output. But on the other side, it has negative issues, as its architecture that produces certain inherent limitations in both performance and versatility. The first one is limited by a fixed gain-bandwidth product and a slew rate whose maximum value is determined by the input stage bias current. The second one is constrained by the single-ended output, since the device cannot be easily configured in closed-loop to provide a controlled output current, because it is used for the implementation of closed-loop voltage-mode circuits. Also, the performance of analog systems degrades because small size devices cannot be used due to noise and offset constraints. Often, low voltage operation leads to complex circuits with degraded performance, forcing the analogue designers to look for new circuit architectures. Toward this end, current-mode design techniques offer voltage independent and high performance analogue circuits like Current Conveyors (CCs).

The purpose of this project is to design and synthesize a modified-version CCTA, which is newly named current controlled current conveyor trans-conductance amplifier (CCCCTA). Some example applications as a universal filter and grounded inductance simulator are comprised. They confirm that only single CCCCTA is employed for each application. The new structure reduces the requirements of large bias current and high power which are used in the translinear structure. It also requires fewer amounts of MOSFETs while the performances are better. The purpose of this is to introduce the new structured CCCCTA. The balanced differential-pair structure is used instead of the translinear structure as in the original CCCCTA [2]. The major difference between the original CCCCTA and our proposed block are the requirements of bias current which is used to control the parasitic resistance at the input current port and the number of MOSFETs.

2. Literature review

A CC is a minimum 3-terminals device which, when is arranged with other electronic elements in a circuit, can perform many useful analog signal processing functions. The CC simplifies circuit design as the op-amp does, due to the fact that the one offers an alternative way of abstracting complex circuit functions. The op-amp has several attractive features, such as the differential pair input stage that is very good in rejecting common-mode signals. Moreover, this device only requires a single-ended output to provide a negative feedback and to drive a load, and its implementation is simpler than a fully differential or balanced output. But on the other side, it has negative issues, as its architecture that produces certain inherent limitations in both performance and versatility. The first one is limited by a fixed gain-bandwidth product and a slew rate whose maximum value is determined by the input stage bias current. The second one is constrained by the single-ended output, since the device cannot be easily configured in closed-loop to provide a controlled output current, because it is used for the implementation of closed-loop voltage-mode circuits. Also, the performance of analog systems degrades because small size devices cannot be used due to noise and offset constraints. Often, low voltage operation leads to complex circuits with degraded performance, forcing the analogue designers to look for new circuit architectures. Toward this end, current-mode design techniques offer voltage independent and high performance analogue circuits like Current Conveyors (CCs).

In 1966 A. Sedra was working on his Master's thesis project under the supervision of Prof. K. C. Smith at the University of Toronto. The goal of the project was to design programmable instruments for their implementation in a system for computer controlled experiments. His task was to design a voltage controlled waveform generator, but at the end he designed a novel circuit, where the control variable was current and not voltage as it was required.

As an alternative for the voltage-mode, the Current Conveyor (CC) represented the building block designed for current signal processing, which was published in 1968 by A. Sedra and K.C. Smith [3 and two years later, in 1970, they published a second version of a CC named Second Generation Current Conveyor (CCII) [4], but any of these circuits became popular because of the introduction of the integrated op-amp at that time. The concept of the current conveyor (CC) was first presented in 1968 and further developed to a second version or generation in 1970. The CC is considered a general building block with practical applications.

The Third Generation CC or CCIII appeared in 1995 designed by A. Fabre in [5]. It’s operation is very similar to the CCI, with the difference that the current through the Y-terminal flows in an opposite direction than the current through the X-terminal. In 2007, the current controlled current conveyor trans-conductance amplifier (CCCCTA) was first introduced by M. Siripruchyanun, et. al. as a new block to the current-mode building block for analog signal processing which the parasitic resistance at input terminal and its output current gain can be controlled by input bias currents. Its application can be tuned over a wide current range. It can be used only one active element to perform applications such as current-mode universal filter, grounded inductance simulator and oscillator.

