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CURRENT CONTROLLED TRANSCONDUCTANCE AMPLIFIER (CCTA) USING ADVANCED DESIGN SYSTEM

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Abstract

Complementary Metal Oxide Semiconductor (CMOS) is a technology used to produce integrated circuit. CMOS circuits are found in several types of electronic components, including microprocessors, batteries and digital camera image sensors. The MOS in CMOS refers to the transistor in a CMOS component called MOSFETs (metal oxide semiconductor field-effect transistors). In the project we are going to design novel CCCCTA, developed in CMOS technology using Advanced Design System (ADS). 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 have emerged as an important class of circuits in the field of analog electronics. The new structured CCCCTA the balanced differential-pair structure is used instead of the trans-linear structure as in 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:

COMS, MOSFTs, CCCCTA, Advanced Design System

1. INTRODUCTION

The CMOS basically stand for complementary metal oxide semiconductor, it is technology used to design analog circuits like data converters, image sensor etc. and also to construct ICs with less complexity. MOS in CMOS refers to the transistor in a CMOS component called MOSFETs (metal oxide semiconductor field-effect transistors). MOS is metal oxide semiconductor field effect transistor, is a type of insulated-gate field-effect transistor fabricated by controlled oxidation of a semiconductor, typically Silicon. Each MOSFET includes two terminals (‘source’ and ‘drain’) and a gate, which is insulted from the body of the transistor. When enough voltage is applied between the gate and body, electrons can flow between the source and drain terminals [2] [8]-[11].

An operational amplifier or op-amp is a voltage amplifying device designed to use with external feedback components such as resistors and capacitors between its output and input terminals. 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 [1].

The 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).

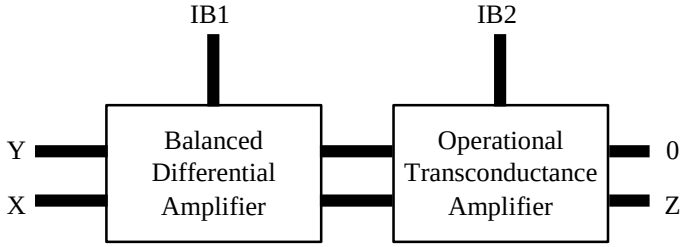


Fig.1. Block diagram of current controlled current conveyor transconductance amplifier

2. LITERATURE REVIEW

An amplifier which amplifies the difference between the two input signals is called differential amplifier. An operational amplifier or op-amp is a voltage amplifying device designed to use with external feedback components such as resistors and capacitors between its output and input terminals. The operational amplifier (op-amp) has been the basic analog building blocks in circuit design it has been evolved by introducing new analog integrated circuit applications and by changing the analog circuit requirements [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.

Sedra and Smith [3] [4] designed a 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 [3] and two years later, 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) and further developed to a second version. The CC is considered a general building block with practical applications.

The Third Generation CC or CCIII appeared in [5]. Its 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.

A current controlled current conveyor trans-conductance amplifier (CCCCTA) was first introduced by Siripruchyanun et al. [6] 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.

A new active building block for analog signal processing, namely, differential voltage current conveyor trans-conductance amplifier (DVCCTA), was introduced. A voltage-mode quadrature sinusoidal oscillator with independent current tunable frequency of oscillator is constructed. 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 [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 trans-linear loop as the input section. Though the trans-linear structure is simple, the large offset voltage and the poor voltage performance. In this project we design a new CMOS CCCTA, namely the balanced differential-pair structure was proposed by using the advanced system design software in new version which offers high-speed design platform and less complex circuit. The new structure reduces the requirements of large bias current and high power which are used in the trans-linear structure. It also requires fewer amounts of MOSFETs while the performances are better.

3. CURRENT CONVEYOR TRANS-CONDUCTANCE AMPLIFIER

A device which accepts an input signal and produces an output signal proportional to the input is called Amplifier. There are variety of amplifiers available depending upon the natures of the input and output signals. These types are the voltage amplifier, current amplifier, transconductance amplifier and trans-resistance amplifier. An amplifier which amplifies the difference between the two input signals is called differential amplifier.

CMOS is a technology used to produce integrated circuit. CMOS circuits are found in several types of electronic components, including microprocessors, batteries and digital camera image sensors. The CMOS fabrication process flow is conducted using some basic fabrication First we have to choose a substrate as a base for fabrication. The selective diffusion of n-type impurities is accomplished using SiO_2 as a barrier which protects portions of the wafer against contamination of the substrate. The selection etching, the SiO_2 layer is subjected to the photolithography process. In this process, the wafer is coated with a uniform film of a photosensitive emulsion. Masking is the continuation of the photolithography process. The mask is removed and the unexposed region of photoresist is dissolved by developing wafer. The wafer is immersed is an etching solution of hydrofluoric acid, which removes the oxide from the areas through which dopants are to be diffused. An oxidation layer is deposited over the wafer which acts as a shield for further diffusion and metallization processes. In the gaps formed after removal of excess metals terminal are formed for the interconnections.

