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Low Power Low Voltage CNTFET-based VDIBA and its Application as Biquad Filter

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Abstract: This paper presents low power low voltage Carbon Nanotube based VDIBA and its application as biquad filter. The proposed configuration is verified at ±0.9V supply. The dissipated power is significantly reduced as compare to conventional CMOS model of VDIA. CNTFET based VDIBA has been designed and simulated at 32nm technology node. The workability of the proposed model has been conformed using HSPICE simulations. It is compared with conventional CMOS based VDIBA. The comparative analysis has revealed improvement in various performance parameters like transconductance, less power consumption as compare to CMOS technology node at 32 nm. We have verified the AC and DC analysis of CNTFET based VDIBA and its application as biquad filter. We have also verified Port resistance with respect to number of tubes and interchange CNT-pitch.

Keywords: Carbon Nanotube Field Effect Transistors (CNTFETs), Voltage Differencing Inverting Buffered Amplifier (VDIBA).

1 Introduction

The current trend of miniaturization of device has motivated researchers for coping up the end use requirement, this in turn has opened a new era of low voltage, low power processing circuits. Low voltage design is mandatory for interfacing of analog and digital circuits. This in turn has resulted in different low voltage ad low power design [1-11]. Threshold voltage is reduced to zero in CNTFET due to which it will reduce the voltage demand in circuit which is turn will reduce the dissipation. Behaviour model of active elements are also reported in literature [12]. In behavioural design voltage differencing unit have replaced CDBA, CDTA etc. For generally difference in voltage in active elements differential input OTA is introduced. This has simplified the structure. The VDIBA uses only six MOS circuit, hence increased the simplicity. The OTA and buffers have introduced at input and output of VDIBA. The modification also introduced VDIBA [20] lie parameters variations are suppressed by tunability of OTA. According to the application the different parameters of VDIBA lie high transconductance, AC, DC analysis is introduced.

In the proposed work the CMOS element of Conventional VDIBA is replaced with CNTFET. This proposed modification is improved in different parameters like g_m of the system which is 767 µA/V compared to approx 600 µA/V CMOS based VDIBA. This CNTFET based VDIBA is used to implement biquad filters which does not have the requirement of component matching and inversion of sign. Moreover output resistance has significantly improved with increase in number of tubes and inter-pitch CNT

VDIBA is active element having two input voltages and one output current and one output voltage. The generalize diagram of CNTFET based VDIBA is as shown in figure 1.

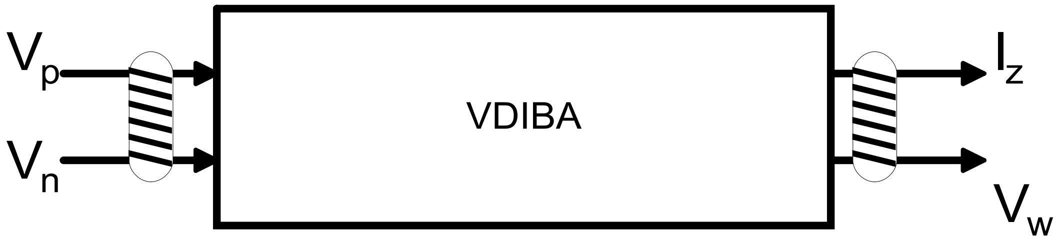

Figure: 1 generalize diagram of CNTFET based VDIBA

The matrix representation of VDIBA is give below

$$\begin{bmatrix} I_p \\ I_n \\ I_z \\ V_w \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ G_m & -G_m & 0 & 0 \\ 0 & 0 & -\beta & 0 \end{bmatrix} \begin{bmatrix} V_p \\ V_n \\ V_z \\ I_w \end{bmatrix} \quad (1)$$

Where G_m is transconductance and β is ideally unity.

2 Brief overview of CNTFET

Carbon nanotube field effect transistors are made from carbon nanotube in which nanotube which is made up of allotropes of carbon. It is generally a four terminal device same as conventional MOSFET's only difference is material of channel length which is placed between drain and source terminal. The evolution of carbon nanotube by Ijima of NEC Japan in 1993. The property of carbon nanotube is easily varying from metallic, semiconductor or insulator depending upon the chirality vector [n, m].

