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Current-mode biquad filter using CNTFET-based ZC-CITA

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A CNTFET-based z-copy current inverting *trans*-conductance amplifier (ZC-CITA) has been proposed. The proposed model uses 28 CNTFET-based transistors, 3 current sources and it uses supply voltages of ±2V with 32 nm technology mode. This paper also introduces the validity of ZC-CITA showing its application as biquad filter which has not been designed yet with an added advantage of power reduction. The result has been verified using HSPICE.

Keywords: Carbon nanotube field effect transistor (CNTFET), Carbon nanotube (CNT), Low power, Current inverting transconductance amplifier (CITA), Biquad filter

1 Introduction

Current mode and voltage mode are the active building blocks which are used in designing of analog signal processing circuit in recent past years due to their dynamic properties like large dynamic range, low power consumption, less area, high bandwidth[1,2]. A number of active building block is available in literature as current mode and voltage mode circuits such as current conveyor, current differencing buffered amplifier (CDBA), operational transconductance amplifier (OTA), current inverting transconductance amplifier (CITA)[3-5], current operational amplifier (COA) and have been brought in as a response to these demands. In this paper, a new CNTFET based current-mode circuit structures for ‘‘Z-copy current inverting transconductance amplifier (ZC-CITA)’’ has proposed that were recommended as multipurpose current mode analog building blocks by Biolek[6]. It has been observed that there is an improvement in universal CDTA with the addition of Z-copy current, *i.e.*, current (I_z). A traditional current mirror and the third generation current conveyor circuit are commonly used to achieve z-copy output current[7]. The main aim of the paper is to enhance the performance like transconductance, power dissipation of CITA by sing CNTFET. The internal structure of ZC-CITA is taken from the structure of[8] by grounding the p-terminal. The generalised block diagram of ZC-CITA is given in Fig. 1.

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The port relation of CITA is given by these equations:

$$V_n = 0 \quad \dots (1)$$

$$I_z = -I_n \quad \dots (2)$$

$$I_x = \pm g_m v_z \quad \dots (3)$$

2 Proposed CNTFET Based ZC-CITA

The CNTFET based ZC-CITA is shown in Fig. 2 in which we use 28 CNTFET MOSFETs (M1-M18, M19- M28 are identical Table 1). The output current (I_+) of the proposed ZC-CITA can be calculated as:

$$I_+ = g_{m16} v_{g16} - g_{m21} v_{g21} \quad \dots (4)$$

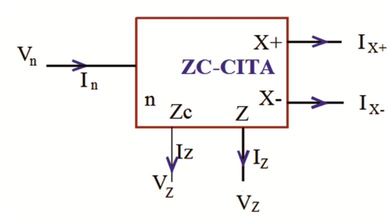

Fig. 1 — Generalised block diagram of ZC-CITA.

Table 1 — CNTFET based transistor dimensions.

Transistor	Diameter (nm)	Inter-pitch (nm)	Number of tubes	Channel length
M1-M18	1.5	20	6	32
M19-M24	1.5	20	5	32
M25-M28	1.5	20	6	32

