

# Applications of Trans-Conductance Amplifier in CMOS Technology

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**Abstract:** Operational Transconductance Amplifiers (OTAs) are currently essential elements of modern analog circuit design due to their flexibility, tunability by electronics, and CMOS integration feasibility. OTAs turn input differential voltages into output currents as opposed to the traditional voltage-mode operational amplifiers (VOAs), which are not. They are particularly well-suited for current-mode signal processing. Their special transconductance characteristic, which can be controlled by biasing, makes them suitable for a variety of applications such as filters, analog-to-digital converters, biomedical amplifiers, and active gain control systems. This paper discusses the history, design methods, and applications of OTAs with a focus on CMOS technology. There have been several OTA architectures proposed, including folded-cascode, NCFF (No-Capacitor Feed-Forward), and fully differential topologies, each seeking to enhance gain, bandwidth, linearity, and power efficiency. Biomedical applications led to the evolution of low-power, low-voltage OTAs for operation under stringent noise and signal requirements. Methods such as DTMOS biasing and current-mode circuit design have been implemented to optimize OTA performance in such applications. Furthermore, VDTA and MO-CCCCTA-based structures provide enhanced flexibility and integration for analog signal processing. OTA implementation challenges such as limited linear input range, temperature sensitivity, and requirement for frequency compensation in multi-stage OTA structures are also discussed in the study. Active filter structures like Gm-C filters illustrate the effectiveness of OTA in high-frequency domains with decreased power consumption and area. The research scans recent innovations and systematic reviews between 2017 and 2021, providing insights into OTA development trends, technology usage, and application-specific optimizations. Overall, OTAs continue to be a pillar in analog design, allowing for compact, tunable, and power-efficient solutions in various application domains, especially in CMOS-compatible systems.

**Keywords:** Operational Transconductance Amplifier (OTA), CMOS Technology, Analog Circuit Design, Gm-C Filters, Low-Power Electronics

## I. INTRODUCTION

Operational trans conductance amplifiers are used in a very distinct kind of multiple-amplifier filter (OTAs). Conventional operational amplifiers should have zero output resistance, infinite input resistance, and nearly infinite gain. The realizations outlined in the previous paragraph effectively make the circuit realization independent of the operational amplifier gain by utilizing a significant quantity of feedback. An output voltage proportionate to an input current is produced by the operational trans conductance amplifier. In this way, it closely resembles the fundamental operation of the solid-state electronics that made it possible. By changing the circuit's bias, the trans conductance gain  $g_m$  can be changed over a long period of time. In an Active-RC circuit, trans conductance can be used in place of the resistors to create a device that is active with high-frequency performance that is far better than multiple-amplifier circuits that use traditional operational amplifiers.

OTAs are represented as a triangle with circles that overlap at the output terminals. One major disadvantage of employing OTAs is the limited differential input swing needed to guarantee linearity.

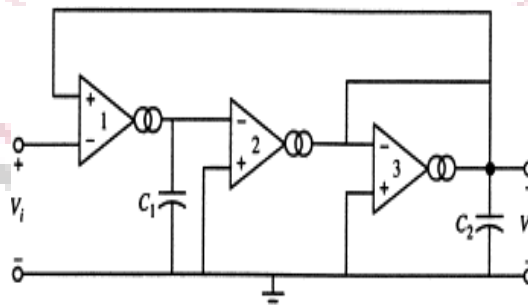


Fig. 1 Low pass Filter used in Operational

### A. Tran's conductance Amplifier

The conventional voltage mode operational amplifier (VOA) is without a doubt the most widely used and adaptable building block in the field of analogue signal processing. During approximately 1985, there was also a strong research focus on Gm-C and OTA-C (Operational Transconductance Amplifier-Capacitor) circuits, with a focus on the

electronically tunable feature and their amenability for integration with both bipolar and CMOS technologies.

### B. Operational Transconductance Amplifiers

(OTAs) are crucial components of analogue circuitry. OTAs have been employed in industry and the subject of academic study ever since the early days of integrated circuit science. Over the years, the literature has identified a wide range of OTA design techniques and methodologies. Despite these significant improvements in IC, some fundamental building blocks are still required. Voltage regulators, reference sources, analogue filters, analog-to-digital converters, etc. are needed for the majority of analogue projects. The operational transconductance amplifier (OTA), one of these fundamental circuits, has many analogue applications. The differential pair is one of an OTA's fundamental building blocks.