If m = n than carbon nanotube behaves as conductor otherwise as semiconductor. The diameter of the CNT can be varied by varying the chirality vector.

$$D_{CNT} = 0.0783 \times \sqrt{n^2 + m^2 + nm} \quad (2)$$

CNTFET layout diagram is shown in figure 2. In CNTFET, Single Wall Carbon Nanotube (SWCNT) was used in parallel combination which results in merging of channel [22]. However source and drain terminals are heavily doped whereas channel is kept undoped [23-24]. Parameters of CNTFET are given in [23].

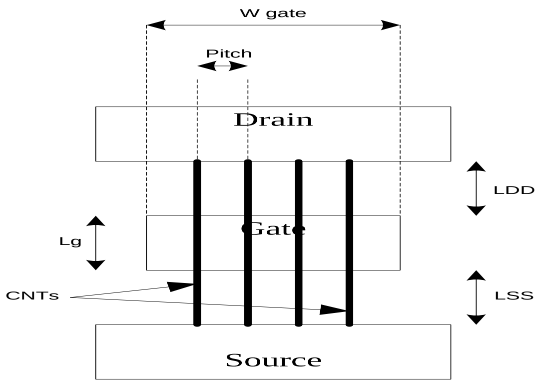

Figure2. General CNTFET Layout diagram [21]

The width of CNT is calculated as

$$W = (N-1) * S + D_{cnt} \tag{3}$$

3 Proposed CNTFET based VDIBA and CMOS VDIBA

MOSFET's based VDIBA [20] in figure 3 was presented at 180 nm. But the downscaling of MOSFET leads to degradation of circuit performance below the 180nm so we replace the MOSFET's by CNTFET. A new CNTFET based VDIBA circuit is proposed figure 4.

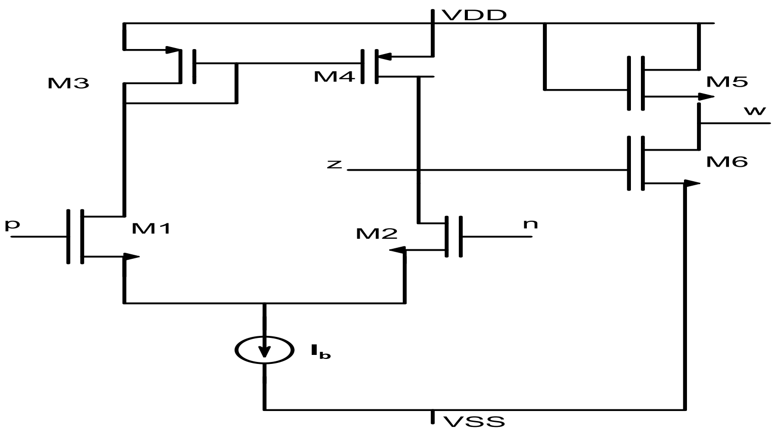

Figure 3 CMOS implementation of VDIBA [20]

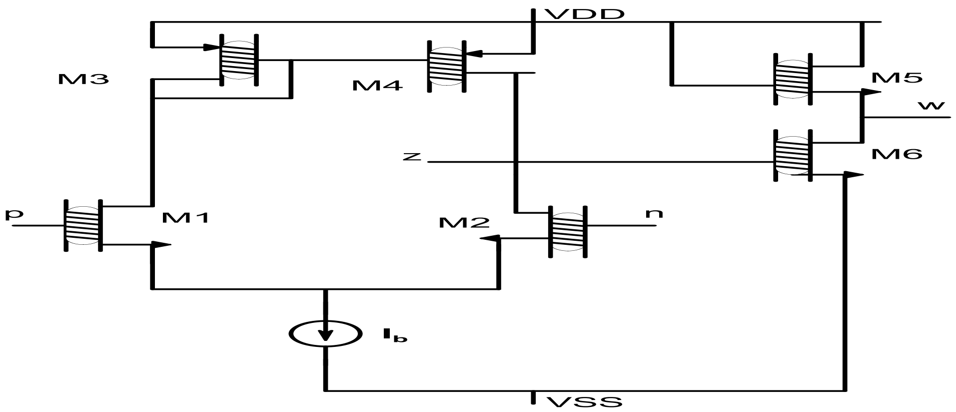

Figure 4 CNTFET implementation of VDIBA

4 Analysis of CNTFET based VDIBA

DC response of the circuit as plot between Iz and Vp, Vn is shown in Figure 5. The analysis domain for input is varying from -500ma to 500ma with output current is -100µA to 100µA.

