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Design of Local Oscillator Circuit for FINFET and SET

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Abstract— **Nanometer scale devices have the potential of replacing the CMOS based device as because of low power operation. Nanotechnology is the new and challenging field or technology of 21st century. Researchers were trying to scale the MOSFET to nano-metric scale from 180nm to 13 nm, but beyond 10nm the MOSFET faced quantum effects and thus the characteristic of normal MOSFET was altered to large extend. So, to cope up with technology development, researcher introduces new technology in which electronics work beyond 10 nm. The first transistor developed was SET, which used single electron for operation. The fundamental principle of SET device action is the coulomb blockade phenomena, which result in on or off states of this transistor. Inverter design using FINFET and SET has been done. Ring oscillators are probably the simplest type of oscillator used in RFIC design. They can be designed for a fixed frequency and variable frequency operation. Three stage ring oscillator for SET and FINFET has been designed using HSPICE and the waveform has observed. For SET based device the output waveform was unstable in the beginning with observable fluctuation but after a period of time it was stable. FINFET based circuit was stable compared to SET based. The Frequency for SET base oscillator has been calculated as 40.2 GHz and the frequency for FINFET based oscillator has been calculated as 38.6 GHz.**

***Index Terms*— CMOS, FINFET, HSPICE, SET**

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I. INTRODUCTION

Due to small and flexible devices demand in electronic equipment is rising, so the researchers are giving there day and night for shrinking the size of transistor. Previous CMOS technology was meeting the requirement of the consumer and scaling was the major factor, which was driving the technology. But due to sub-threshold conduction, hot electron and scattering type limitations in CMOS transistor, scaling below 13 nm was not possible.

Then researcher thinks of shifting the CMOS technology to some other technology, which can overcome the limitations. So the first to take the place of CMOS transistor was FINFET device, which consist of the multiple gates, followed by CNTFET, SET and RTD, which lead to further scaling.

Nanotechnology is new and emerging field in each and every field of engineering. It may be an electronic circuit or a polymer, nanotechnology have found their way to make and enhance the new material which make life more flexible and comfortable. It is the science dealing with device with dimension in scale of nano-meters. Nanotechnology is present in medical, electronics, polymer, fibers and medicine applications. The first and the most important device in the Nanotechnology was the Carbon Nano-Tube. Then followed by transistor from Carbon Nano-tube and lots other application

II. FINFET

A FINFET refers to a FET which has multiple number of gates embedded on a single device. Single gate electrode act as controlling device for the FINFET as it has many number of gates, wherein the multiple gate surfaces act electrically as a single gate, or by independent gate electrodes. These devices were developed keeping in mind the drawback which was observed in CMOS when they were scaled to very

small value. Rich diversity of design styles, made possible by independent control of FinFET gates can be used effectively to reduce total control of FinFET gates, can be used effectively to reduce total active power consumption. There are basically 3 types of orientation possible for the FINFET. [1][2][3]

1. Planar
2. Vertical
3. FINFET

Figure 1 displays three types of FINFET. All the three types of FINFET have different geometry but the basic working principle is same for all the three types.

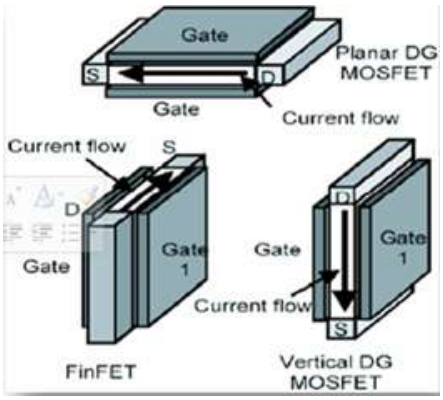

Figure 1 Different types of FINFET

III. SET

SET is single electron tunneling device designed in nano-scale. The basic principle of SET device action is coulomb blockade phenomenon. Figure 2(a) display the SET structure which clearly shows three terminal devices namely gate, drain and source. The source and drain is isolated with island to which gate is connected. [5]

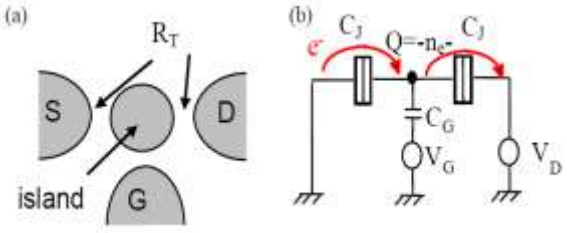

Figure 2 (a) Geometry of SET (b) Equivalent Circuit of SET [6]

Single electron transistor consists of small tunnel junctions, capacitances, and voltage sources. A tunneling electron can be described as a discrete charge due to stochastic nature of a tunneling event. Figure 2 (b) illustrate the nodes, where node 1 represents source electrode, node 2,4 is island, while node 3 represents drain electrode. In between these nodes are tunnel junctions, which are described by tunnel capacitance(C) and tunnel resistance(R).

