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AC and Transient Analysis of N Type Carbon Nanotube Based cum CMOS based Folded Cascode Operational Amplifier

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Abstract—**Carbon Nanotube Field Effect Transistor (CNTFET) will play vital role in designing of combinational and sequential circuits which are back bone of digital computers. It is clear that carbon nanotube field effect transistors are the future of electronic circuit. This paper also explores the analog applications of carbon nanotube based circuits for nanoelectronics. In this research paper, simulation of N Type CNFET based folded cascode Op Amp based on carbon nanotubes (CNT) has done at 45 nm technology. N Type Carbon Nanotube Field Effect Transistor (CNTFET) based Folded Cascode Operational Amplifier (FC-OPAMP) is analyzed through AC and Transient Response. In the Frequency Response of N Type CNTFET based Folded Cascode Op Amp, it is clear that the amplifier is efficiently working since the DC Gain is almost constant upto 1 MHz. It is also clear that the N Type CNTFET based Folded Cascode Op Amp is working as low pass filter, so it has applications in the low pass circuits. Further, it is clear from Phase response that it is stable amplifier. So, we can use it in robust conditions where stability is main concern. Furthermore, it is clear that the amplifier is power efficient since in all the conditions, the Transient Power is in nano watts.**

Index Terms- **CNTFETs, folded cascode Op Amp, simulation, AC Analysis, Transient Analysis.**

I. Introduction

The history of metal-oxide-semiconductor field-effect transistor (MOSFET) starts as early as 1964 when the first MOSFET is invented and since then, this device has dominated in digital application especially related to modern computers. This is not surprising since MOSFET offers high reliability and low power consumption, plus it can also be packed in large numbers within a single integrated circuit due to its relatively small size. As CMOS technologies evolves well into short channel length, there is decrease in supply voltage and decline in device characteristics. Due to these conditions Operational Amplifier is rigorous. Intrinsic gain of the transistor becomes low due to inferior device output impedance. Now in order to ensure further improvement in Field Effect Transistor performance with sustaining Moore's Law, it is necessary to find out the other technique like Carbon Nanotube Field Effect Transistors that gives the better performance than existing MOSFETs. A lot of work has been available in the literature on the digital applications of Carbon Nanotube Field Effect Transistors but its analog applications have not been explored. Keeping the foregoing in mind, this paper investigates in detail the performance of N Type CNFET based folded cascode Op Amp based on carbon nanotubes (CNT) has done at 45 nm technology for AC and Transient Analysis. There are several effects that appear as the MOSFET size reaches nanometer scale and becomes the limiting factor that affect the performance of the MOSFET itself. The factors are : (a) Short channel effect (b)Tunnelling effect (c)Ballistic transport (d) Oxide thickness (e) Threshold voltage.

Another perspective of limitation factors to scaling process of MOSFET are (a) Theoretical limit (b) Technology limit (c) Economical limit.

In 1991 a Japanese scientist, Sumio Iijima, studied the carbon soot created by a direct current arc-discharge between carbon electrodes, he discovered a range of molecules that have been the object of intense scientific research ever since. Using a high-resolution transmission electron microscope (HRTEM), it is found that this long molecules consisting of several coaxial cylinders of carbon. This discovery drives the research field for carbon nanotube although the preparation of carbon filaments were already started in 1980's and 1970's through the synthesis of vapor grown carbon fibers.

Carbon nanotubes (CNTs) are one of the most promising candidate that might offer a solution to some of the problems mentioned above. They are self-assembled one dimensional (1-D) macromolecular systems with some exceptional electronic properties. Carbon nanotubes can be either metallic or semiconducting depending on their structure, which suggests their potential for quite different nanoelectronic applications. On the one hand the semiconducting CNTs, with their high current densities and the lack of interface states, in comparison with the silicon/SiO2 interface, would be ideal candidates to replace silicon in future transistors. As a matter of fact, it has already been demonstrated that CNT field-effect transistors (FETs) can have a performance superior to the most advanced silicon MOSFETs [1-2].

For instance, carbon nanotubes exhibit thermal conductivities even larger than that of diamond at room temperature . This is quite intriguing, since heat dissipation is already a crucial issue in today's ICs. Further, nanotubes show exceptional mechanical and chemical stability. Their elastic modulus can be as high as 1 TPa [3-4].