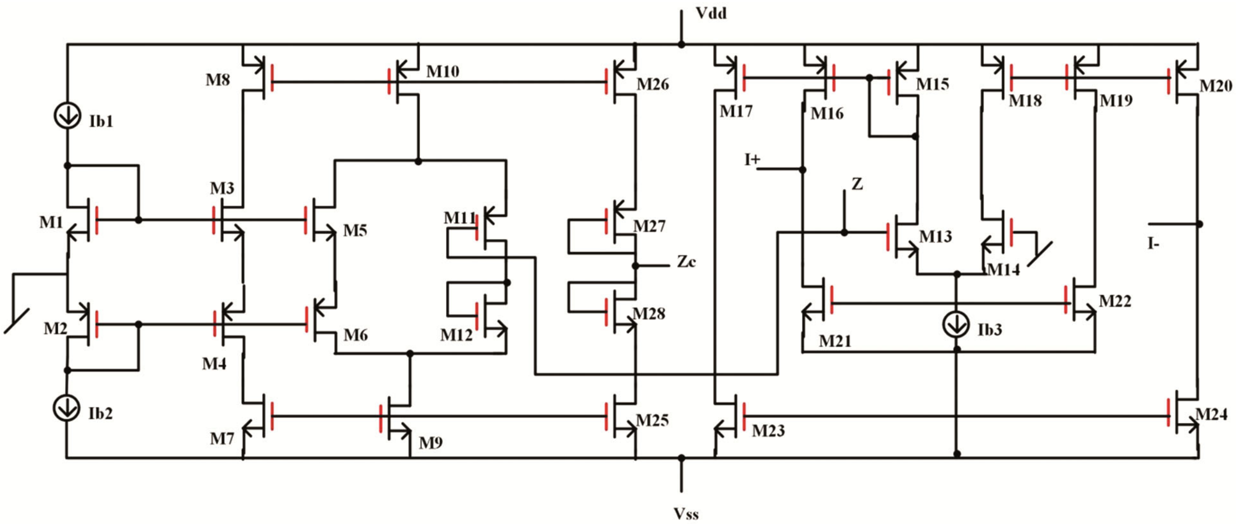

Fig. 2 — Proposed circuit of CNTFET based ZC-CITA.

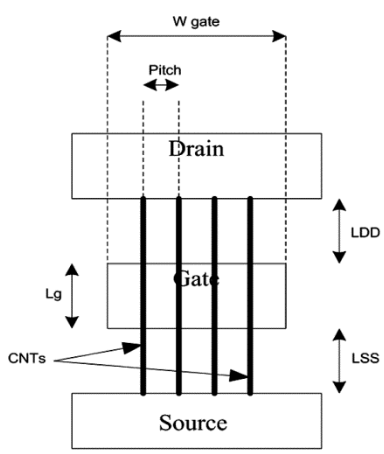

Fig. 3 — Transconductance (g_m) of CNTFET based ZC-CITA.

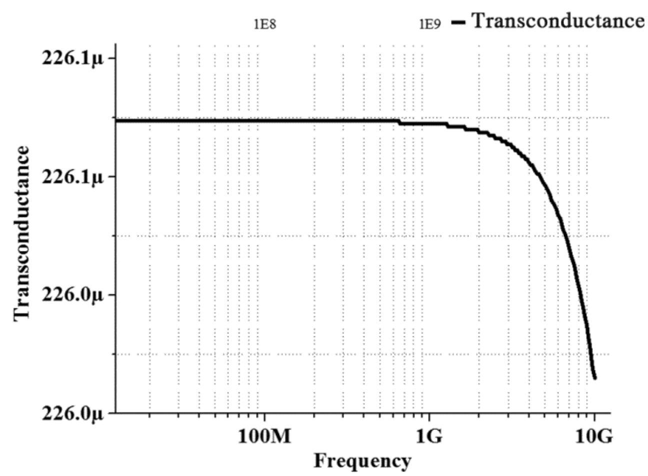

Fig. 4 — Input-output characteristic.

The power supply voltage is taken as $V_{dd} = - V_{ss} = 2$V and the bias current I_{b1} and I_{b2} which is equal to 85 µA, Hence for finding the different values of transconductance we can vary the I_{b3} from 10 µA to 1 mA, where we have take the value of I_{b3} = 200 µA and we get inverted current shown in block diagram of ZC-CITA. Where transconductance (g_m) at I_{b3} = 200 µA is 226.1 µA/V is shown in Fig. 3. This transconductance can be varies with the change in value of I_{b3} and the power dissipation is 441.5 µW and the DC current and input-output transfer characteristics are shown in Fig. 4 and Fig. 5, respectively.

The CNTFET based z-copy use MOSFET which are having identical channel size and 32 nm technology node considered oxide thickness is 4 nm and supply voltage of ±2 V. The HFO_2 is taken as

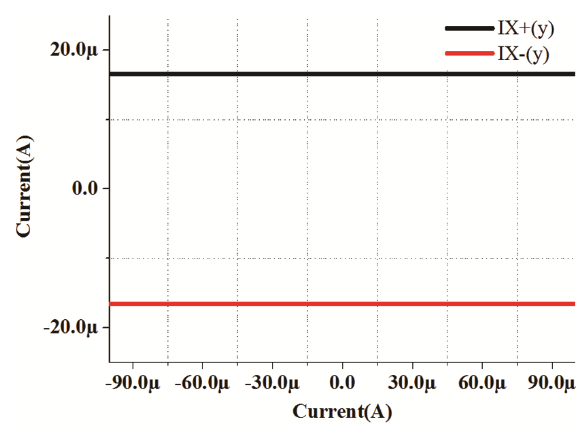

Fig. 5 — DC transfer characteristics of I_{in} and I_z.

gate oxide which has dielectric constant of 16, whereas the mean free path is 200 nm and doping of 12.5 nm[9-13]. The channel length ratio will depend on count of carbon nanotube used in p and n type MOSFET. The parameter of general CNTFET is shown in Table 2[14]. The port resistance (input and output resistance) with respect to pitch and number of tubes are shown in Fig. 6 and Fig.7, respectively.