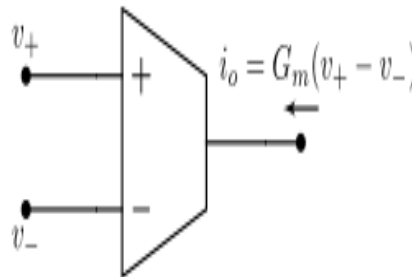


Fig. 2 An OTA symbol for balanced input/single output

However, in more current technologies, we regularly find the arrangements using either bipolar or MOS transistors sharing their emitters or sources, respectively. Originally, the differential pair was formed with the cathodes coupled together. In Figure 2, a typical OTA symbol is depicted. The OTA in this diagram has a single current output and a balanced or differential voltage input. Keep in mind that the output current depends on the input voltage differential and is inversely correlated with the transconductance of the device ( $G_m$ )

## II. LITERATURE REVIEW

According to Thandri et al. [1], high-frequency operational Transconductance amplifiers are built using updated feed-forward techniques (OTA). The two- and three-path folded-cascode OTAs show better settling accuracy and quicker response time than the traditional folded-cascode topology with equal transistor size and power budget. In an NCFE compensation technique, a high-frequency pole-zero doublet is utilized to realize high GBW, increased gain, and robust phase margin. Even while the OTA architecture with Miller adjustment uses bigger transconductance values, the NCFE topology's settling time can be quicker.

Most commonly used analogue processing block is operational transconductance amplifier (OTA) as per Shankar et al. [2]. OTA with very low conductivity, low voltage, low power, and improved linearity has been developed mainly for biomedical applications over the past few years. The CMOS-based operational transconductance amplifier presented in this research is tunable in frequency and can be modified by adjusting the control voltage. The frequency of the OTA can be set to be used for a range of biomedical applications, such as ECG, EEG, and ERG applications, which operate at frequencies of 250Hz, 200Hz, and 100Hz, respectively. The design of the proposed OTA was finished in a 90nm CMOS technology with supply voltage around 0.35V.

By employing CMOS technology, Mahendra et al. [3] proposed a two-stage, fully divergent transconductance amplifier with low power and low voltage. The paper discusses a new adaptive biasing technique combined with Dynamic Threshold MOSFET (DTMOS) technology to achieve a higher slew rate without any power supply overhead. The differential OTA presented using DTMOS operates at a dual supply voltage of  $\pm 0.5$  V. It delivers an average slew rate of 168 V/ $\mu$ s with a mere 0.104 mW of static power dissipation. Moreover, the circuit realizes a DC gain of 73.86 dB and has a phase margin of  $72^\circ$  to ensure both performance and stability. For a 10-pF load capacitor, the recommended OTA's figure of merit is 16.15 [(V/s). pF/W]. Compared to earlier attempts, it demonstrates a notable improvement. The suggested universal voltage mode filter is used in a simulation to confirm the concept's resilience. The Mentor Graphics Eldospec with 0.18  $\mu$ m TSMC level 53 CMOS technology was used to assess the performance and utility of the suggested circuit.

Silva-Martinez et al. [4] have reported that feed-forward methods are in active research for high-frequency

operational transconductance amplifier (OTA) design. The recycling folded-cascode OTA provides over twice the slew rate (231.1 V/ $\mu$ s vs. 99.3 V/ $\mu$ s) and GBW (197.2 MHz vs. 106.3 MHz) than a traditional folded-cascode OTA, at the same load, power, and transistor size. This structure provides efficiency rivaling that of a telescopic OTA. An NCCF (no-capacitor feed-forward) compensation method for multistage amplifiers is also explored, employing a high-frequency pole-zero doublet to realize a phase margin of over 70°, a GBW of 325 MHz, and a DC gain of more than 90 dB. The NCCF topology also exhibits faster settling than OTAs using Miller compensation. These outcomes validate the performance of feed-forward methods in both NCCF compensation and recycling folded-cascode OTA, both realized in TSMC 0.18  $\mu$ m CMOS.

Zaffer et al. [5] give a detailed review of studies conducted to use the Voltage Differencing Transconductance Amplifier (VDTA) as an active building block to design analog signal processing circuits, especially filters. VDTA, being a newly introduced active element, has been successfully used to design filters and other analog processing networks. The authors emphasize the dominant benefits provided by the ideal features of VDTA. Additionally, some forms of active filters make use of VDTA's potential for electronic transconductance gain tuning. The review starts with a summary of filters and their applications before proceeding into detailed analysis that also includes coverage of non-VDTA-based designs.