Inspired by the fullerene research, a number of research groups theoretically considered a hypothetical carbon structure consisting of only a single sheet of graphite wrapped into a tube that resembles a stretched fullerene molecule – the single-walled carbon nanotube (SWCNT) [8, 9, 10]. Some exciting properties were predicted for SWCNTs, for instance that they should be either semiconducting or metallic and

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behave like 1-D conductors. SWCNT were discovered only a short time later, in 1993.

This paper begins with an overview of Carbon Nanotube Field Effect Transistors (CNFET) and Folded cascode Op Amp in Section 2. Section 3 covers the AC and Transient Analysis of N Type CNTFET based Folded Cascode Op Amp. Section 4 gives Result & Discussion. Section 5 gives conclusion.

II. CARBON NANOTUBE AND CARBON NANOTUBE FIELD EFFECT TRANSISTOR

Now in order to ensure further improvement in FET performance with sustaining Moore's Law, it is necessary to look for alternative like Carbon Nanotube Field Effect Transistors (CNFETs) that promise to deliver much better performance than existing MOSFETs. CNFET technology can also be easily clubbed with the bulk CMOS technology on a single chip and utilizes the same infrastructure. A single walled carbon nanotube is a one-dimensional conductor, that can be either metallic or semiconducting depending upon the arrangement of carbon atoms decided by their Chirality, Ch (i.e. the direction in which the graphene sheet is rolled) whose magnitude and relationship with CNT diameter is given by Eqs. (1) and (2) respectively where 'a' is the graphene lattice constant (0.249nm) and n1, n2 are positive integers that specify the chirality of the tube [9]-[12] , [19].

$$C_h = a \sqrt{(n_1^2 + n_2^2 + n_1 n_2)} \qquad (1)$$

$$D_{CNT} = C_h / \pi \qquad (2)$$

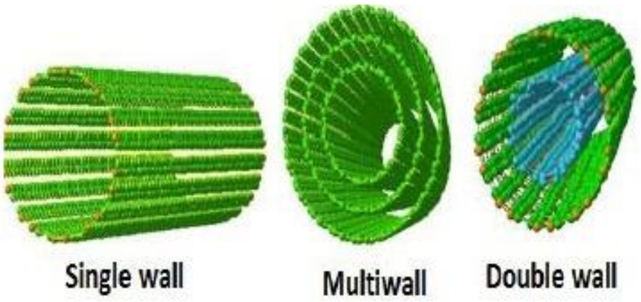

Figure 1: Different types of Carbon NanoTubes.

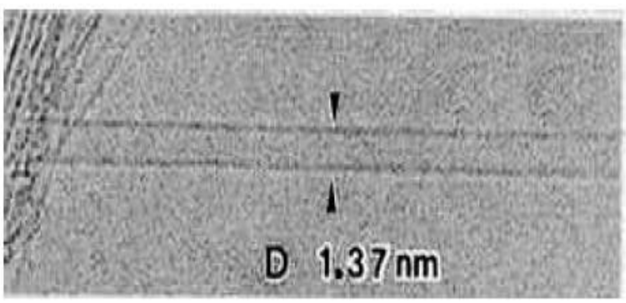

Figure 2: One of the first TEM images of a SWCNT from Iijima et al. [7].

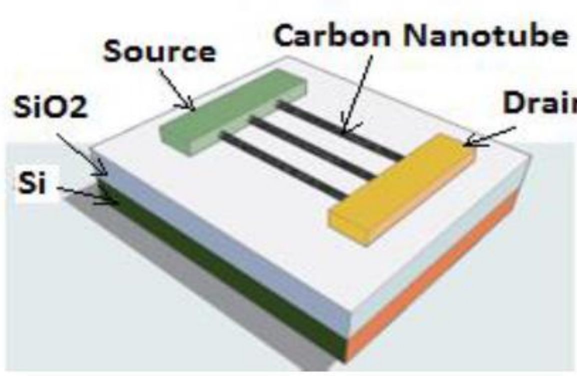

Figure 3: Three Dimensional CNTFET structure.

