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A novel carbon nanotube field effect transistor based arithmetic computing circuit for low-power analog signal processing application

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Abstract

There is a need to explore circuit application in new emerging technologies for their rapid commercialization as the CMOS technology is approaching its limits. Carbon Nanotube Field-Effect Transistor (CNFET) is a promising candidate for future electronic devices for low-power low-voltage digital or analog circuit application. In this paper, we presented a low-power, low-voltage CNFET operational amplifier (OPAMP) based analog arithmetic computing circuit such as inverting amplifier, non-inverting amplifier, summer, substractor, differentiator, and integrator for low-power analog signal processing application. The proposed computing circuits operation are studied by using HSPICE software for circuit simulation at 0.9V input supply voltage. Simulation results show that the proposed computing circuits well suited for low-power low-voltage analog signal processing application for their lower power consumption, and high speed operation.

Keyword: analog computing; arithmetic operation; CNFET; OPAMP.

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1. Introduction

The CMOS technology is approaching its limits in the presence of challenges like extreme short-channel effects, lithographic limitations, process variations, leakage current and source-to-drain tunneling [1]. Many technological and device structure variations have been proposed in the literature like single electron transistor (SET) [2], FinFETs [3], and CNFETs [4, 5] etc. to provide improvements in electrostatics over CMOS. Among that, Carbon nanotubes (CNTs) field-effect transistors are one of the new devices for designing low-power and high-performance circuits [5]. CNTs have special electronic and mechanical properties [6] that make them attractive for the future integrated circuit applications. Transistors with carbon nanotubes as their channel are called Carbon Nanotube Field Effect Transistor (CNFET). Carbon nanotube based transistor has significant potential to replace CMOS in the future due to its better electrostatics and higher mobility [5]. Using the physics of nano-scale devices directly for computation is quite appealing. It not only enhances the functionality per device but also allows us to integrate a profusion of high-functionality devices in a small chip area.

Operational amplifiers (OPAMPs) are key elements of the analog and mixed signal circuit. Designing high-performance analog integrated circuits is becoming increasingly exigent with the relentless trend toward reduced supply voltages. The DC and AC performance of a CNFET OPAMP has already been analyzed and measured [9-11]. There has been a lot of work available in the literature on the digital circuit applications [8] of CNFET but its analog applications have not been explored. This paper present the first time CNFET operational amplifier (OPAMP) based analog arithmetic computing circuits (such as inverting amplifier, non-inverting amplifier, summer, substractor, differentiator and integrator) to propose their suitability in a wide range of future high performance, low-power analog system applications such as signal processing, remote sensing, portable bio-instrumentation. It begins with an overview of CNFET technology in Section 2. Section 3 covers the optimum design of CNFET operational amplifier. Section 4 presented the proposed analog computing circuits based on CNFET OPAMP. Section 5 presented the simulation results of CNFET OPAMP and the proposed analog computing circuits. In section 6 conclude the paper.

2. CNFET Technology

Carbon Nanotube (CNT) is a sheet of graphite which is rolled up along a wrapping vector. The Single-walled carbon nanotube (SWCNT) could be metallic or semiconducting, depending on its chirality vector, which is determined by (n, m) indices and specify the arrangement angle of the carbon atoms along the nanotube. If n - m=3k (k ε Z), the SWCNT is conducting and otherwise it is semiconducting [5]. In Carbon Nanotube Field Effect Transistors (CNFETs) one or more semiconducting SWCNTs are used as the channel of the device as shown in Fig. 1.

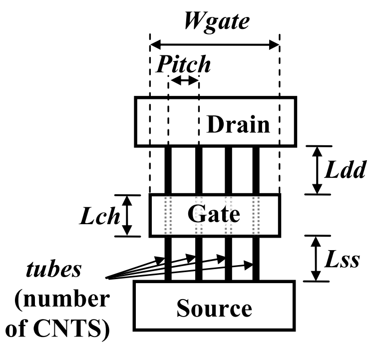

Fig. 1. Schematic diagram of a CNFET.