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Design and Simulation of High Performance Low Power Voltage Mode OTA-C Universal Filter for Biomedical Applications at 90nm Technology Node

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Abstract: In this paper, Carbon Nanotube (CNT) based Universal filter for Biomedical Applications are proposed at 90 nm technology node. Cascode Operational Transconductance Amplifier (COTA), a new class of operational amplifier is used as basic building block. The proposed Universal filter is electronically tunable, flexible and low power consuming. Average Power dissipation in the proposed structures i.e. Low-Pass (LPF), the High-Pass (HPF), the Band-Pass (BPF) and Band Reject (BRF) are very small. It has been designed using 20 CNTs, 1.5 nm Diameter of CNTs, 20 nm Pitch of CNTs. The low power dissipation, use of high speed CNT based devices and small devices dimensions at 0.9V supply voltage make proposed structures suitable for biomedical applications.

Keywords: CMOS, CNTFET, Cascode -OTA, Power consumption, Universal Filter

I. INTRODUCTION

This paper introduces a voltage-mode universal filter using two OTAs and the filter can realize the Low-Pass (LPF), the High-Pass (HPF), the Band-Pass (BPF) and band reject (BRF) transfer function by connecting the terminal V1,V2 and V3 at appropriate conditions laid down in table 2 . CNTFET technology can easily club with the bulk CMOS technology on a single chip and utilizes the same infrastructure at 90 nm [1-10].

II. CASCODE OPERATIONAL TRANSCONDUCTANCE AMPLIFIER (COTA)

Operational Transconductance (OTA) is a voltage controlled current source, it takes the difference of the two voltages as the input for the current conversion. There is an additional input for a current to control the amplifier's transconductance. Operational Transconductance Amplifier (OTA) is a new class of Operational Amplifier (OP-AMP). Flexibility and tunability are the big advantages of OTAs. OTA has more advantages compared to OP-AMP like higher input-output isolation, higher input impedance, high output impedance, higher gain or higher bandwidth with additional applications. The output current Io of the ideal OTA can be expressed by equation as follows:

$$io = gm\,(vp - vn)$$

Where gm is the transconductance, vp and vn are positive and negative input terminals respectively. Cascode amplifier configuration improves gain due to high output resistance and bandwidth due to reduced Miller capacitance. The ideal OTA has infinite output resistance. All of io flows in the external capacitive load and none flows in the OTA's own output resistance .Towards increasing the OTA output resistance, the current mirrors are cascaded[11-14].

III. CARBON NANOTUBE FIELD EFFECT TRANSISTOR

Carbon Nano Tubes (CNT), an allotrope of carbon, were first discovered by Dr. Sumio Iijima of NEC Japan in 1991, while studying the surface of graphite electrode in an electric arc discharge. They possess unique and extra ordinary mechanical, electrical and thermal properties and are considered as promising future materials. They are 100 times stronger than steel, have superior field emission property, have very large current
density of more than 109 A/cm², and have thermal conductivity more than that of diamond . They exist in two forms: (i) Single Wall Carbon Nano Tube (SWCNT) and (ii) multiwall carbon nanotube and can have metallic and semiconducting properties, as shown in Fig1(a). A unique property of CNTs is their ability to show metallic and semiconducting behavior. It all depends on the chirality or chirality vector (Ch) of CNT that determines whether a CNT is metallic or semiconducting. A CNT shows metallic characteristics if n = m or n-m = 3i where i is an integer, otherwise it is a semiconductor . An important and prominent application of a CNT is Carbon-Nanotube Field Effect Transistor (CNTFET). A CNTFET is a promising future device and has a potential to replace the conventional

MOSFET and the extend the validity of Moore's law further. A CNTFET has large transconductance, very low intrinsic capacitance, nearly ideal subthreshold slope and very strong covalent bonding . It has been found that the CV/I characteristics of an intrinsic n or p type CNTFET is 13 times better than the conventional bulk MOSFET. There are two types of CNTFETs: Schottky Barrier (SB) CNTFET (SB-CNTFET) and MOSFET-like CNTFET (MOS-CNTFET). A Schottky barrier type CNTFET can be realized by directly attaching the intrinsic single wall CNTs to the metal source/drain contacts. This type of CNTFET shows ambipolar carrier transport. The MOSFET like CNTFET has CNT based channel connecting heavily doped source and drain regions. It has unipolar conduction, has large ON current (ION), higher ION/IOFF ratio and lower leakage power. It shows better scalability in comparison to the SB-CNTFET . CNTs can exist in three forms, armchair, zig-zag and chiral as shown in Figure (2) [15-27].

