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Title: Design and Simulation of Carbon Nanotube based Devices for Nanoelectronics Applications

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Abstract:- Silicon is indeed a nature's gift to mankind, as silicon based devices have been serving mankind relentlessly since around 1960. Because of so many advantages of silicon over other semiconductors, more than 90% of electronic devices are made up of silicon. At device/circuit levels of abstraction, it has been silicon MOSFET/silicon CMOS which have kept Moore's law valid till date. The miniaturization/scaling of silicon devices is the driving force for keeping Moore's law. The scaling of devices has resulted in high speed, low power consumption, large functionality in integrated circuits/processors. Indeed, it is because of scaling of MOS devices that we current see terascale integration in ICs. However, a million dollar question is How long can we use these silicon devices or silicon CMOS to extract more and more performance out of them? How long can we keep Moore's law valid with silicon based MOSFETs? The fact of the matter is that most of the researchers believe that Moore's law is already in saturation and it is extremely difficult to keep it valid by just scaling the dimensions of silicon based MOSFETs. The era of silicon bulk MOSFET is nearing its end and the scaling of dimensions below 32/22 nm technology is extremely difficult, due to various short channel effects (SCE), increase in leakage, mobility degradation, oxide tunneling, channel transport limitations, increase in source /drain series resistances, random dopant fluctuations etc. Besides, further scaling of device dimensions demand that the supply voltage (V_{DD}) need to be scaled down, to keep power consumption in check and to prevent device breakdown. However, this results in a significant decrease in the speed of the operation of the devices.

Therefore, the electronics world currently has an urgent and immediate need of new material, which can replace silicon and new device which can successfully replace the silicon based MOSFET. However, the new device is expected to outperform and outshine the current silicon based devices, must enable new application domain and must result in a significant cost reduction. Many new and novel devices are currently present, like FinFET, double gate MOSFET, Pi-FET, Gamma FET; however, it appears extremely difficult to replace the conventional bulk MOSFET by these alternative devices. These devices are complex and costly and cannot be the perfect solution.

From the last two decades, the focus of device designers is on a unique material with unique properties that is the carbon nanotube (CNT) and its associated device carbon nanotube field effect transistor (CNTFET). CNT has unique and extra ordinary electrical, mechanical, photonics etc. properties and is being foreseen as a future material. It is extremely strong, has best electrical and thermal conductivity, is flexible and has excellent emission properties.

The use of CNTFETs in ICs will significantly increase the speed of operation, reduce power consumption and will significantly increase the packing density in ICs. It can indeed extend the life of Moore's law significantly. These advantages of CNTs have provided us enough motivation to go for the CNTFET based circuit designing. CNTFETs have been extensively used in digital circuit designing, however, comparatively not much CNT based work has been done in

analog domain. Therefore, in this thesis we have decided to employ the CNTFETs in designing some popular analog basic building blocks and finally comparing their performance with the conventional CMOS based analog building blocks. The various analog basic building blocks designed and developed in this thesis work include operational transconductance amplifiers (OTAs), cascade operational transconductance amplifiers (COTAs) and multistage operational amplifiers, all employing carbon nanotube field effect transistors. It has been observed that the CNT based design has many advantages in comparison to the conventional CMOS based designing, however, some issues need to be addressed to increase the domain of CNT based designing.