CMOS Advantages: CMOS transistors are known for their efficient use of electrical power. They require no electrical current expect when they are changing from one state to another. Additionally, the complimentary semiconductors work together to limit the semiconductor work together to limit the output voltage. This result is a low-power design that gives off minimal heat.

CCCCTA is basically two stages differential amplifier which accept input and produces an output which is proportional to the input. In the circuit we apply voltage and at the output we take currents. The amplifier which accept a voltages and produce currents, and current get controlled itself by amplifiers known as current controlled current conveyor transconductance amplifiers. 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,

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ R_s & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & \pm g_m & 0 \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \\ V_o \end{bmatrix} \quad (1)$$

$$Rx = c\frac{V_t}{2Ib_1} \text{ and} \quad (2)$$

$$gm = \frac{Ib_2}{2V_t} \quad (3)$$

where, *mg* is the trans-conductance gain of the CCCCTA and *TV* is the thermal voltage.

As *Rx* and *gm* are intrinsic resistance and trans-conductance, respectively.

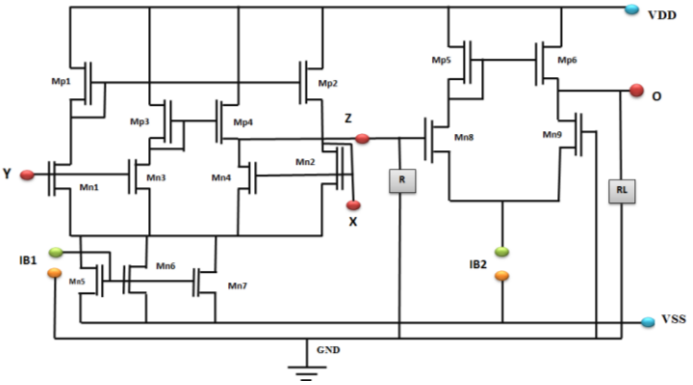


Fig.2. Current conveyor trans-conductance amplifier

The CMOS CCCCTA consists of two building blocks:

3.1 A BALANCED DIFFERENTIAL-PAIR CCTA CIRCUITS

A differential amplifier is a type of electronic amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the inputs. Operational amplifier or op-amp is a differential amplifier with very differential-mode gain, very high input impedance, and low output impedance. The circuit consists of a balanced differential-pair structure as the input stage which is realized using MOSFETs Mp_1, Mp_2 and Mn_1, Mn_2. The output current at Z terminal is conveyed from the input current at X terminal is realized using MOSFETs Mp_3, Mp_4 and Mn_3, Mn_4. The bias circuit is realized using current mirror which composed of MOSFETs Mn_5 - Mn_7. The input and output resistances looking into the X terminal and Z terminal are formulated as:

$$Rx = \frac{1}{gmD} = \frac{1}{\sqrt{Ib_1 \mu_n C_{ox} \frac{W_D}{L_D}}} \quad (4)$$

where, IB_1 is the 1st input bias current.

$$Rz = \frac{1}{g_{ds}m + g_{ds}m} \quad (5)$$

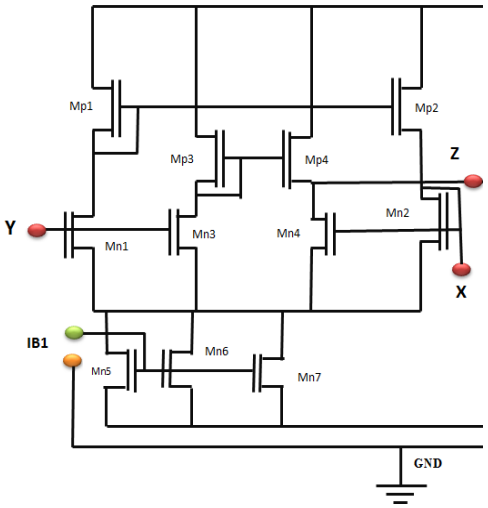


Fig.3. A balanced differential-pair CCTA circuit

Advantages of differential pair circuits are as follows

- High differential voltage gain
- Low common mode gain
- High CMRR
- Two input terminals
- High input impedance
- Large bandwidth
- Low offset voltages and currents.
- Low output impedance.

3.2 AN OPERATIONAL TRANS-CONDUCTANCE AMPLIFIER (OTA)

The operational transconductance amplifier is amplifier whose differential input voltage produces an output current. MOSFETs Mn_8, Mn_9 working as differential pair and Mp_5, Mp_6 working as current mirror with B_2 and I is the 2nd input bias current. The output resistance at O terminal is,

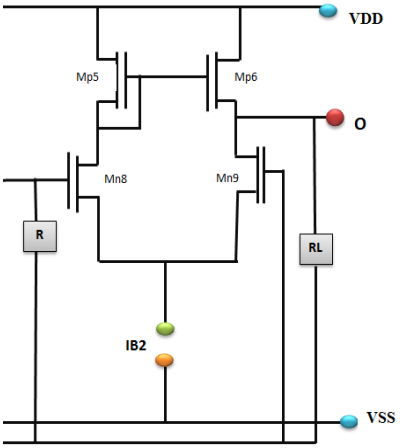


Fig.4. Operational Transconductance Amplifier circuit

Advantages of operational transconductance amplifier are as follows,

- Wide bandwidth
- High slew rate
- High transconductance
- Low quiescent current

A balanced differential pair and operational transconductance amplifier provide some advantages thus they are used in various circuit design such as,

- Current amplifier,
- Voltage to current convertor
- Current differentiator /integrator,
- Current summer,
- Instrumentation amplifier
- In filters designing etc.