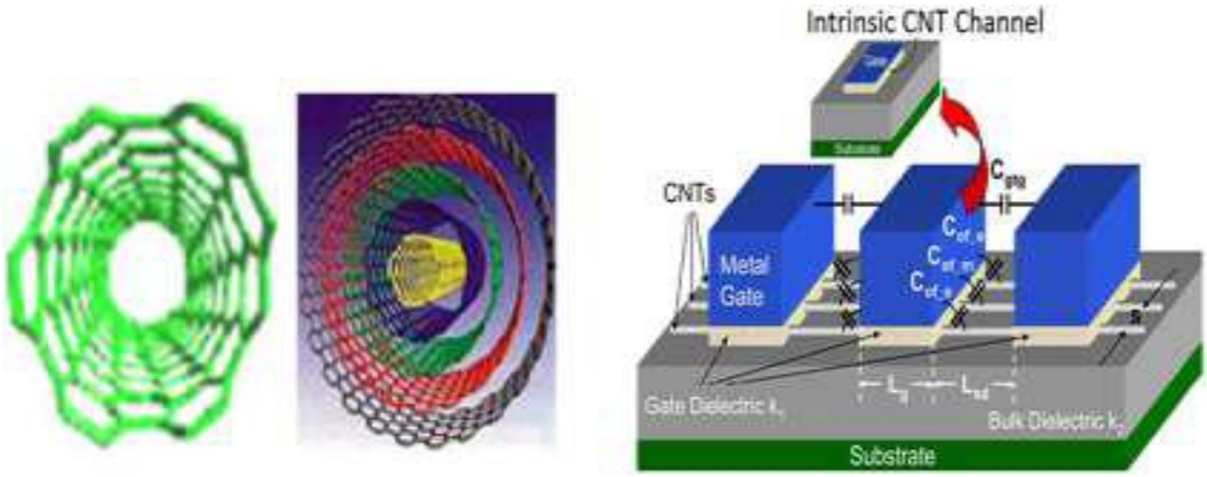

Figure 1: (a) Single wall CNT (b) multi wall CNT (c) 3D CNFET structure

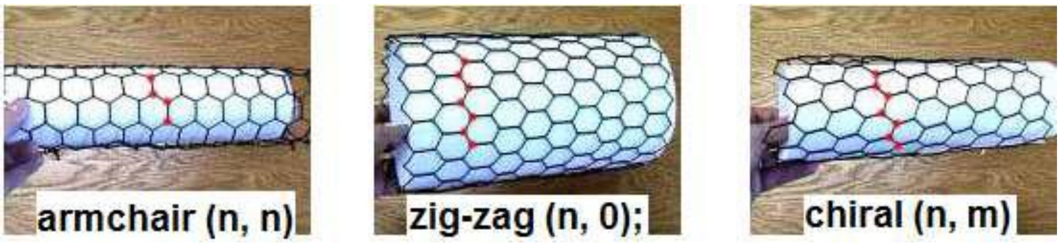

Figure (2). Three types of SWCNTs based on the chiral vector and chiral angle (θ)

IV. PROPOSED CASCODE OPERATIONAL TRANSCONDUCTANCE AMPLIFIERS

The Cascode operational transconductance amplifier(COTA) circuit is used to design Filters at 90 nm. Figure(3), shows the Cascode OTA.

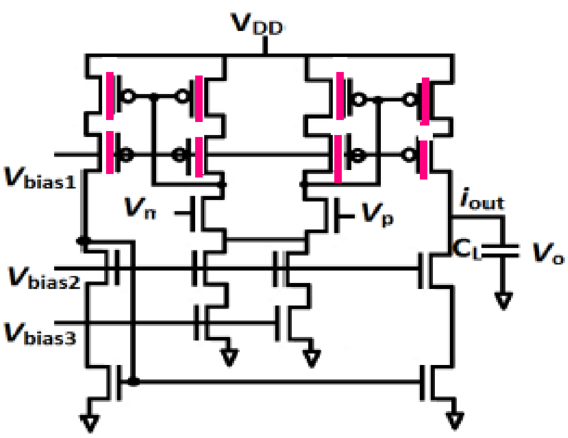

Figure (3) Cascode OTA

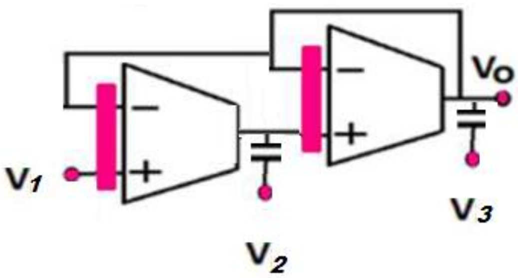

Figure (4) Proposed Voltage Mode OTA-C Universal Filter

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Considerable flexibility in controlling those specific filter characteristics that are usually of interest is possible with COTAs. Operational Amplifier based active filters have serious limitation over the applications in the high frequency regions. To overcome these limitations active filters using OTAs are popular due to the salient features of OTA such as, the adjustable transconductance (gm) over wide range of bias current , excellent matching between amplifiers, the linearity of transconductance with bias current , controlled impedance buffers and high output signal to noise ratio, which popularizes OTA in active filter design.