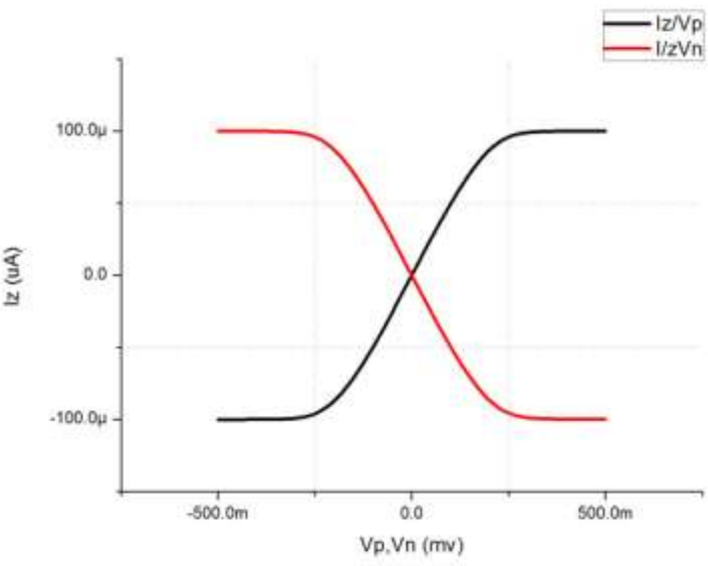

Figure 5 Dc analysis Iz versus Vpand Vn

For the routine analysis of circuit considered parameters are Vp and Vn as input voltages, whereas I_b (bias current) in figure 3 and 4 are taken as 100µA, the aspect ratio of CMOS based VDIBA and CNTFET based VDIBA represented in Table 1

Table 1 : Relationship in aspect ratio of CMOS and CNTFET based VDIBA

CNT-Transistor	No. of tubes	L(nm)	Diameter	Inter-Pitch CNT	(W/L) μm[20]
	CNTFET				CMOS
M1-M4	10	32	1.5nm	20nm	18/1.08
M5-M6	30	32	1.5nm	20nm	54/0.18

As compare to CMOS technology transconductance (g_m) of CNTFET based VDIBA is 767 μA/V which is much better than CMOS 600 μA/V as shown in Figure 6 whereas Power dissipation of the circuit is 0.18mW.

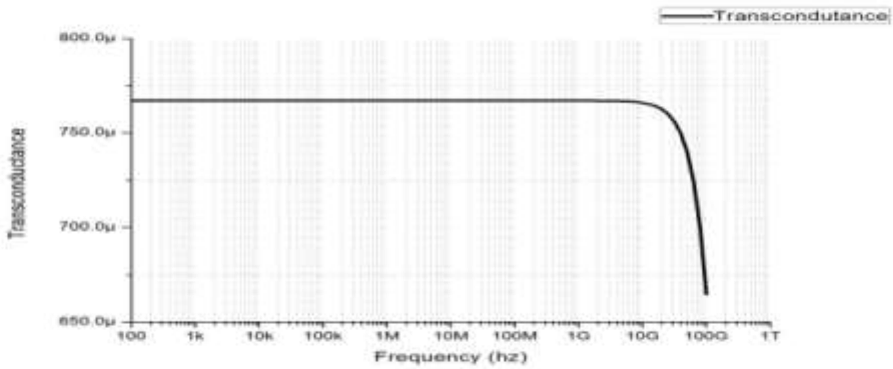

Figure 6 Ac analysis Transconductance of CNTFET VDIBA

CNTFET based VDIBA is combination of OTA and inverting buffer and the frequency response along with the complete structure and individual stage is represented in figure 7-9. The transconductance of OTA (figure 7) with bias current I_b = 100μA with -3db frequency and voltage gain (figure 8) with -3db frequency and complete frequency response with -3db (figure 9). The inverting buffer response shown in figure 10

