DESIGN AND OPTIMIZATION OF TRANSCONDUCTANCE AMPLIFIER USING CURRENT GENERATORS

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ABSTRACT
Briefly, the transconductance amplifier, featuring a differential pair serves to convert input voltage signals to output currents. A self-biasing Transconductance Amplifier is designed by using two current generator circuits. The innovative topology not only achieves a broad input dynamic range but also introduces positive feedback, enhancing the overall transconductance and performance of the circuit. The current generators are configured using two n-channel and p-channel cascode current mirrors by which a high input dynamic range is achieved. To ensure stability, constant current sources are paralleled with the current mirror topologies, implemented with input drivers comprising two n-channel and p-channel input differential pairs. This method not only uses idle devices as new devices, it causes higher transconductance, also completes self-biasing topology of the proposed Operational Transconductance Amplifier (OTA). For the Rail-to-Rail operation at the input it is assumed that the input common mode voltage goes up so that p-channel input drivers turn off. Proposed OTA may not provide constant transconductance, but the circuits topology is able to properly operate under a rail-to-rail Input Common Mode Range (ICMR).
Keywords: Amplifier, current generator, current mirror, operational transconductance amplifier (OTA), rail-to-rail, self-biasing.

INTRODUCTION

A transconductance amplifier is a type of analog electronic device designed to convert an input voltage signal into an output current signal. Unlike voltage amplifiers that amplify voltage signals, transconductance amplifiers focus on amplifying the current in response to a varying input voltage. The term "transconductance" refers to the transfer of electrical conductance from the input (voltage) to the output (current) of the amplifier. Transconductance amplifiers operate on the principle of changing input voltage resulting in a proportional change in output current. The gain of a transconductance amplifier is measured in Siemens (S), which is the unit of conductance. Commonly used in applications where a current signal is more relevant than a voltage signal, such as in communication systems, instrumentation, and control systems. Often employed in circuits requiring modulation or amplification of current, such as in radio frequency (RF) applications. The input voltage is applied to the amplifier, causing change in the output current proportional to the transconductance gain. This conversion is particularly useful in systems where current signals are more easily manipulated or transmitted than voltage signals. By controlling the input voltage, the transconductance amplifier effectively controls the output current, providing a means of signal amplification or modulation. The transconductance gain (gm) is a key parameter that defines the sensitivity of the amplifier to changes in input voltage. It represents the ratio of the change in output current to the change in input voltage. In summary, transconductance amplifiers play a crucial role in applications where the conversion of voltage signals to current signals is essential. Their ability to modulate and amplify current signals makes them valuable in various electronic systems, particularly those requiring efficient handling of current-based information. Rail-to-rail operation in electronic circuits, particularly in amplifiers, refers to the ability of the device to operate and provide output signals that span the entire voltage range between its 9 power supply rails. In the context of amplifiers, this means that the amplifier can accept input signals and produce output signals very close to both the positive and negative power supply voltages.

