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Research Article

Comparison of the Transistor Channel Length and Performance Parameters of a Fully Differential Operational Amplifier

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Abstract

Today's practical applications require an amplifier with high-performance specifications. Researchers have been trying to design small size transistors to get more performance. Reduce the scale of transistor sizes in operational amplifiers (op-amps) to obtain better values for the performance characteristics are important. The main objective of this study was to understand the relationship between the performance parameters of a fully differential amplifier and the channel length of the transistors. In this study, fully differential op-amp performance metrics were examined and contrasted with their channel lengths utilizing a common 1.8V power supply. The graphs were plotted using Python software. The outcome demonstrates that, as the transistor's channel length decreases, the gain and unity gain band width of the fully differential op-amp increase. This demonstrates how reducing the transistor's size allows for high amplification devices. There for to obtain amplified signal one cane use small size transistors. The totally differential op-amp's power dissipation and settling time are also decreased as the transistor's channel length is decreased. This shows that in order to create fully differential op-amps that operate for long periods of time, the transistor size needs to be decreased. Therefore in this work we can understand that to get an op-amp which operates better we must reduce their size as much as possible.

Keywords

Transistor Channel Length, Python Software, Performance Parameters

1. Introduction

Op-amps are incredibly high-gain circuit components. Differentiation, addition, subtraction, multiplication, division, integration, and logarithm are some of the mathematical operations that it is used for [1, 2]. Op-amps can be used for accurate measurement in a variety of other applications; including active filters, switching amplifiers, comparator, telecommunication, source control, and information processing. Voltage gain, slew rate, input resistor, unity gain bandwidth (UGB), output resistor, supply voltage, common mode rejection ratio, etc. are the major parameters of an Op-amp [3, 4].

Due to their strong capacity to withstand noise sources, differential signals have been used mostly in data transmission, telephone systems, and audio systems. It is getting more used in data acquisition today. Today's technological

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downscaling, complementary metal-oxide semiconductor (CMOS) technology, and growing demand for newly developed low-power, low-voltage, and battery-operated devices have imposed some major constraints on analog designs. Analog circuits must be able to function in conjunction with digital systems at very low supply voltages, which is typically the worst scenario for an analog block's performance [5, 6].

We must reduce transistor size to create an op-amp device with good performance criteria. Such a device uses less energy while operating and delivers the output swiftly [6, 7]. Due to their high input resistance, low power consumption, wide voltage supply range, good noise immunity, etc., CMOS technologies currently dominate the market [1, 4, 8].

Finding the portable performance characteristics of op-amps, which are utilized in consumer electronics, hearing aids, wireless communication goods, etc., is necessary for designing analog circuits [9, 10]. In order to reduce power consumption, transistor channel length must be decreased [11]. This will result in a smaller, lighter battery with a longer lifespan. Small circuits are also suggested in a similar way to reduce thermal dissipation [12, 13]. The overall tendency of this work is to reduce the circuit size in order to obtain better performance parameter values.

In comparison to their single-ended counterparts, fully differential amplifiers have a greater dynamic range, a stronger capacity for rejection, and less harmonic distortion [14]. Differential signaling is a better option for systems that need differential transmission lines because of these characteristics. However, a typical drawback of fully differential amplifiers is the need for a separate circuit called as common mode feedback to keep them stable [15].

Figure 1 shows some of the differences between a fully differential amplifier and a conventional voltage-feedback operational amplifier. There are differential inputs on both varieties of amplifiers. While the output of a typical operational amplifier is single-ended, fully differential amplifiers have differential outputs. The output is differential, and the output common-mode voltage can be regulated separately from the differential voltage in a fully differential amplifier. Setting the output common-mode voltage is the function of the input in the completely differential amplifier. The output common-mode voltage and the signal are identical in a typical operational amplifier with a single-ended output. In a conventional operational amplifier, the negative input and output are connected by a single feedback loop. Multiple feedbacks are present in a completely differential amplifier [7, 16].