Analog circuits require operational trans conductance amplifiers (OTAs), which are fundamental components. OTAs have been employed in industry and the subject of academic study ever since the early days of integrated circuit science. Numerous methods and strategies for OTA design have been noted in the literature over the years. We hope to present a summary of the most important journal papers that discuss OTA design and were published from 2017 to 2021 through this systematic review. Bendre et. al. [7], initially discovered 128 publications and 24 primary studies of OTA design during this inquiry. There have been discovered to be ten distinct approaches. Additionally, we assessed utilized technology, the process of characterization and inversion. We help to highlight recent OTA design advances with this study.

Using the multiple-output current regulated current conveyor Tran's conductance amplifier (MO-CCCCTA), Roy et al. [8] are able to create creative designs for basic circuits and current-mode squaring square-rooting circuits. The suggested circuits may operate at high frequencies and are ideal for IC manufacturing because they don't require any additional external components.

Furthermore, their gains are not affected by temperature and can be easily altered by varying the MO-CCCCTA bias currents. Furthermore, the effect of MO-CCCCTA non-idealities on the proposed circuits has been investigated and talked about. The mentioned circuits have also been utilized as a 2-input vector summation circuit to enhance the design concepts.

Singh et al. [9] observe that over the last three decades, several new analog circuit building blocks have been introduced, complementing the conventional structures including the operational transconductance amplifier (OTA), operational amplifier (op-amp), current feedback amplifier, and current conveyors. Of these, the Operational Transresistance Amplifier (OTRA) has proven to be a novel architecture and has attracted serious attention in the literature. This work is a detailed, up-to-date review of bipolar and CMOS realizations of OTRAs and their uses in linear and nonlinear analog signal processing and generation. The work contains a complete bibliography of developments between the years 1992 and the current date.

The FCTs of the two-stage OTAs must be considered in analog design, according to Mohammed [10]. All other multi-stage OTA FCTs are thought to require them. The evolution of the two-stage OTAs' primary FCTs is investigated in this paper. This brief investigation tracks each major FCT's evolution from the start. The description of these early efforts is reviewed, along with the possibility of enhancements for each primary strategy, as some of these approaches have not yet reached their full potential. Furthermore, this paper displays the constant evolution of each major FCT, which could help predict the future of these FCTs. Design engineers and universities offering graduate-level advanced courses can use this work as a reference.

Three low-noise amplifier topologies used in neural recording applications are compared in this work. Ruiz-Amaya et al. [11] provide a comprehensive analysis of the designs on the basis of their noise efficiency, power consumption, and silicon area performance. Furthermore, simulations of transistor-level implementations in a 0.13- $\mu$ m CMOS technology at 1.2V supply voltage support the theoretical findings.

(Riad et al., 2019) reviews a wide range of previously reported layouts and suggests a novel classification approach that reveals aspects common to seemingly disparate compensation schemes and acts as a guide to choose which kind of OTA is appropriate for a particular application. To help the designer decide which OTA architecture best fits the particular tradeoffs of the application, a novel figure of merit (FoM) is also suggested. Results from transistor-level simulations support theoretical considerations.

The nonlinear operation of the (CBTA) current backward trans conductance amplifier at low frequencies is modeled using a SPICE-compatible macro model, report Márquez-Cabrera et al. [13].

The macro model based on the projection is unique with parasitic elements located at the input and output ports of the Current Buffered Transconductance Amplifier (CBTA) and the real physical active device performance characteristics. The CBTA is first realized based on 2.5 V and 0.35  $\mu\text{m}$  AMS standard CMOS technology, from which important performance measures—such as DC gain, bandwidth, slew rate, dynamic range, and parasitic parameters—are derived. As per these findings, a SPICE-compatible macro model is formulated, and an equivalent behavioral model of the CBTA is created. Later, two Saturated Nonlinear Function Series (SNFS) topologies, constructed around the CBTA, are formed to test the validity of the derived behavioral model. Both the SNFS circuits are fed with an experimentally obtained chaotic signal, using both the transistor-level implementation of the CBTA and the new macro model. Consequently, the macro model decreases CPU processing time by an order of magnitude or more over the transistor-level simulations while maintaining accurate capture of nonlinear circuit behavior in the time domain.