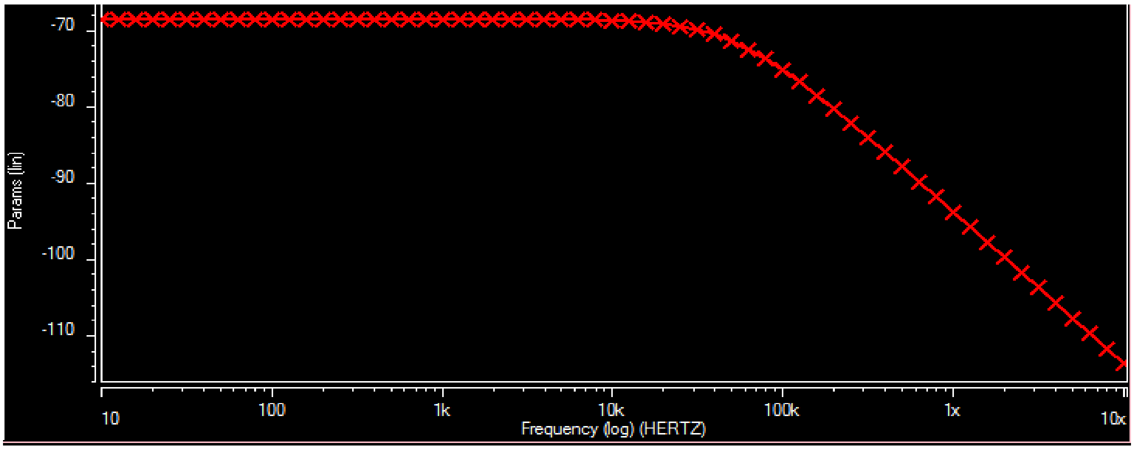

Figure (5) Proposed Low Pass Filter

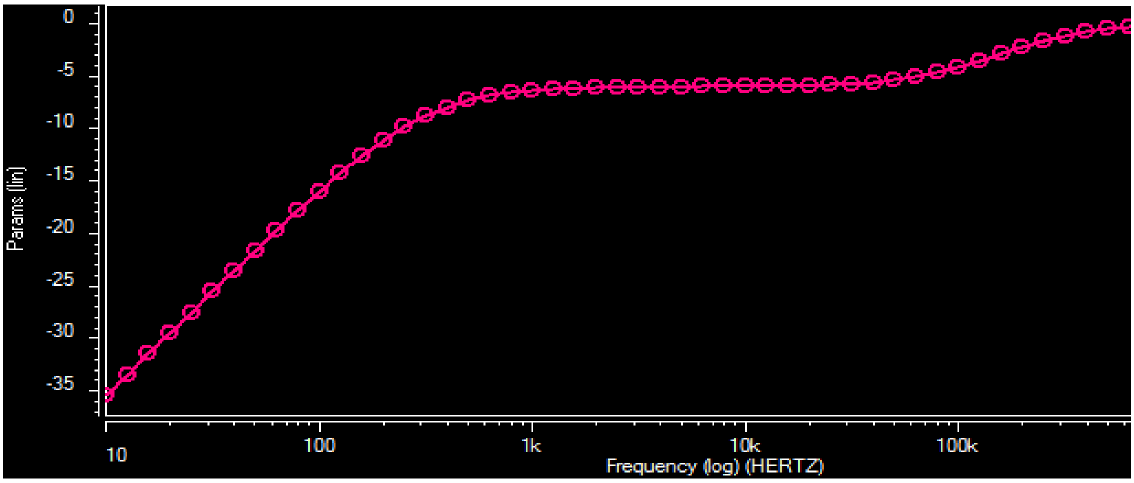

Figure (6) Proposed High Pass Filter

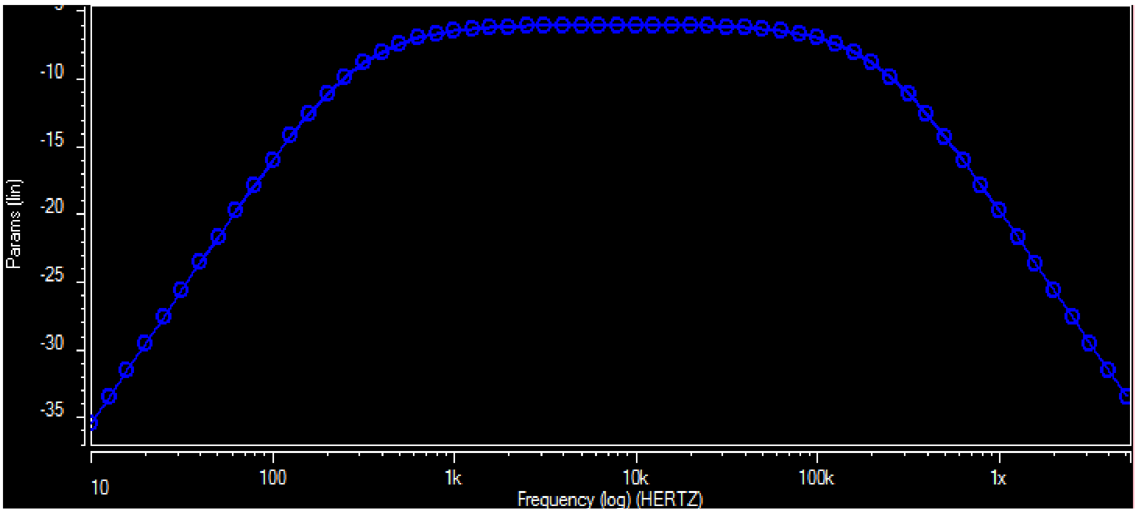

Figure (7) Proposed Band Pass Filter

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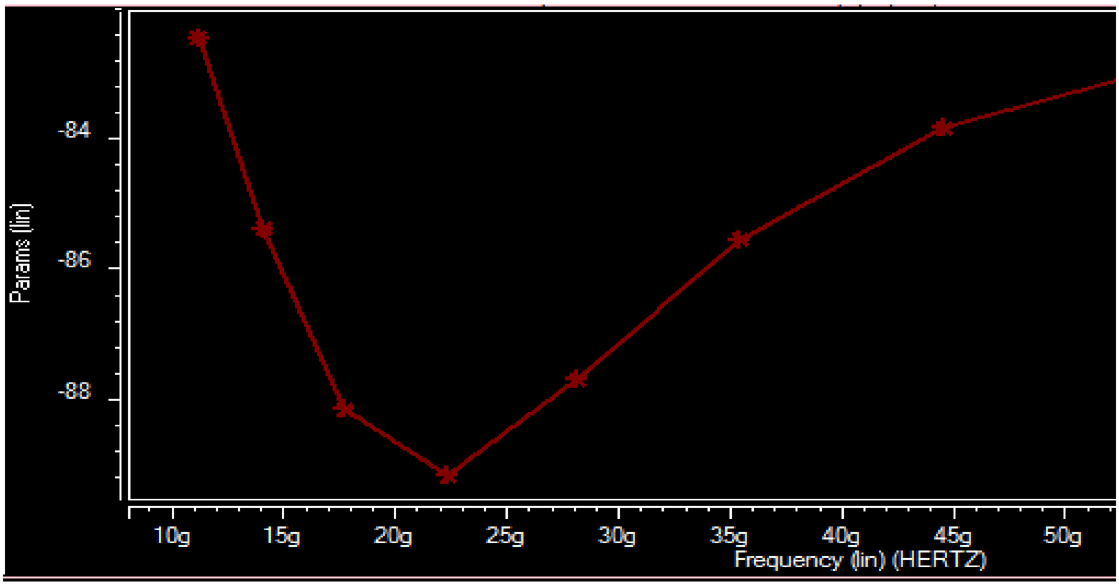

Figure (8) Proposed Band Stop Filter

Table 1:- Power Dissipations of Various Filter

S. No.	Type of Filter	Power Dissipation
1	LPF	4.2610E-05 W
2	HPF	2.3693E-07 W
3	BPF	2.1693E-07 W
4	BSF	4.2610E-05 W

Table 2:- Inputs conditions for Filter Response

S. No.	V1	V2	V3	Vout
1	1	0	0	LP
2	0	1	0	HP
3	0	0	1	BPF
4	1	0	1	Notch

V. CONCLUSION

Cascode Operational Transconductance Amplifiers (COTA) based Universal Filter is designed and simulated at 90 nm technology for biomedical applications at 0.9V. It has been designed and simulated using novel carbon nanotube based MOS structures . Average Power dissipation in the proposed structures are very small .The use of high speed CNT based devices and small device dimensions are suitable for biomedical applications.

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