When the bias voltage is zero, Fermi levels of both source and drain are in the state of equilibrium until the bias voltage is exerted. An electron will tunnel independently through the tunnel junctions from source to drain via dot when there is empty state at the energy level of the island which is between the Fermi levels of the electrodes. The electron tunneling alters the electrostatic potential of the island as well as charge. [7]

IV. RING OSCILLATOR

RFIC design include the ring oscillators because these are simplest and good type of oscillator. Designing the fixed variable frequency operation oscillotor is possible. They are usually included on the 'die' as a way of checking the process used in manufacturing the die to see it meets the relevant spice predictions thus verifying other circuits on the chip.

The output compared to the input provided by the amplifier is a replica. Oscillator doesn't require any input signal for the production of the output. It produces damped and un-damped oscillation according to the requirement. Figure 3 shows the three fundamental parts of a feedback oscillator .The resonator may contain transformers or other impedance transforming components such as coupling capacitors.

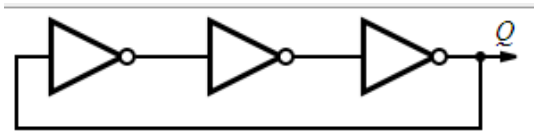

Figure 3 Circuits for three Stage Ring Oscillators [8]

There is no signal provision for the amplifier, but even if it is considered to be noise-free amplifier, somewhere noise will interfere in the system. This noise will be considered for the input of the amplifier where amplification will take place and at each stage with feedback, the noise signal will reach to noticeable spot. [9]

V. DESIGN OF RING OSCILLATOR USING SET

SET is single electron tunneling device designed in nano-scale, this act as a switch in the many circuit.3 The source and drain is isolated with island to which gate is connected. The three stage Ring oscillator for the SET based device is build using HSPICE software. The spice code for the three stage ring oscillator is being developed and the model file for SET has been downloaded from the internet and being included in the code [10]. Figure 4 shows the circuit diagram for SET based ring oscillator which clearly illustrate the SET inverter connected in series with feedback.

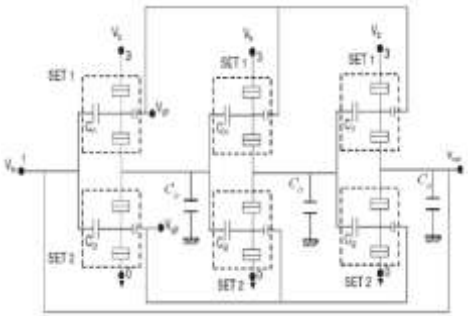

Figure 4 Design of three-stage SET based ring oscillator

The 3-stage SET based ring oscillator has been developed, the delay calculation and frequency calculation has been carried out as per equation (1)

$$Freq_{osc} = 1/ (2*N*Td) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

To obtain the frequency of oscillator, the following parameters are taken in to account:

No of stages= 3 Stages
Total Delay = I1 + I2 + I3
= 1.374 + 1.381 + 1.384
= 4.139 ps
= 1 / (2 * 3 * 4.139 ps)
= 1/ 24.834
= 40.2 GHz

VI. DESIGN OF RING OSCILLATOR USING FINFET

FINFET are the device which have more than one gate. A FINET is like a FET, but the channel has been turned on its edge and made to standup. The three stage Ring oscillator for the FINFET based device is build using HSPICE software. HSPICE is a powerful general purpose analog and mixed-mode circuit simulator that is used to verify circuit designs and to predict the circuit behavior. Model file is nothing but just a file describing the behavior of the transistor. It contains various parameters of the transistor which describe its properties. [10] The spice code for the three stage ring oscillator is being developed and the model file for FINFET is downloaded from the internet and being included in the code. Figure 5 display the design of oscillator, which include integration of three inverter based on FINFET transistor. Each inverter comprises of two transistor attached together.