CNTFET layout diagram is shown in Fig. 8. In CNTFET, single wall carbon nanotube (SWCNT) was used in parallel combination which results in merging of channel. However source and drain terminals are heavily doped whereas channel is kept undoped[14-17].

In CNTFET-based ZC-CITA the finest parameters related to structure are estimated as:

Count of tubes (*N*): Individual Nanotube based transistor will not be able to cope up with the performance as compared with CMOS so that to increase the performance of the circuit, count of CNT has to increase and used in the form of array which is calculated as:

$$W = (N-1) * S + D_{cnt} \quad \ldots (5)$$

Inter-CNT Pitch (*S*): The distance between the two adjacent Nanotube forming centre is called inter CNT pitch, denoted by *S*.

$$V_{th} = \frac{a v_{\pi}}{\sqrt{3 q D_{cnt}}} \quad \ldots (6)$$

Diameter of CNT (D_{cnt}): Diameter of the CNT is directly related to threshold voltage and the parameter of Chirality of tube (m,n) which is calculated as[18-20]:

$$D_{cnt} = \frac{A\sqrt{(n^2 + m^2 + mn)}}{\pi} \quad \ldots (7)$$

Table 2 — CNTFET parameter.

CNTFET parameters	Considered values
Work function (CNT)	4.5 eV
Mean Free path: Intrinsic CNT	200 nm
Gate oxide	HFO_2
Dielectric constant	16
Power supply	±2V
Mean free path: Doped CNT	12.5 nm
Physical channel length (L_{ch})	32 nm
Oxide thickness (T_{ox})	4 nm
Pitch	20 nm
Chirality of tube (m,n)	19,0

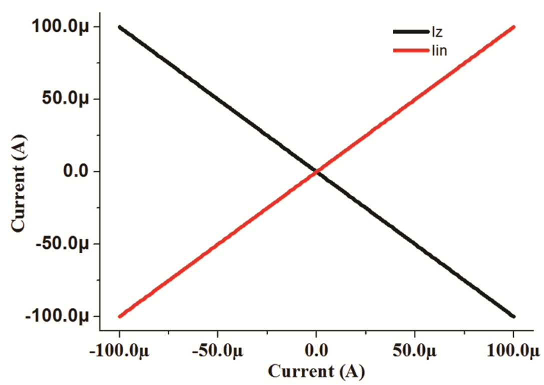

Fig. 6 — Port resistance with respect to inter pitch CNT.

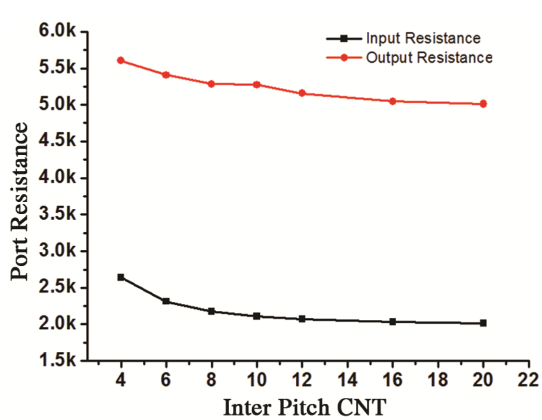

Fig. 7 — Port resistance with respect to number of tubes.

3 Proposed CNTFET ZC-CITA Based CM Biquad Filter

The proposed design of biquad filter circuit consists of two capacitor and a ZC-CITA block which has three outputs I_{o1}, I_{o2}, I_{o3}, shown in Fig. 9.