III. PROPOSED CNTFET BASED FOLDED CASCODE OPERATIONAL AMPLIFIER DESIGN

The Figure 4 shows the schematic of a conventional folded cascode op-amp using a class AB output buffer. In the frequency response of the op-amp , the load of the op-amp is a 1 pF capacitor. We have simulated N Type CNTFET based FC-OP AMPs and analyzed AC and Transient Response.

AC Analysis of N Type CNTFET based Folded Cascode Operational Amplifier.

The Frequency Response of N Type CNTFET based Folded Cascode Op Amp is shown in figure 6. In this response, it is clear that the amplifier is efficiently working since the DC Gain is almost constant upto 1 MHz. It is also clear that the N Type CNTFET based Folded Cascode Op Amp is working as low pass filter , so it has applications in the low pass circuits. The Phase Response of N Type CNTFET based Folded Cascode Op Amp is shown in figure 7. Further , it is clear from Phase response that it is stable amplifier. So, we can use it in robust conditions where stability is main concern.

Transient Analysis of N Type CNTFET based Folded Cascode Operational Amplifier.

Power Variation of N Type CNTFET based Folded Cascode Op Amp is shown in figure 8. In this response, it is clear that the amplifier is power efficient since in all the conditions the Transient Power is in nano watts.

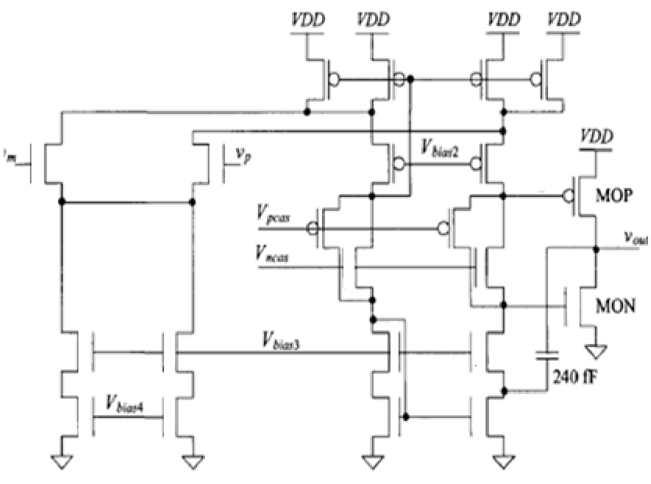

Figure 4: Conventional FC-OP-AMP

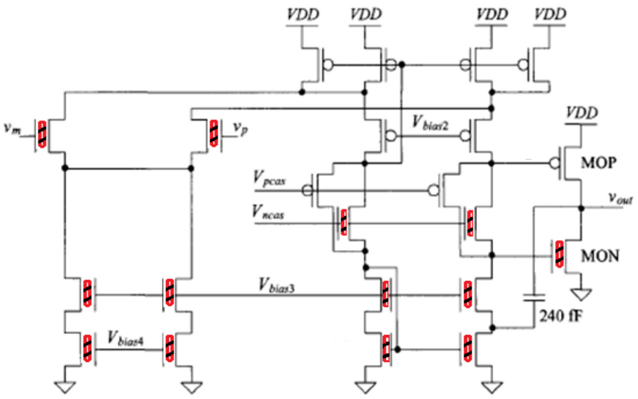

Figure 5: Proposed PMOS-NCNT-FC-OP-AMP

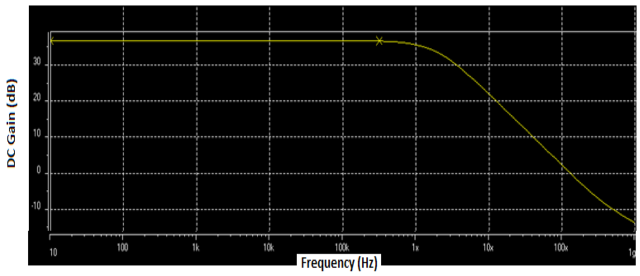

Figure 6: Frequency Response of N Type CNTFET based Folded Cascode Op Amp (AC Analysis)