A fully differential amplifier is very similar in architecture to a standard voltage-feedback operational amplifier, with a few differences, as illustrated in Figure 1. Both types of amplifiers have differential inputs. Fully differential amplifiers have differential outputs, while a standard operational amplifier's output is single-ended [2, 4, 8]. In a fully differential amplifier, the output is differential, and the output common-mode voltage can be controlled independently of the differential voltage. The purpose of the input in the fully differential amplifier is to set the output common-mode voltage. In a standard operational amplifier with single-ended output, the output common-mode voltage and the signal are the same thing. There is typically one feedback path from the output to the negative input in a standard operational amplifier. A fully differential amplifier has multiple feedback paths [6].

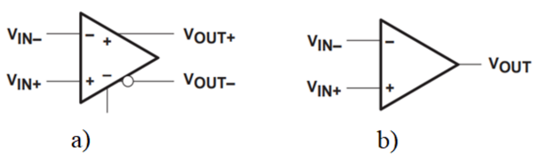

Figure 1. *a) Fully- differential amplifier b) Standard operational amplifier.*

2. Methodology

We chose dates that were taken from the literature and conducted the investigation in accordance with those dates. The Payton program was used to create the graphs. The performance characteristics of transistor channel lengths and completely differential amplifiers have been examined and compared using graphs. Eventually, choices were made. The simulation results for fully differential op-amp performance characteristics utilizing varied Chanel lengths are shown in Table 1 [17].

Table 1. *Simulation result of performance parameters of fully differential op-amp.*

Chanel length of transistor (µm)	Gain (dB)	unity gain band width (MHz)	Power Dissipation (mW)	Settling time (ns)
1.6	95	116	52	61.5
0.35	129	161	3.89	23.5
0.18	138.6	999	3.13	5.86

3. Result and Discussion

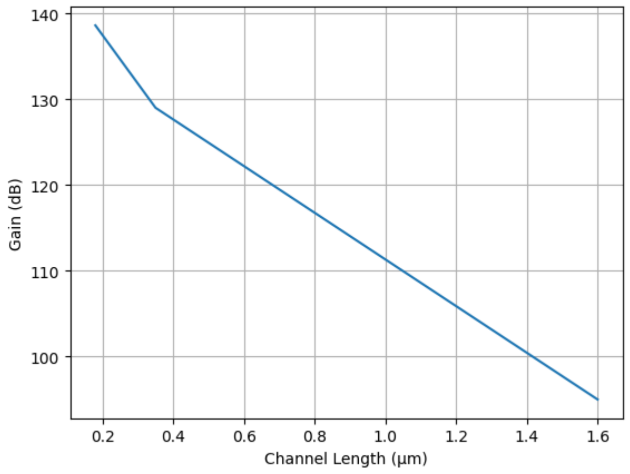

Figure 2. Gain versus channel Length of a fully differential op-amp.

Figure 2 depicts the relationship between the fully differential op-amp's gain and channel length. This figure illustrates how the gain of a fully differential op-amp increases as the channel length or transistor length decreases. This demonstrates that smaller CMOS devices work better when designing massive operational amplifiers. Additionally, scaling down the CMOS results in quicker speeds.

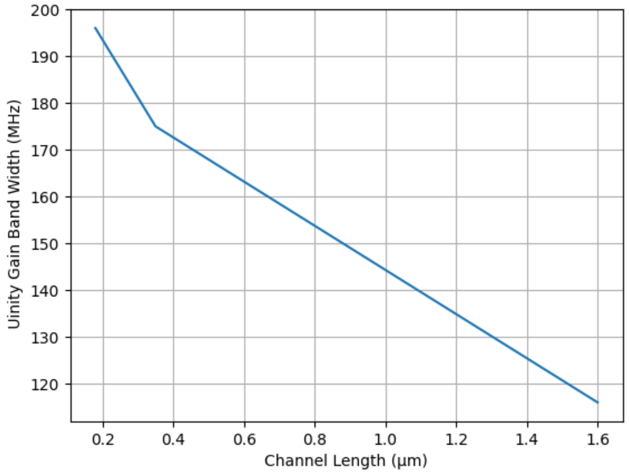

Figure 3. Unity gain band width versus channel length of a fully differential op-amp.

Figure 3 depicts the link between the fully differential op-amp's channel length and unity gain band width (UGB). Figure 3 makes it evident that the fully differential op-amp's unity gain band width increases as the channel length or transistor length decreases.

