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Single Electron Transistors and its Study in the Application of Electronics Devices

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Abstract: Due to the increase in Electronics application, Electronic devices power is the main topic of research. Single electron transistor provides high operating speed along with low. Single Electron Transistor (SET) is switching device operating at nano-scale, its properties are control by the removal or insertion of a single electron. The IC fabrication technology reached its limits in terms of size beyond which further scaling is not possible. In this way, Single Electron Transistors is Considered as Future of IC fabrication. Single Electron Transistor is able to shear domain with silicon transistor in future and enhance the device density. Single Electron Transistor has been made with dimensions of few nanometer using metal, semiconductor. Working of the SET is based on the principle of Coulomb blockade. In this paper, we study the theoretical concept of Single Electron Transistors and its application in Flip Flop and a half adder.

Keywords: Transistors, Coulomb Blockade, Single Electron Transistor, Fabrication.

1. INTRODUCTION:

Miniaturization has brought today's electronic devices in scale very small to the size where quantum phenomena will interfare the operation of the device hence changing its whole properties. The Increasing relevance of IOT and other application give more focused on electronic device power consumption. Currently ultra-low power consumption is one of the main research topics in electronics world. Single electron transistor provide high operating speed along with low power consumption. Single Electron Transistors (SET) is a device through which only single electron can be transported at a time.

To study about the SET first we have knowledge of Electron Tunneling and Coulomb blockade.

1.1 **Electron Tunneling**:

A very thin insulating barrier between two conducting electrodes. According to laws of classical electrodynamics no current can flow through an insulating barrier. Tunneling is the ability of using quantum wave properties of an electron to allow transmission from a thin voltage potential barrier. According to laws of thermodynamics which states that no current can flow through an insulating barrier and on other side quantum mechanics said that there is finite probability for an electron on one side of barrier can reach other side. When apply a bias voltage there will be current. The tunneling current is proportional to the applied bias voltage.

1.2 The Coulomb Blockade:-

The Single-Electron transistor of a metallic island which is placed between two tunneling junctions connected to a drain and a source and has a gate electrode as it was present in normal FET transistors. Quantum dots have also been used as islands for the Single electron transistors. The tunneling junction are simply a thin oxide layer between the island and the electrodes. Coulomb blockade will observed in

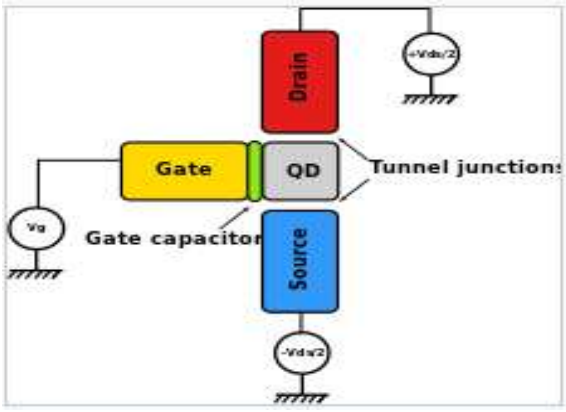
Quantum dot (Quantum dots are semiconductor crystals in nano range). Electron inside the device the device will create a strong coulomb repulsion preventing other electron to flow. The difference between a FET and BJT shown in Table.

Table 1: The difference between a FET and BJT :-

FET	SET
It is Based on its input voltage and a transistors allows a precise amount of current to flow through it.	The Single electron transistors device uses controlled electron tunneling to amplify current. The single electron means one electron precision charge is transfer in tunneling.

2. SET Construction:-

In SET a electron transport from a quantum dots (QD). A QD's is semiconductor in nano range whose electron are confined in three dimensions. The island is QD. Which is also connected to drain and source terminals. The Transfer of electron occurs only with drain and source terminals, they are connected to current and voltage meters.



Fig(I):- A SET based Flip-flop

The gate terminal has electrostatic coupling. When there is no coupling in source and drain then an integer number N of electrons in the island. The total charge in the island is quantized and equal to qN. The electric potential of the island can be tuned (Changed) by a GATE. In the blocking state no energy levels are accessible to electron. All energy levels on the with lower energies are occupied. When a positive voltage is applied at GATE the energy of island electrode are lowered after that the electron can tunnel onto the island.

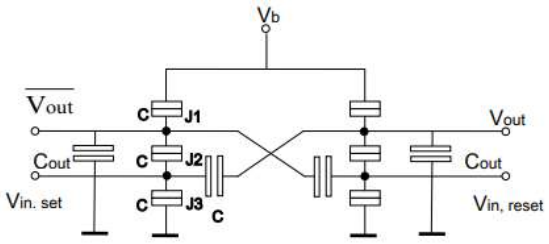
3. Application of SET

The aim is to explore the possibility of circuits that has low power dissipation.

3.1 SET based Flip-Flop:

The basic unit of storage is called as flip flop and it is the simplest kind of sequential circuit having two states either 1 or 0. Flip flops are two state sequential circuits that flip from one state to another and flop back.

SET devices can used to design SET memory cell or flip-flop and its operation is equivalent to a conventional flip-flop.



Fig(II):- A SET based Flip-flop

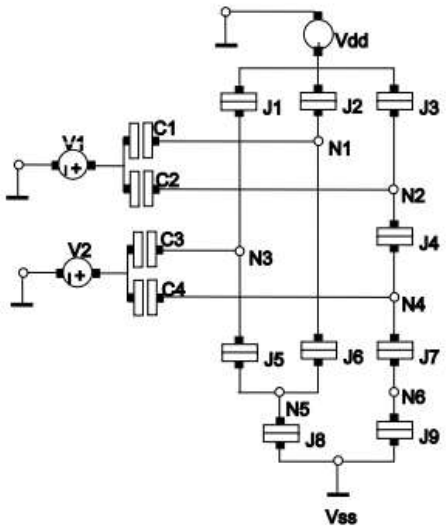
2.2 SET based Half Adder

Half Adder is a electronic circuit that perform addition of numbers. SET can be produce the effect of a half adder. The Circuit shown in fig(C). The circuit has six islands N1-N6 which are

bounded by nine tunnel junctions J1-J9 the capacitance of each junction 10^{-18}F.

Table 2: Voltage Logic

Voltage-Source	Voltage	Logic level
V1	0.0	Logic`1`
V2	20.0	Logic`2`



Fig(III): SET based half adder.

Table 3: Truth table

Input X	Input Y	Sum (Z)	Carry(C)
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

2.3 Detection of Infrared Radiation:

The SET can also be used to detect infrared signal at room temperature. The exciting electrons over an electrically induced energy barrier both the range of detectable wavelength and the sensitivity of the devices can be controlled. The sensor works when an infrared signal excites conduction band electron in deep electron reservoir. Electron with energy greater then the height of the barrier are injected into the storage node and then they read as change as changes in the current which is flowing through the transistors.

Conclusion:

The IC fabrication technology reached its limits in terms of size beyond which further scaling is not possible. In this way Single Electron Transistors is Considered as Future of IC fabrication. Single Electron Transistor is able to shear domain with silicon transistor in future and enhance the device density. The precise electronic control afforded over electron spins is promising for developing scalable quantum computing.

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