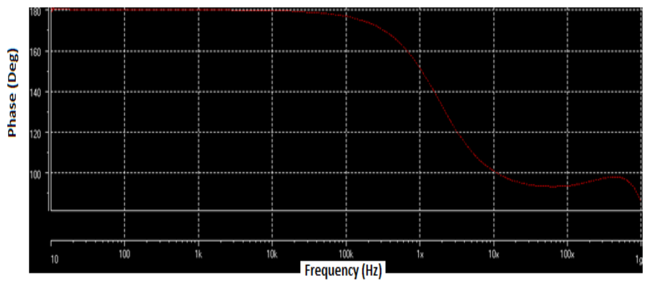

Figure 7: Phase Response of N Type CNTFET based Folded Cascode Op Amp (AC Analysis)

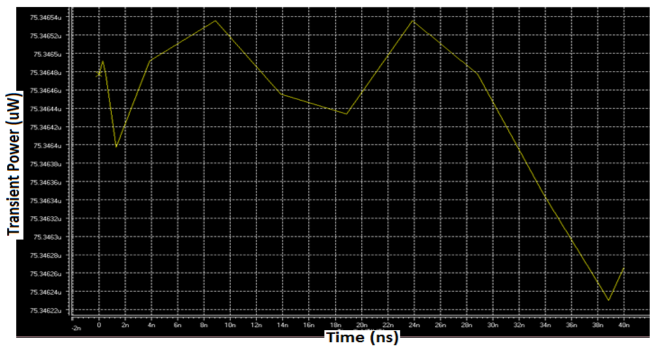

Figure 8: Power Variation of N Type CNTFET based Folded Cascode Op Amp (Transient Analysis)

Table 1: TECHNOLOGY PARAMETERS OF CNTFET

S. No.	Parameter	Value
1.	Oxide Thickness (T_{OX})	4 nm
2.	Physical Channel length (L_{ch})	45nm
3.	Power Supply	0.9 V
4.	Gate Dielectric	HfO_2
5.	Dielectric Constant	16

IV. RESULT AND DISCUSSION

In this research paper, simulation of N Type CNFET based folded cascode Op Amp based on carbon nanotubes (CNT) has done at 45 nm. We have simulated N Type CNTFET based FC-OP AMPs and analyzed AC and Transient Response.

In the Frequency Response of N Type CNTFET based Folded Cascode Op Amp, it is clear that the amplifier is efficiently working since the DC Gain is almost constant upto 1 MHz. It is also clear that the N Type CNTFET based Folded Cascode Op Amp is working as low pass filter , so it has applications in the low pass circuits. Further, it is clear from Phase response that it is stable amplifier. So, we can use it in robust conditions where stability is main concern. Furthermore, it is clear that the amplifier is power efficient since in all the conditions, the Transient Power is in nano watts.

This paper also explores the analog applications of carbon nanotube based circuits for nanoelectronics. It is clear that carbon nanotube field effect transistors are the future of electronic circuit. CNFET will play vital role in designing of combinational and sequential circuits which are back bone of digital computers.

Further, role of CNT based cascode amplifier which is designed in this paper is having applications in various electronic circuits like filters , integrators , differentiators , ADC , DAC etc. The low voltage applications and lower dissipation at nano scale is a remarkable innovation in the work.

Furthermore , carbon nanotube has higher current carrying conductivity more transconductance and both semiconducting cum metallic behaviour. So , the proposed circuit is better in terms of speed , gain , power and durability. CMOS will be replaced by CNFETs in near future due to better properties.

Finally , it is clear that the proposed N type CNTFET based cascode amplifiers are important building blocks in analog circuits design. This model is perfect for low VLSI applications. The proposed model explores compact design in which both CNTFET based circuits and interconnects are made up of carbon nanotubes.

V. CONCLUSION

In the Frequency Response of N Type CNTFET based Folded Cascode Op Amp, it is clear that the amplifier is efficiently working since the DC Gain is almost constant upto 1 MHz. It is also clear that the N Type Carbon Nanotube based cum CMOS based folded Cascode Operational Amplifier is working as low pass filter , so it has applications in the low pass circuits. The phase response of N Type Carbon Nanotube based cum CMOS based folded Cascode Operational Amplifier is stable. So, we can use it in robust conditions where stability is main concern. Furthermore, it is clear that the amplifier is power efficient since in all the conditions the Transient Power is in nano watts.

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