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Topic: Design and Simulation of CNT Based High-Performance Analog Signal Processing Circuits

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Findings

The research was carried out with a focus on analog signal processing circuits, which were described as a crucial part of modern electronic systems. These circuits were said to act as a bridge between the real-world analog signals and the digital systems that process information. Among them, Digital-to-Analog Converters (DACs) were identified as especially important because of their wide applications in communication, medical devices, IoT systems, and consumer electronics. It was noted that as the demand for faster, more accurate, and energy-efficient systems increased, the weaknesses of MOSFET-based DACs had become more evident. Researchers explained that at very small technology scales, MOSFETs suffered from problems such as power loss, leakage current, short-channel effects, and reduced reliability under varying conditions of voltage and temperature. These drawbacks were highlighted as major barriers to meeting modern performance requirements.

It was pointed out that Carbon Nanotube Field Effect Transistors (CNTFETs) offered a promising alternative. CNTFETs, which are built using carbon nanotubes, were described as having excellent electrical and thermal properties. They were said to allow very fast electron movement, provide high current density, and maintain strong thermal stability. Compared to MOSFETs, CNTFETs were reported to consume less power, switch faster, and perform more reliably at nanoscale levels. Although researchers had already applied CNTFETs in digital circuits and some analog designs, their role in mixed-signal circuits such as DACs was said to remain relatively underexplored. The current study was therefore intended to close this gap.

The main aim of the work was explained as the design, simulation, and analysis of CNTFET-based Current Steering DACs (CS-DACs) at the 32 nm technology node, with a comparison against MOSFET-based equivalents. The focus was placed on parameters such as Integral Nonlinearity (INL), Differential Nonlinearity (DNL), glitch energy, Spurious Free Dynamic Range (SFDR), power consumption, and stability under varying voltage and temperature conditions. By addressing these aspects, the study was expected to assess whether CNTFET-based designs could provide real improvements over MOSFET-based DACs.

The work was further said to include different DAC architectures: a 4-bit thermometer-coded DAC, which although simple, consumed more power and was useful for testing accuracy improvements; a 4-bit unary-weighted DAC with Gate Diffusion Input (GDI) logic, chosen for its compact design and suitability for low-power applications; a 6-bit binary-weighted DAC with cascode current mirror, which was aimed at improving accuracy, SFDR, and efficiency; and an 8-bit segmented DAC with a novel current reference, designed for high-speed operation at 1 GS/s and 1 V supply, demonstrating CNTFET's ability to combine speed, robustness, and energy efficiency. Through these case studies, the research was expected to show where CNTFETs offered the most significant benefits.

It was also explained that the study aimed to address broader practical requirements such as energy efficiency and device reliability. As portable and IoT devices became more widespread, power-saving was considered an essential design goal, and CNTFET-based DACs, with their low switching energy, were thought to be suitable for such applications. Reliability in the face of voltage and temperature variations was also highlighted as a critical factor, and CNTFETs were reported to show greater stability than MOSFETs.

Finally, the objective extended to preparing design frameworks that could be applied at smaller technology nodes, including 22 nm, 12 nm, and 7 nm, in line with industrial scaling. The study was also said to encourage the idea of hybrid systems, where CNTFETs would handle the high-performance core circuits and CMOS would continue supporting peripheral blocks, thereby offering a gradual path for adoption.

In short, the research was explained as an effort to demonstrate that CNTFET-based CS-DACs could outperform MOSFET-based designs in terms of accuracy, efficiency, speed, and reliability. By simulating and comparing multiple architectures, the study was expected to provide useful evidence that CNTFETs could play an important role in future analog and mixed-signal circuits, contributing to the progress of nanoelectronics.

List of Publications

A. SCI Listed Journals

1. Suvarna Mujumdar, Sajad A. Loan, and N Afzal. " CNTFET based 4-bit Thermometer Current Steering Digital to Analog Converter: design and analysis", Analog Integrated Circuits and Signal Processing, vol. 114, issue no. 2, pp. 241-251, January 2023.

doi:10.1007/s10470-022-02118-8

2. Suvarna Mujumdar, Sajad A. Loan, and N Afzal, "Design and analysis of 4-bit lowpower, high-performance current steering DAC implemented using CNT-GDI logic. ", AEU - International Journal of Electronics and Communications, vol. 173, January 2024.

doi: 10.1016/j.aeue.2023.154977

B. Publications in International Conferences

1. Suvarna Mujumdar, Sajad. A. Loan, and Neelofer Afzal " A 4-bit Binary weighted Current Steering Digital To Analog Converter based on CNTFET", 2021 International Conference on Microelectronics,(ICM), New Cairo City, Egypt. Date of Conference: 19-22 Dec. 2021.doi: 10.1109/ICM52667.2021.9664934

2. Suvarna Mujumdar, Sajad. A. Loan, M. Rafat and N Afzal, "CNTFET based 2-bit Unary weighted Current Steering Digital to Analog Converter using Cascode Current Mirror Technique", 2022 International Conference on Microelectronics (ICM), Casablanca, Morocco, 04-07 December 2022, pp. 70-73. doi: 10.1109/ICM56065.2022.10005533