LITERATURE SURVEY

[1] M. Akbari, S. M. Hussein, Y. Hashim, and K. Tang, "An enhanced input differential pair for low-voltage bulk-driven amplifiers," IEEE Trans. Very Large Scale Integr. (VLSI) Syst., vol. 29, no. 9, pp. 1601–1611, Sep. 2021. This article presents a low-voltage high-transconductance input differential pair for bulk-driven amplifiers. The proposed structure employs two bulk-driven flipped voltage follower (FVF) cells as nonlinear tail current sources to enhance the slewing behavior. This method also increases the transconductance of the proposed amplifier two times against the conventional one. The enhanced topology is merged with a conventional bulk-driven input differential pair using cross-coupled connections to significantly increase the transconductance. These circuitry ideas lead to an improvement in the amplifier's specifications, such as dc gain, slew rate (SR), and input noise without any degeneration in other parameters. [2] L. Lah, J. Choma, and J. Draper, "A continuous-time common-mode feedback circuit (CMFB) for high-impedance current-mode applications," IEEE Trans. Circuits Syst. II, Analog Digit. Signal Process., vol. 47, no. 4, pp. 363–369, Apr. 2000. A continuous-time common-mode feedback circuit (CMFB) is presented. A two-stage high-gain architecture is used to stabilize and minimize the offset of the common-mode voltage. A long-channel differential-difference amplifier (DDA) input stage enables this CMFB circuit to have a wide input voltage range without a serious linearity problem. A special compensation scheme enables this circuit to be used in high-impedance current-mode systems without a stability problem. This circuit has been implemented within a continuous-time switched-current modulator in a 2 -μm CMOS process. [3] This article presents a class-AB operational transconductance amplifier (OTA) with a high slew rate. The proposed class-AB OTA is applied with a slew-rate enhancement technique using an extremely low quiescent current. The additional current-reference common-mode feedback loop resolves the susceptibility to process, voltage, and temperature fluctuations resulting from slew-rate enhancement transistors. The proposed class-AB OTA is most widely used in block design, including, a switched-capacitor circuit, analog-to-digital converter, digital-to-analog converter, low-dropout regulator, and switched-capacitor DC-DC converters. In this study, performance was validated by applying the proposed class-AB OTA to a switched capacitor delta-sigma modulator which requires high performance and high precision. The circuit was designed and simulated using a 0.18-μm complementary metal-oxide semiconductor process.

EXISTING METHOD

The schematic of the proposed RTRTA is shown in Figure. As shown in Figure, the RTRTA is composed of two current generator circuits. In this, along with the two current-generator based transconductances, n-channel and p-channel differential pairs are used to play two roles including current sources and input drivers. To get the high CMRR differential pairs are added with the constant current sources M5a and M7a. This method not only uses idle devices as new devices, it causes higher transconductance also completes self-biasing topology of the proposed OTA. For the Rail-to-Rail operation at the input, it is assumed that the input common-mode voltage goes up so that p-channel input drivers M1a and M2a turn off. If one input differential pairs is off then it reduces the transconductance of the small signal amplifier. Proposed OTA may not provide a constant transconductance, but the circuits topology is able to properly operate under a Rail-to-Rail high input common-mode range (ICMR).