In 2009, a new active building block for analog signal processing, namely, differential voltage current conveyor trans-conductance amplifier (DVCCTA), was introduced (Jantakun et. al., 2009). A voltage-mode quadrature sinusoidal oscillator with independent current tunable frequency of oscillator is constructed in (Lahiri A. et. al., 2010). The DVCCTA has a trans-conductance stage at its back end and hence it provides the feature of electronic tuning to the circuit parameters, while also reducing the number of resistors by one. The DVCCTA device is obtained by cascading of the differential voltage current conveyor (DVCC) with the operational trans-conductance amplifier (OTA) in monolithic chip for compact implementation of analog function circuits. The DVCCTA is based on DVCC and consists of differential amplifier, current mirrors, and trans-conductance amplifier (Pandey N. & Paul S. K., Tangsrirat W. & Channumsi O., 2011) [7].

The original CCCCTA composed of the current-controlled second generation current conveyor (CCCII) and an operational trans-conductance amplifier (OTA) circuit. The CCCII is consisted of a translinear loop as the input section. Though the translinear structure is simple, the large offset voltage and the poor voltage performance. Recently, the new CMOS CCCII, namely the balanced differential-pair structure was proposed. The new structure reduces the requirements of large bias current and high power which are used in the translinear structure. It also requires fewer amounts of MOSFETs while the performances are better.

3. Aim of project

- Reduce the large offset voltage and the poor voltage performance.
- Reduces the requirements of large bias current and high power.
- Fewer amounts of MOSFETs.

4. Proposed project

The current controlled current conveyor trans-conductance amplifier (CCCCTA) as a new block to the current-mode building block for analog signal processing which the parasitic resistance at input terminal and its output current gain can be controlled by input bias currents. Its application can be tuned over a wide current range. It can be used as the only one active element to perform applications such as current-mode universal filter, grounded inductance simulator and oscillator. The operation of CCCCTA can be given with following matrix equation,

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ R_x & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & \pm g_m & 0 \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \\ V_o \end{bmatrix},$$

where $R_x = \frac{V_T}{2I_{B1}}$,

and $g_m = \frac{I_{B2}}{2V_T}$,

where,

$m\ g$ is the trans-conductance gain of the CCCCTA and T V is the thermal voltage.

As $R x$ and $g m$ are intrinsic resistance and trans-conductance, respectively.

The proposed novel CMOS CCCCTA consists of two building blocks: a) a balanced differential-pair CCCII circuit and b) an operational trans-conductance amplifier (OTA).

The proposed CCCCTA realized in CMOS technology is shown in Fig. 1. The circuit consists of a balanced differential-pair structure as the input stage which is realized using MOSFETs Mp1, Mp2 and Mn1, Mn2. The output current at Z terminal is conveyed from the input current at X terminal is realized using MOSFETs Mp3, Mp4 and Mn3, Mn4. The bias circuit is realized using current mirror which composed of MOSFETs Mn5 - Mn7. The simplified OTA is realized using MOSFETs Mp5, Mp6 and Mn8, Mn9. The resistor at Z terminal is conducted from CMOS CCCII+.

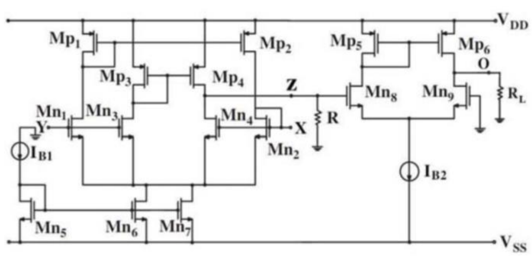

Fig. 1. The proposed current-controlled current conveyor trans-conductance amplifier

Proposed Work and Objectives:

- Design of new novel CCCCTA.
- Simulation using <35nm CMOS technology.
- CMOS layout.
- Comparison of proposed and original CCCCTA based on parameters such as power supply voltages, power consumption, Ro, Rz, Ry etc.

5. Conclusion

This paper presented an overview on CMOS Current Controlled Current Conveyor Transconductance Amplifier.

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