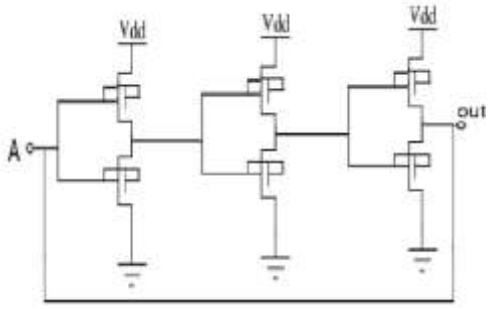

Figure 5 Design of three-stage FINFET based ring oscillator

The 3-stage ring oscillator design for FINFET based has been developed, the delay calculation and frequency calculation has been carried out as per equation number (2) and mentioned below:

$$Freq_{osc} = 1/ (2*N*Td)\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

To obtain the frequency of oscillator, the following parameters are taken in to account:

No of stages= 3 Stages
Total Delay = I1 + I2 + I3
= 1.438 + 1.425 + 1.451
= 4.314 ps
= 1 / (2 * 3 * 4.314 ps)
= 1/ 25.884
= 38.6 GHz

VII. RESULT AND DISCUSSION

The code for local oscillator for both FINFET and SET has been written in HSPICE software and silualtion result were observed. Figure 6 and 7 display the otput waveform for SET and FINFET based local oscillator respectively. The graph obtained is amplitude(in milli-volts) versus time period. The output can be observed as single-single inverter output and the third output of inverter is observed as the final oscillator output. In statring some of fluctuation were observed in case of SET but afterward it was

improved. FINFET based oscillator were observed more stable compared to SET based oscillator.