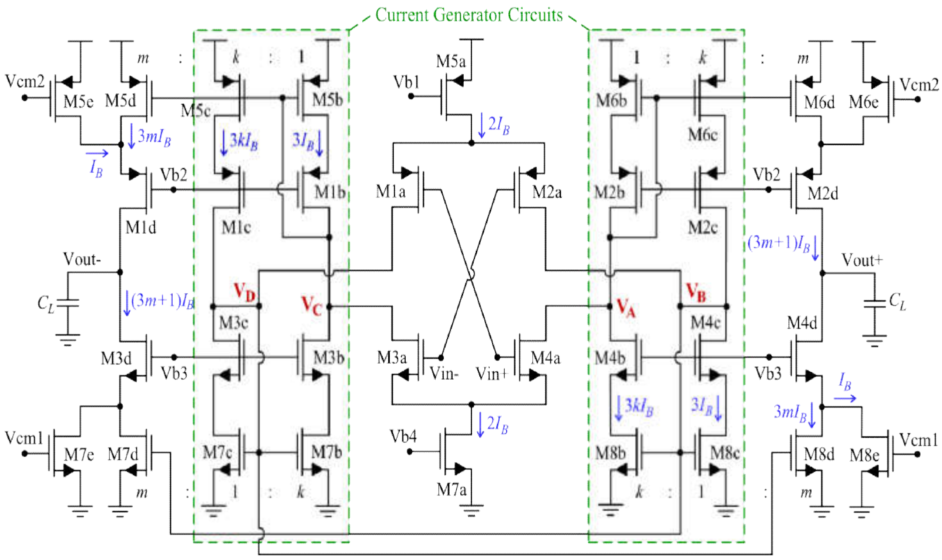

Figure.1. Schematic diagram for proposed model

PROPOSED METHOD

The schematic of proposed method is shown in figure. Operational transconductance amplifiers (OTAs) are fundamental building blocks in analog integrated circuits, offering versatile and efficient means of signal processing. OTAs are particularly prevalent in applications requiring voltage-to-current conversion and amplification, such as filters, oscillators, and voltage-controlled amplifiers. MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) are commonly utilized in OTAs due to their advantageous characteristics, including high input impedance, low noise, and ease of integration in CMOS (Complementary Metal-Oxide-Semiconductor) processes. In an OTA circuit, MOSFETs are employed as voltage-controlled current sources, where the output current is directly proportional to the input voltage. By modulating the gate-source voltage of the MOSFET, the transconductance, which represents the amplification capability of the OTA, can be controlled. This feature enables precise and flexible adjustment of the gain and bandwidth of the amplifier. The core principle of operation in an OTA using MOSFETs involves biasing the MOSFETs in their active region and configuring them to operate in the saturation region. In this region, the MOSFETs exhibit a transconductance that is relatively constant over a wide range of input voltages, ensuring linear amplification. By properly sizing the MOSFETs and designing the biasing network, the OTA can achieve desired performance metrics such as gain, bandwidth, and linearity. Additionally, various techniques can be employed to enhance the performance of MOSFET-based OTAs. This includes cascode configurations to increase the output impedance and improve the bandwidth, as well as current mirrors and active loads to enhance linearity and reduce distortion. Moreover, feedback networks can be incorporated to stabilize the amplifier and control its frequency response. Overall, MOSFET-based OTAs offer a powerful platform for implementing high-performance analog circuits, providing designers with the flexibility to tailor the amplifier's characteristics to suit specific application requirements. With advancements in semiconductor technology and circuit design methodologies, MOSFET-based OTAs continue to play a vital role in modern analog and mixed-signal integrated circuits.

THE DESIGN STRUCTURE OF THE TRANSCONDUCTANCE AMPLIFIER USING CURRENT GENERATOR

A rail-to-rail amplifier is an amplifier that can operate with its input and output signals very close to its supply rails, typically ground and the positive supply voltage (VCC). This allows the amplifier to handle signals that swing close to these rails without distortion. The input stage of a rail-to-rail amplifier is designed to operate close to the supply rails. This can be achieved using various techniques such as cascode configurations, dynamic biasing, or input common-mode feedback. The gain stage amplifies the signal received from the input stage. This stage is designed to provide high gain while ensuring that the output can swing close to the supply rails. The output stage of a rail-to-rail amplifier is crucial for ensuring that the output signal can swing close to both supply rails. This stage often employs complementary transistors (both NPN and PNP for bipolar designs or NMOS and PMOS for CMOS designs) configured to operate in their linear regions over a wide range of output voltages. Level shifting and biasing circuits are used to ensure that the amplifier operates within its linear range even when the input and output signals are close to the supply rails. Common-mode feedback circuits can be included to maintain a constant common-mode voltage at the input of the amplifier, which helps improve the linearity and stability of the amplifier, especially when operating near the supply rails. Additional circuitry may be included to protect the output stage from overvoltage or overcurrent conditions, which could occur when the amplifier is operating close to the supply rails.

RESULT ANALYSIS

The schematic circuits of the Rail-to-Rail amplifier and OTA are simulated in Tanner Tool using PMOS and NMOS. The circuits are simulated with the supply voltage 1V. Compared to Rail-to-Rail amplifier, the linearity and band width are large in OTA.