As per Bansal and Jyoti [14], the healthcare industry is greatly dependent on smart healthcare monitoring systems. Of these, wireless health monitoring systems are one of the greatest advances in current medical technology. These advanced systems have the ability to continuously monitor essential parameters like the body temperature, heart rate, neurological signals, and abnormally occurring physiological activities in real time. This paper surveys and reviews applications of an (LNA) Low Noise Amplifier in the medical field, including neural recording systems, medical implantable systems, ECG and EEG monitoring systems, biosensor applications, etc. Additionally, LNA design requirements for various applications have been studied. A front-end receiver Low-Noise Amplifier (LNA) is required to satisfy a number of imperative design specifications such as low noise figure, nominal supply voltage operation, high gain-bandwidth product, and adequate signal-to-noise ratio. Input and output impedance matching is also required for the best possible performance. These parameters are thoroughly discussed in this paper, which also emphasizes their importance in a range of application contexts.

An amplifier called an operational trans conductance amplifier (OTA) is a gadget that takes differential voltages as input and provides output in the form of current. The OTAs play an essential role in the build-up of analogue circuits, which were previously implemented with Op amps. (Mann et. Al. [19] gives an overview of different methods of the design of the OTA and the subsequent realization of active filters based on the proposed OTA. The findings in this research will assist future researchers aiming to develop improved operational transconductance amplifiers (OTAs) with improved linearity, high frequency operation, and low power dissipation.

| Topology           | Speed   | Gain     | Power Consumption | Output Swing |
|--------------------|---------|----------|-------------------|--------------|
| Single stage       | Fast    | Low      | Low               | Low          |
| Two stage          | Slow    | High     | Moderate          | Highest      |
| Telescopic Cascode | Fastest | Moderate | Low               | Moderate     |
| Folded Cascode     | Fast    | Moderate | Moderate          | Moderate     |

### III. APPLICATIONS OF TRANSCONDUCTANCE AMPLIFIERS

OTAs are different from operational amplifiers in that current, rather than voltage, is a significant output parameter for OTAs. In linear applications, open-loop systems without undesirable feedback are also more commonly used with OTAs. This is because even with proportionally large differential input voltages, the OTA is prevented from saturating by the high output resistance, which controls the output voltage and can be carefully selected so that it does not. The hybrid device can be used as a working amplifier by including an output buffer amplifier, which effectively converts the OTA current output into voltage output.

The OTA has uses in sensors, bio-medical signal amplification, compact devices, filters, and analogue to digital converters. Active filters can be implemented in CMOS technology using a variety of circuit architectures, including switched-capacitor structures, OTA-C, Gm-C, and op-amp-RC. Gm-C is the most popular of these structures since it offers a straightforward layout with less power consumption and less room. The transfer function of Gm-C filters

is derived using voltage to current converters, trans conductance, and capacitance.

Both first-order active filters and second-order active filters can use the operational trans conductance amplifier (OTA) in place of a traditional op-amp. It is intended, at least in part, to familiarize the technology student with the fundamentals of OTA functioning as well as the use of the already available commercial OTA in practice.

Real OTA circuits frequently have a suitable limit to the input voltage differential that produces a linear response because of the input stage transistors' properties. Additionally, OTAs frequently display temperature-sensitive trans conductance behavior. The trans conductance control current's effect on an OTA's input and output impedances, input bias current, and input offset voltage.

The three basic OTA configurations—DISO (Differential Input, Single Output), SISO (Single Input, Single Output), and DIDO (Differential Input, Differential Output)—provide a variety of fully differential input-output functions appropriate for a range of analog signal processing applications.

An OTA element is a fundamental component that is used to streamline automatic gain designs. Applications include fast-pulse integrators, active filters, control loops for capacitive sensors, (LED) light-emitting diode driver circuits, and more. [20].

#### IV. CONCLUSION

The conventional voltage mode operational amplifier (VOA) is without a doubt the most widely used and adaptable building block in the field of analogue signal processing. But there is also a lot of research on Gm-C and OTA-C circuits, with an emphasis on their electronic tunability and suitability for integration in CMOS and bipolar technologies. OTAs differ from operational amplifiers in that current, as opposed to voltage, is an important output parameter for OTAs. This essay examines the OTA and its uses.

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