4. PERFORMANCE SIMULATION

For designing and examine the performance of current controlled transconductance amplifier we used the advanced design system. Advanced design System (ADS) is an electronic design automation software system produced by keysight EEs of EDA, a division of keysight technologies. Keysight ADS supports every step of design process-schematic capture, layout, design rule checking, frequency domain and time domain circuit simulation and electromagnetic field stimulation.

ADS have advanced capabilities for the design process, before fabrication of wireless components such as power amplifiers and RF front-end modules. It allows to creates and analyze circuit and system designs and display simulation data. While design in ADS we have to select MOSFETs with some selective parameters and they are as given in the Table.1. Here, MOSFETs of trans-linear type is used.

Table.1. Transistors width and lengths

Transistors	Width (µm)	Length (µm)
NMOS $[Mp_1, Mp_2, Mp_3, Mp_4]$, $[Mp_5, Mp_6]$	260µm	20µm
PMOS $[Mp_1, Mp_2, Mp_3, Mp_4, Mp_5, Mp_6, Mn_7], [Mn_8, Mn_9]$	260µm	10µm

The process of design circuits in software are as follows,

1. Open the software and select the option as per requirement.
2. Create a new workspace and after that new window get opened.
3. Design new schematic window.
4. After that new window page open in which we have to deign circuits.
5. Design and stimulate the circuit.

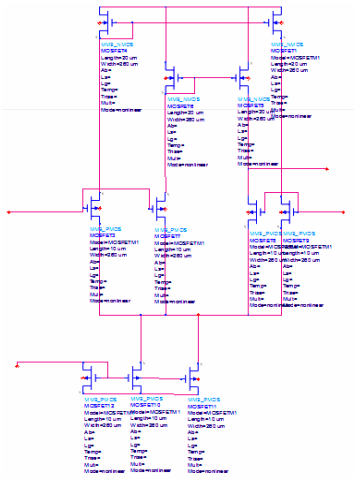


Fig.5. Design circuit of differential balanced amplifier stage

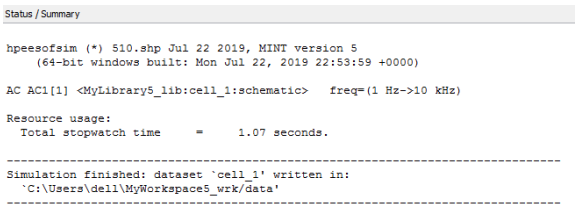
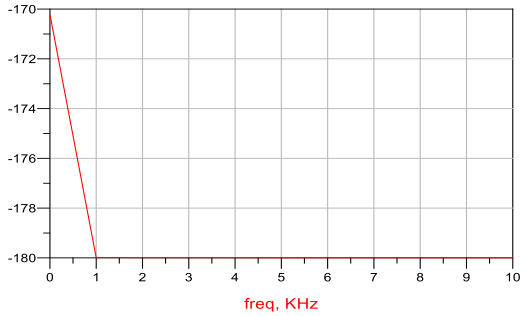
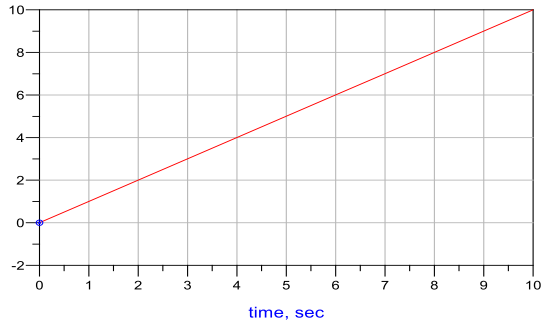


Fig.6. Simulation results



(a)



(b)

Fig.7. Transfer analysis of CCCCTA

4.1.1 Applications of CCCCTA:

CCCCTA are used in following applications and they are,

- Video/Broadband equipments
- Communication equipments
- High speed data acquisition
- Wideband LED drivers
- Control loop amplifiers
- Wideband active filter,
- Line drivers
- Instrumentation amplifiers etc.

5. CONCLUSION

In these a new structure of current controlled transconductance amplifier has been given. The whole current transconductance amplifier design by using CMOS technology and stimulated in advanced design system (ADS) 2020 of keysight technology by considering the parameters for MOSFETs and considering 1.5 voltage supply during stimulations. Advantages of proposed circuits are the less number of numbers of MOSFETs, so it has lower power consumption. The proposed circuit used where we have to reduce the requirement of power i.e. current with reduce size and cost effective.

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