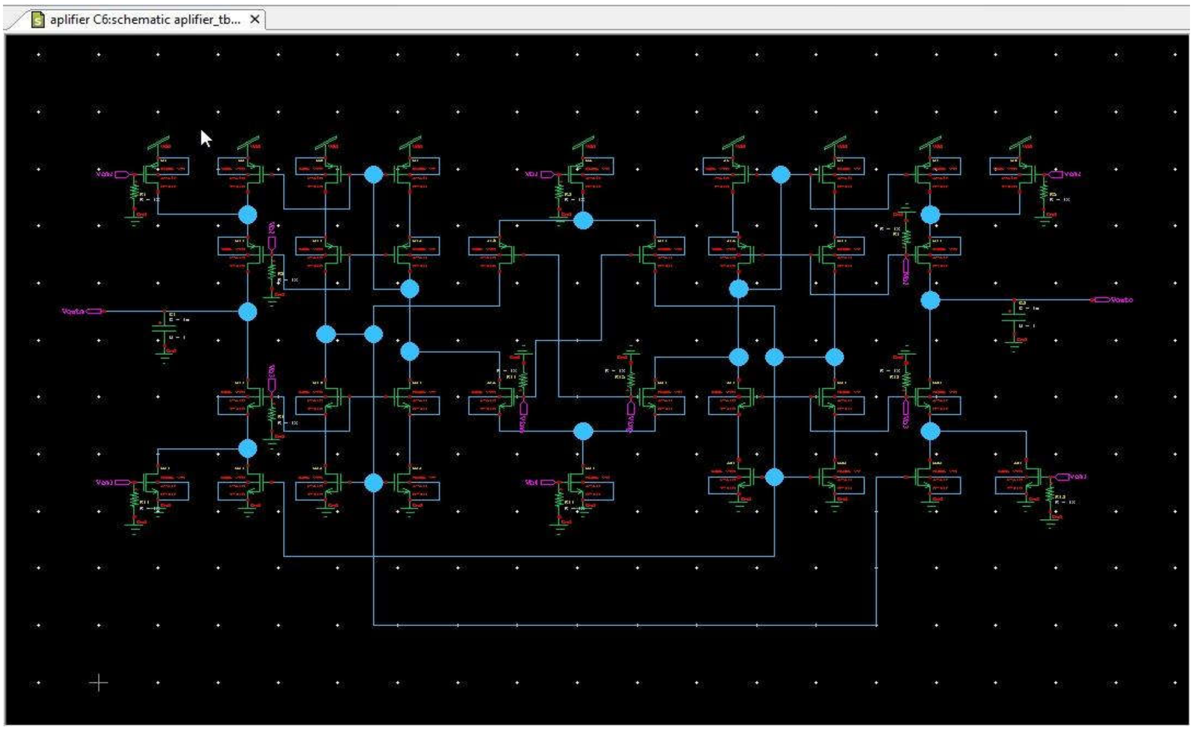

Fig.2. Rail-to-Rail Amplifier

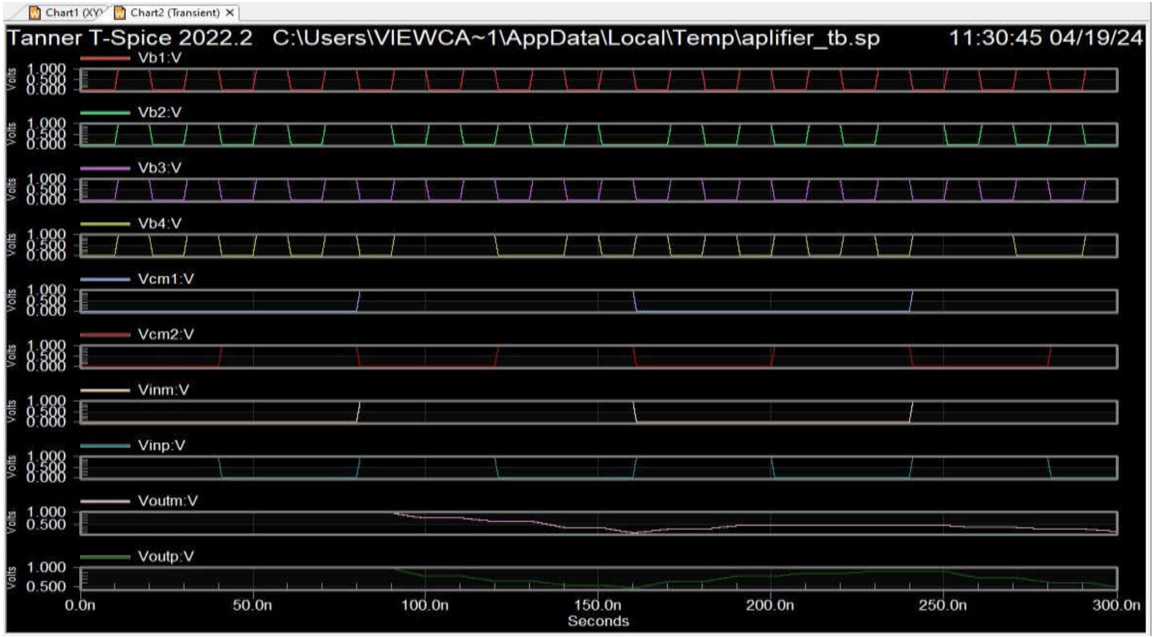

Fig.3. The output response of the Rail-to-Rail Amplifier

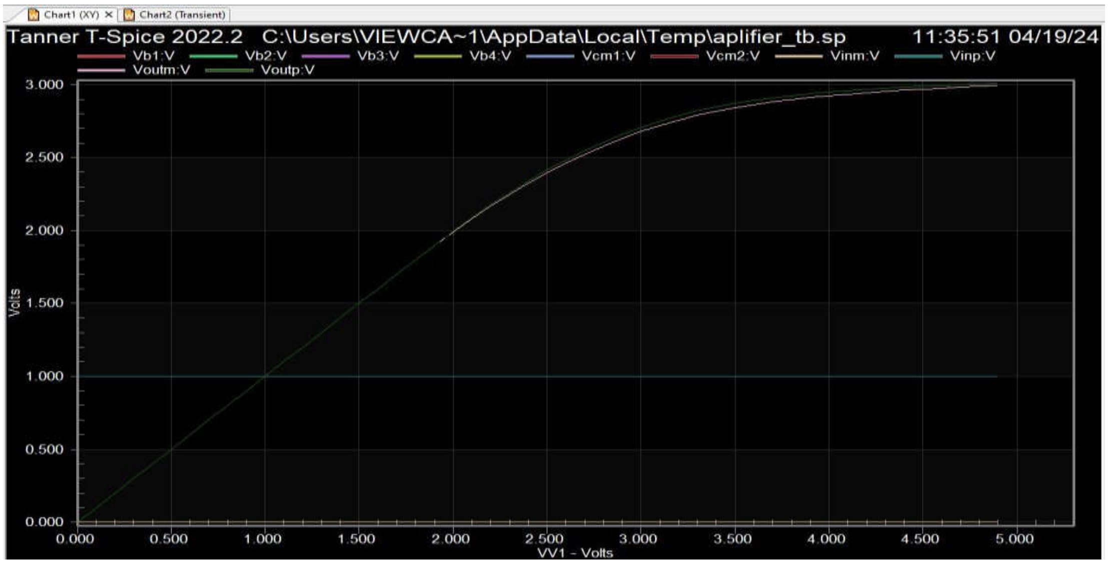

Fig.4. Frequency Response of the Rail-to-Rail Amplifier

POWER RESULTS

Input	From Time	To Time	Min Power	Max power	Average Power
Vcm1	0	4e-008	0	5.0108	8.0103w
Vcm2	0	4e-008	0	5.0182	2.0879w
Vb1	0	4e-008	0	2.5054	1.0503w
Vb2	0	4e-008	0	5.0482	3.3411w
Vb3	0	4e-008	0	5.0322	2.1094w
Vb4	0	4e-008	0	2.5054	4.3443w
Vinp	0	4e-008	0	2.5138	4.1897w
Vinm	0	4e-008	0	2.5142	1.0547w

CONCLUSION

In conclusion, Transconductance Amplifier circuits represent a significant advancement in analog signal processing, offering a versatile solution for a wide range of applications. Transconductance Amplifiers exhibit high linearity, gain, and bandwidth, making them suitable for applications requiring accurate signal amplification across different frequency ranges.

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