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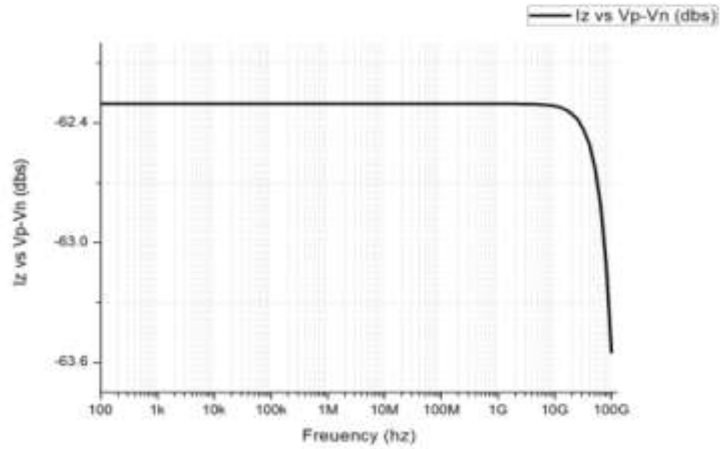

Figure 7 Ac analysis Transconductance gain [IZ versus VP – VN (db)]

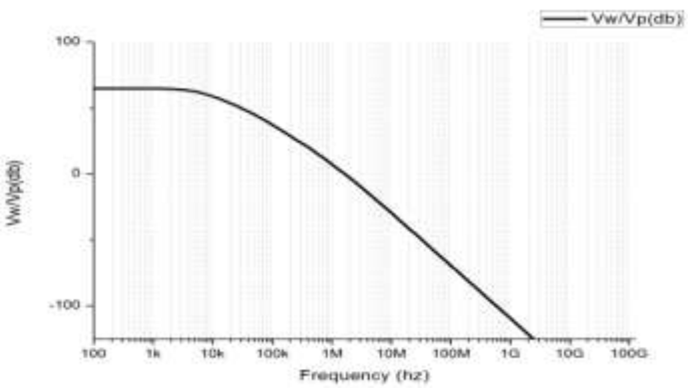

Figure 8 Ac analysis voltage gain [Vw / Vp (db)]

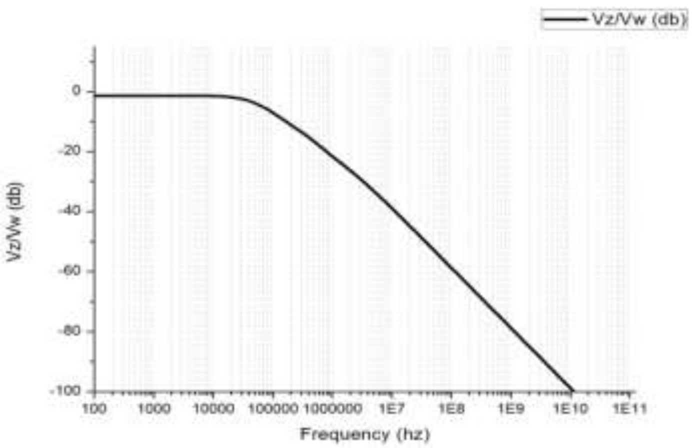

Figure 9 complete frequency response [IZ versus Vz /Vw (db)]

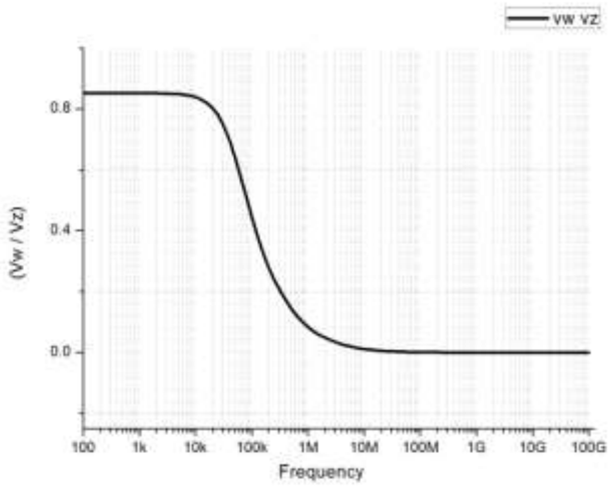

Figure 10 Inverting buffer analysis [IZ versus Vw – Vz]

5 Proposed CNTFET VDIBA based biquad filter

The filter presented by K. L. Pushkar , D. R. Bhaskar, D. Prasad in [19] is regenerated using CNFET based VDIBA is shown in figure 11.