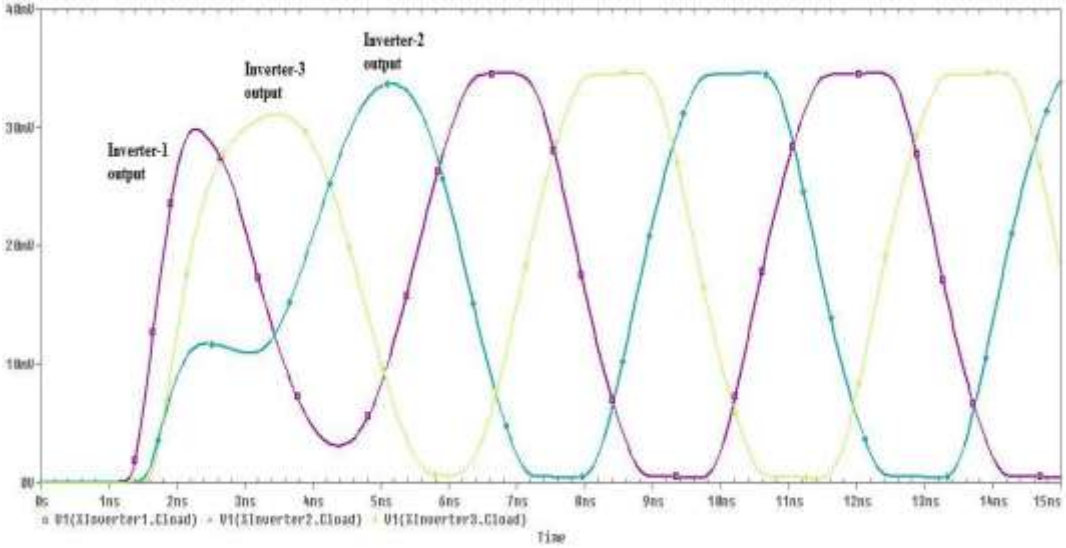

Figure 6: Output waveform for SET based Ring Oscillator

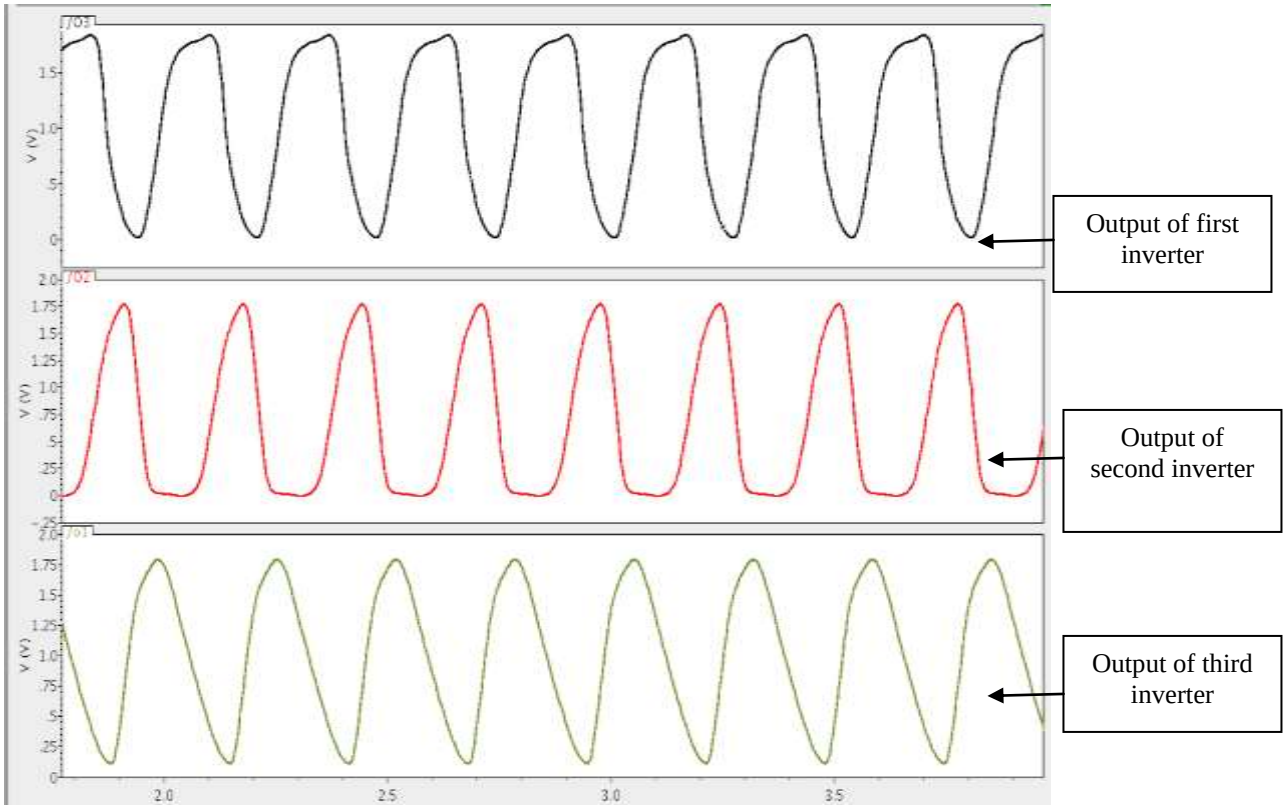

Figure 7: Output waveform for FINFET based Ring Oscillator

VIII. CONCLUSION

Nano device like FINFET and SET model file has downloaded from internet and the spice code for three stage ring oscillator has been written. The code has been executed using HSPICE software and the waveform was observed. For SET based device the output waveform was unstable in the beginning with observable fluctuation but after a period of time it was stable. FINFET based circuit was stable compared to SET based. The Frequency for SET base oscillator has been calculated as 40.2 GHz and the frequency for FINFET based oscillator has been calculated as 38.6 GHz

IX. REFERENCES

[1] Simon Deleonibus, "Electronic Device Architecture for the Nano CMOS Era" Pan Stanford Publication, 2009 ISBN-13 978-981-4241-28-1 Chapter 10

[2] Gen Pei et al, "FinFET Design Considerations Based on 3-D Simulation and Analytical Modeling", *IEEE Trans. Electron Devices*, vol. 49, pp. 1411-1419, Aug 2002

[3] Andrew Marshall, "Circuit design with FinFET processes" [online] http://www.cmoset.com /uploads/Marshall.pdf. Retrieved on 18th June 2012

[4] S. S. Rathod, A. K. Saxena and S. Dasgupta, "Rad-Hard 32 nm FinFET Based Inverters" IEEE 2009

[5] Seiya Kasai and Hideki Hasegawa, "GaAs SINGLE ELECTRON TRANSISTORS AND LOGIC INVERTERS BASED ON SCHOTTKY WRAP GATE STRUCTURES" , Japan Juornal Applied Physics 36 (1997)

[6] Negin Moezi, Daryoosh Dideban and Abbas Ketabi , "A Novel Integrated SET Based Inverter for Nano Power", American J. of Engineering and Applied Sciences ISSN 1941-7020, 2008 Science Publications Electronic Applications

[7] Lee Jia Yen, Ahmad Radzi Mat Isa, Karsono Ahmad Dasuki "Modeling and simulation of single-electron transistors", Journal of fundamental Science, 12 November 2005 .

[8] J P Silver," Ring oscillator Primer" [online] www.odyseus .nildram .co.uk /RFIC_Circuits.../ *Ring_Oscillator.pdf*

[9] "Phase Shift Oscillator" [online] http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/ oscphas.html. Retrieved on 25rd June 2012

[10]"BSIM", [online] http://embedded.eecs.berkeley.edu/pubs/ downloads/bsim/index.htm Retrieved on 16th June 2012.

Haramardeep Singh received B-.Tech .degree in electronics and communication from Lovely Professional University and M.S. degree in VLSI System Design from Coventry University in year 2010 and 2012, respectively.

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