From I_{o1}, I_{o2}, I_{o3}, I_{o4} we can get the transfer functions corresponding to which we get the desired

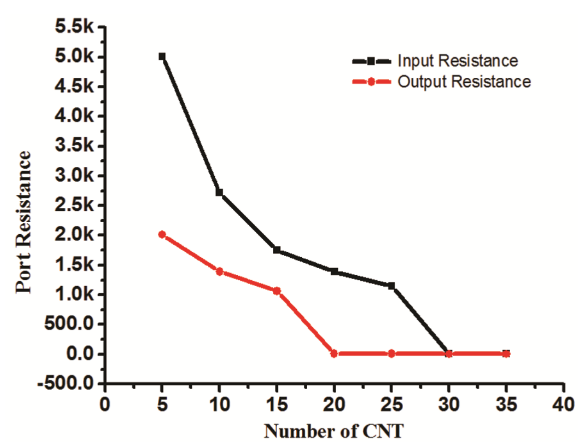

Fig. 8 — General CNTFET layout diagram.

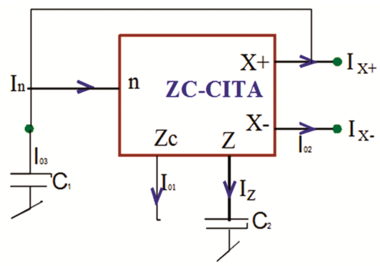

Fig. 9 — Block diagram of proposed biquad filter.

response of low pass, high pass, band pass and band reject filter. After routine circuit analysis technique we find the transfer functions as:

$$\frac{I_{o3}}{I_{in}} = \frac{s^2 C_1 C_2}{s^2 C_1 C_2 + sC_1 C_2 + g_1 g_2} \quad \ldots (8)$$

$$\frac{I_{o2}}{I_{in}} = \frac{g_1 g_2}{s^2 C_1 C_2 + sC_1 C_2 + g_1 g_2} \quad \ldots (9)$$

$$\frac{I_{o1}}{I_{in}} = \frac{sC2 g_1}{s^2 C_1 C_2 + sC_1 C_2 + g_1 g_2} \quad \ldots (10)$$

$$\frac{I_{o4}}{I_{in}} = \frac{s^2 C_1 C_2 + g_1 g_2}{s^2 C_1 C_2 + sC_1 C_2 + g_1 g_2} \quad \ldots (11)$$

The filter natural frequency (ω_o) and the quality factor (Q_o) is calculated as:

$$\omega_o = \sqrt{\frac{g_1 g_2}{C_1 C_2}} \quad \ldots (12)$$

$$Q_o = \frac{\omega_o C_1}{C_1 C_2} \quad \ldots (13)$$

4 Results

The proposed biquad is simulated using HSPICE with component value at C_1=3 nF and C_2=6 nF. The frequency response of proposed biquad is shown in Fig. 10. This CNTFET based ZC-CITA Circuit uses less power consumption and biquad use less number of components, *i.e.*, only two capacitors. From a single circuit we can derive low pass, high pass, band pass and band reject filters as shown in Fig. 10.

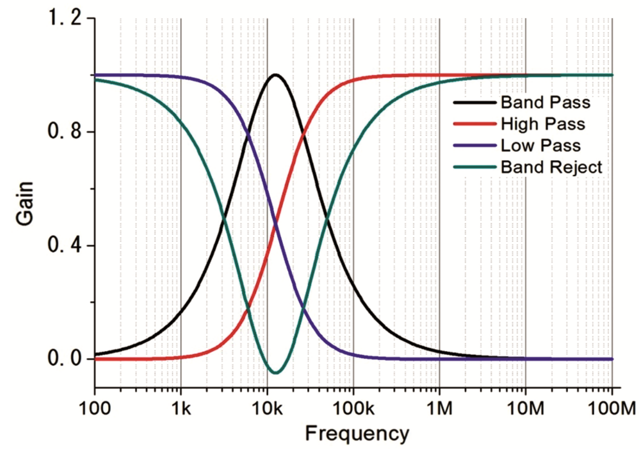

Fig. 10 — Frequency response of a proposed biquad filter.

5 Conclusions

This paper presents ZC-CITA based on CNTFET and its application as biquad filter which has not been designed yet and utilizes fewer number of components i.e. only two capacitors having higher transconductance and low power consumption. This paper present ZC-CITA based on CNTFET which gives better performance as compare to CMOS structure. The result has been verified using HSPICE at 32 nm technology node Input-output characteristics, transconductance, DC transfer characteristics and input-output resistance has also been successfully verified. The improvement in the circuit is also verified with biquad filter of 10 k as cut-off frequency.

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