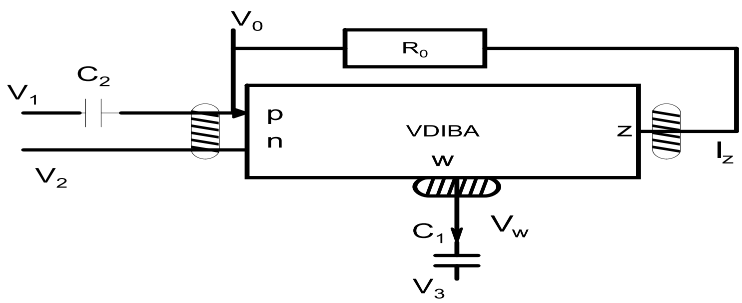

Figure 11 Biquad Filter based on VDIBA

Applying the routine analysis on figure 11 the transfer function of given filter is written as

$$V_0 = \frac{V_1 S^2 - V_3 \frac{1}{R_o C_2} + V_2 \frac{g_m}{R_o C_1 C_2}}{S^2 + S(\frac{1}{R_o C_2}) + \frac{g_m}{R_o C_1 C_2}} \quad (4)$$

The angular frequency is given in following equation

$$\omega_o = \sqrt{\frac{g_m}{C_1 C_2 R_o}} \quad (5)$$

Table 3: Input for filter function

V1	V2	V3	Filter Function
0	V_{in}	0	Low Pass
V_{in}	0	0	High Pass
0	0	V_{in}	Band Pass
V_{in}	V_{in}	V_{in}	All Pass

It can be seen that from equation (5) ω_o can be electronically controlled through g_m biquad filters which does not have the requirement of component matching and inversion of sign. The response of biquad filter is Shown in figure12 and figure 13

Whereas the port resistance (output resistance) with respect to inter-pitch and the port resistance (output resistance) with respect to number of tubes is represented in figure 14 and figure 15 respectively, the port resistance is decreases with increases in diameter of CNT number of tubes.

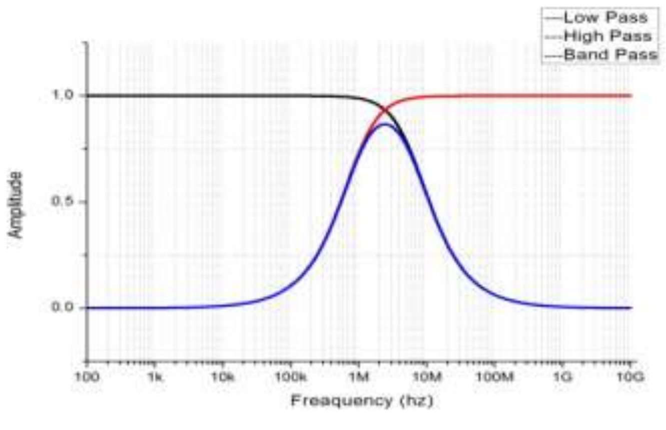

Figure 12 Filter Response: Low Pass, Band pass, High pass

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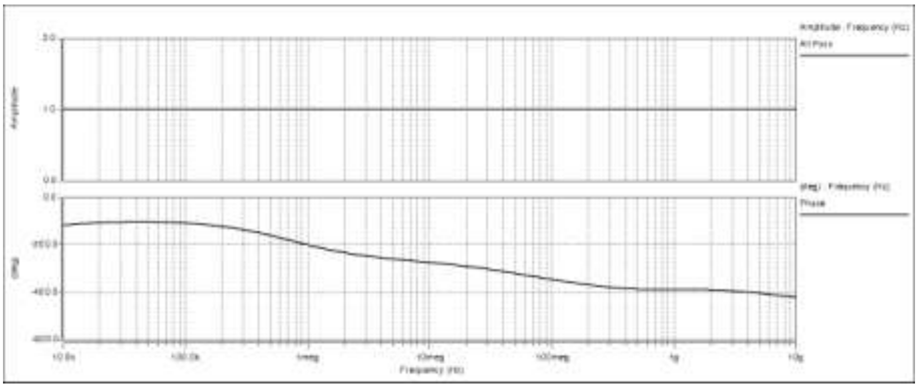

