

# Low Power CMOS Operational Transconductance Amplifier (OTA) Design

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**ABSTRACT:** Operational Transconductance Amplifiers (OTAs) are fundamental building blocks in modern analog and mixed-signal integrated circuits. With the rapid growth of portable, biomedical, and Internet of Things (IoT) applications, there is an increasing demand for low-power and low-voltage analog circuit design. This paper presents an overview of low-power CMOS OTA design techniques, emphasizing power-efficient architectures, key performance parameters, and challenges associated with reduced supply voltages.

**KEYWORDS:** Low Power Design, CMOS OTA, Transconductance Amplifier, Analog Integrated Circuits, Low-Voltage Operation.

## 1. INTRODUCTION

The Operational Transconductance Amplifier (OTA) is a voltage-controlled current source that plays a vital role in modern analog and mixed-signal integrated circuits. It is extensively used in applications such as analog and active filters, data converters, sensor interface circuits, and biomedical signal processing systems. Unlike conventional operational amplifiers, OTAs provide an electronically tunable transconductance, which allows designers to control gain and bandwidth through bias current adjustment. This feature makes OTAs especially suitable for low-voltage and low-power applications.

With continuous scaling of CMOS technology, supply voltages have significantly reduced, introducing stringent constraints on analog circuit design. Lower supply voltages limit voltage headroom, reduce intrinsic gain, and make it challenging to achieve high linearity and wide bandwidth. As a result, the design of power-efficient OTAs that can operate reliably under low-voltage conditions while maintaining sufficient gain, bandwidth, noise performance, and linearity has become a critical area of research. Consequently, low-power

CMOS OTA design is essential for meeting the performance requirements of emerging portable, wearable, and IoT-based systems.

## 2. KEY PERFORMANCE PARAMETERS OF CMOS OTA

The performance of a low-power CMOS OTA is typically evaluated based on several critical parameters:

- **Power Consumption:** Minimizing static and dynamic power dissipation is essential for battery-operated systems.
- **Transconductance (gm):** Determines the gain and bandwidth of the OTA and is directly influenced by bias current.
- **Gain and Bandwidth:** Adequate open-loop gain and gain-bandwidth product (GBW) are required for stable operation.
- **Noise Performance:** Low input-referred noise is crucial in sensor and biomedical applications.
- **Linearity:** Ensures accurate signal amplification with minimal distortion.
- **Supply Voltage:** Low-voltage operation is required to support advanced CMOS technologies.

## 3. LOW POWER OTA DESIGN TECHNIQUES

Several techniques are employed to achieve low-power operation in CMOS OTAs:

- **Subthreshold (Weak Inversion) Operation:** Transistors operate below threshold voltage, significantly reducing power consumption while maintaining high gm/ID efficiency.
- **Current Reuse Techniques:** Stack multiple signal paths using the same bias current to enhance transconductance without increasing power.
- **Bulk-Driven OTAs:** Utilize the bulk terminal as an input to enable operation at ultra-low supply voltages.
- **Self-Biased and Adaptive Biasing:** Dynamically adjust bias currents based on signal conditions to optimize power efficiency.
- **Low-Voltage Topologies:** Architectures such as folded cascode, telescopic, and inverter-based OTAs are optimized for reduced voltage headroom.

## 4. APPLICATIONS

Low-power CMOS OTAs are extensively used in:

- Biomedical devices (ECG, EEG, and implantable sensors)
- Wireless sensor nodes
- Portable and wearable electronics
- Low-power data converters and analog filters
- IoT and energy-harvesting systems

## 5. CHALLENGES AND FUTURE SCOPE

Designing low-power CMOS OTAs presents challenges such as reduced gain due to low supply voltage, increased sensitivity to process variations, and higher noise levels. Future research directions include the integration of AI-assisted analog design, ultra-low power near-threshold circuits, and advanced CMOS process nodes to further enhance performance while minimizing power consumption.

## 6. CONCLUSION

Low-power CMOS OTA design plays a crucial role in enabling energy-efficient analog and mixed-signal systems. By adopting advanced circuit techniques such as subthreshold operation, current reuse, and low-voltage architectures, designers can achieve significant power savings without compromising performance. Continued innovation in CMOS technologies and design methodologies will further advance the development of ultra-low power OTA circuits for next-generation applications.

## REFERENCES

- [1] S. Sharma, D. Yadav, G. K. Soni and G. Shankar, "Operational Transconductance Amplifier for Bluetooth/WiFi Applications Using CMOS Technology," IEEE International Conference on Integrated Circuits and Communication Systems (ICICACS), pp. 1-4, 2024.
- [2] G. Shankar, G. K. Soni, B. Kumar Singh and B. B. Jain, "Tunable Low Voltage Low Power Operational Transconductance Amplifier For Biomedical Application," IEEE 2021 Fourth International Conference on Electrical, Computer and Communication Technologies (ICECCT), pp. 1-6, 2021.
- [3] G. K. Soni, H. Singh, H. Arora and A. Soni, "Ultra Low Power CMOS Low Pass Filter for Biomedical ECG/EEG Application," IEEE 2020 Fourth International Conference on Inventive Systems and Control (ICISC), pp. 558-561, 2020.
- [4] Y. Sahu, G. K. Soni, H. Singh, D. Jangir, A. Rawat, "Design of High Linearity Nanoscale CMOS OTA Based Bandpass Filter for Bluetooth Receiver", Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 6, Issue. 1, pp. 335-338, 2019.
- [5] S. Gour and G. K. Soni, "Reduction of Power and Delay in Shift Register using MTCMOS Technique," IEEE 2020 4th International Conference on Trends in Electronics and Informatics (ICOEI), pp. 202-206, 2020.
- [6] G. K. Soni, G. S. Sharma, "A review on low voltage low power Gm-C and OTA-C low pass filter for biomedical application", International Journal of Engineering and Technical Research (IJETR), Vol. 4, Issue. 2, pp. 33-36, 2016.
- [7] G. K. Soni, H. Arora, "Low Power CMOS Low Transconductance OTA for Electrocardiogram Applications", Springer Recent Trends in Communication and Intelligent Systems. Algorithms for Intelligent Systems, pp. 63-69, 2020.
- [8] B. K. Singh, G. Shankar, Bh. B. Jain, "An Overview on Low Voltage Low Power Operational Transconductance Amplifier (OTA) for Biomedical Application",

International Journal of Engineering Trends and Applications (IJETA), Vol. 8, Issue. 3, pp. 1-5, 2021.

- [9] B. K. Singh, G. Shankar, Bh. B. Jain, "Operational Transconductance Amplifier For Biomedical EMG Application Using CMOS 90nm Technology", International Journal of Technical Research & Science, Vol. 10, 2021.