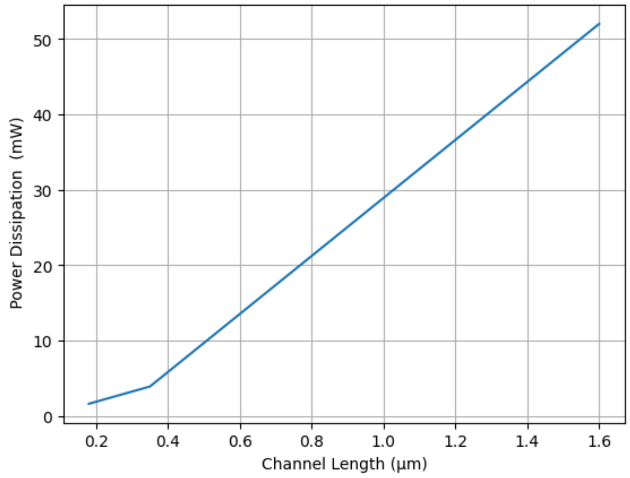

Figure 4. Power Dissipation versus channel length of a fully differential op-amp.

The link between fully differential op-amp channel length and power dissipation is seen in Figure 4. Figure 4 demonstrates how the channel length affects how much power the completely differential op-amp loses. Devices can operate for extended periods of time if they use little electricity. Therefore, we must reduce transistor sizes as much as feasible in order to develop op amps that work for a long time.

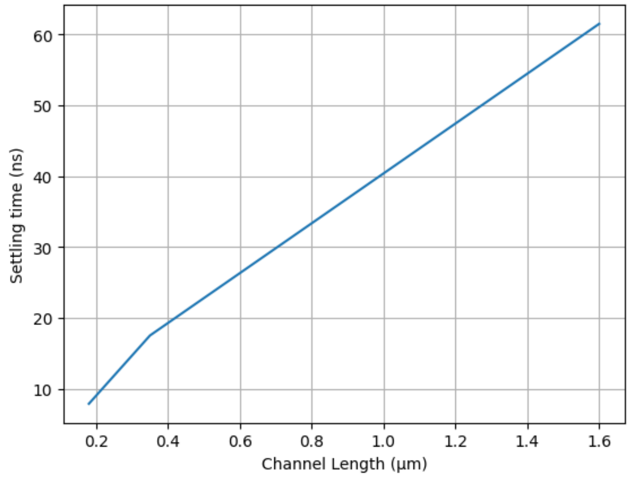

Figure 5. Settling time versus channel length of a fully differential op-amp.

Figure 5 shows the correlation between fully differentiated op-amp settling time and channel length. As can be observed from the graph, the settling time of an op amp lowers as the channel length does. Thus, there was a direct correlation between op amp settling time and channel length.

4. Conclusion

In this paper, we attempted to establish a correlation between Gain and channel length, Power Dissipation and channel length, Settling Time and channel length, and UGB and channel length for a completely differential op-amp. Using the same supply voltage, the fully differential op-amp's channel length and performance metrics have been evaluated. The findings demonstrate that as channel length decreases, an op-amp's settling time increases, and vice versa. A fully differential op-amp's gain also rises when channel length or transistor length decreases. With decreasing transistor or channel length, the totally differential op-amp's unity gain band width also grows. Additionally, as the channel length shrinks, less power is lost by the fully differential op-amp.

Abbreviations

Op amps	Operational Amplifiers
CMOS	Complementary Metal Oxide Semiconductor
UGB	Unity Gain Bandwidth
µm	Micrometer
dB	Decibel
mW	miliwatt

Ethical Approval

I hereby certify that, study didn't include the animal as well as human study. I hereby certify that I have given my consent for the manuscript to be submitted to Analog Integrated Circuits and Signal Processing Journal. I also consent to the journal receiving the author's copyright. The manuscript has been written in accordance with the journal's requirements and has undergone linguistic editing. Additionally, this paper was written entirely by me. I hereby certify that the work in question is entirely original and that it is not already being considered for publication elsewhere.

Author Contributions

Tsegaye Menberu Genzebu is the sole author. The author read and approved the final manuscript.

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Data Availability Statement

All dates used this article are valuable.

Conflicts of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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