Figure 13 Filter response : All pass Magnitude and Phase

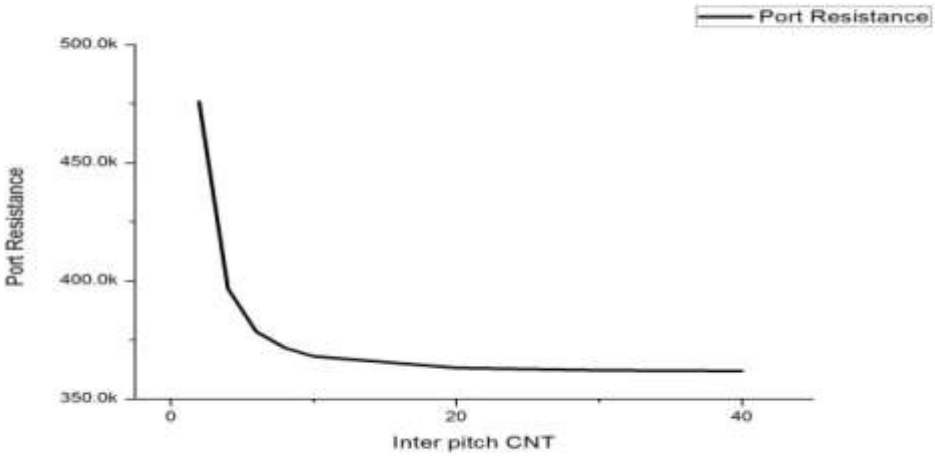

Figure 14 Inter Pitch Vs Port Resistances

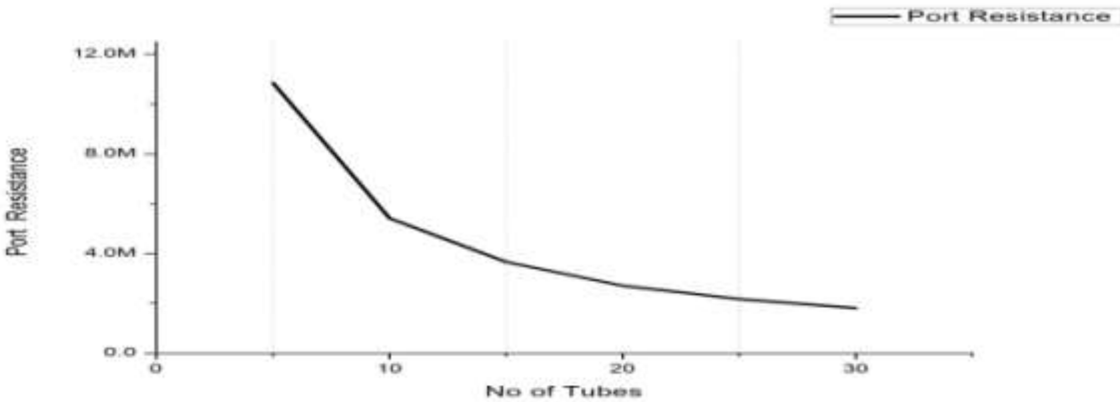

Figure 15 No of Tubes Vs Port Resistance

6 Conclusion

This paper present VDIBA based on CNTFET which gives better performance as compare to CMOS structure. In this CNTFET based VDIBA used to design a biquad filter. This filter utilizes lesser number of components i.e. only two capacitors, one resistor, having higher transconductance and low power consumption. The result has been verified using HSPICE at 32 nm technology node. The variation in Inter-Pitch CNT with respect to port resistance and Output resistance with respect to number of tubes is presented in paper. The improvement in the circuit is also verified with biquad filter of 1M as cut-off frequency. The dissipated power of the CNTFET based VDIBA is also reduced as compare to CMOS.

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