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Logic Synthesis of Contemporary European Model Traffic Control Signaling System Using Novel Nano Scaled Single Electron Tunneling Technology

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Abstract:
Modernization of society has led people in general to use high speed automobiles especially in European region, although the third world countries including India do not lag behind. But safety should not be compromised for luxuries and fastness. Henceforth, the conventional traffic signaling system has been geared up and newer technologies has been introduced and tested continuously for the sake of prevention from major accidents. Here the authors investigate the application of nanotechnology into a refined European advanced traffic control system to venture out the best practices and probabilities in safety measures undertaken. The present model defined here also reduces the power consumption considerably, which predominantly illustrates its on-chip realization; thereby it significantly increases the feasibility of such systems in India and all other major countries.

Key words: *Single Electron Transistors, Nanoelectronics,Coulomb Blockade, Tunneling of Electrons, Low power consuming devices, e-beam Lithography Technique*

1. Introduction

The vision of Richard Feyman [1] to shrink device size in nanometer is now being articulated in major scientific journals and is being realized and implemented in highly sophisticated research labs. With the incorporation of advanced fabrication techniques Scientists all over the world emphasize in designing nano scaled devices to meet up the current needs. Thus the micro-electronics industry charted its route beyond 100nms into the deep nano regime early in the beginning of this century. The integral density of such nano-electronic devices possesses higher bonding compared to conventional electronics. The power consumption is notably low as reported in reputed research publications so far [2-6]. Moreover, with such citations research trend has much deviated from extreme level shrinking of CMOS devices to the e-beam lithography technique based fabricated nano scaled devices. Different novel devices have emerged so far in this context. However, the research area is yet padlocked in device fabrication area only as very few researches has been reported related to application of nano electronic devices in daily human life.

Much talked post CMOS technologies are Quantum Electron devices [7,8], Single Electron Transistor (SET) [9-12] based devices and Spintronic devices [13-16]. Due to process related limitations and physical limitations of Quantum electronics [17-19] authors here opted for SET based devices i.e., Single Electron Devices (SED) to realize the new traffic control system. Spintronics, on the other hand has enormous technological advances and requires absolute detailing which will be considered in our future work.

The data obtained was a major task to identify the characteristics of the junctions during day time as well as in low traffic hours. Based on such crucial statistics the newly proposed traffic model was designed and simulated in Monte-Carlo based simulation platform for the proximity of appropriateness so that it can be implemented on chip for hardware realization. In the following sections we refer a brief introduction of SET technology and in subsequent sections the modus operandi of the SED based advanced traffic control system is detailed along with its circuit diagram. In between the logic synthesis of the required gates in this model is analyzed. The empirical results are compared with the conventional CMOS designing to corroborate the unmatched features of SET technology incorporation.

2. The Underlying Issues of SET

SETs are fabricated by laying two tunnel junctions in series [20-24]. The two tunnel junctions yield a "Coulomb island" where electrons can merely'pass in' by tunneling through one of the insulators. More precisely, the device consists of three terminals, quite identical to that of a FET: i.e., it has two consecutive outer face terminal of each tunnel junction, and a "gate" terminal. The gate terminal as seen in the Fig. 1 is somewhat capacitatively coupled to the node between the two tunnel junctions,whereas the capacitor appears like a third tunnel junction, but the thickness is much higher than the others restricting other electrons to tunnel through it. Ultimately the capacitor functions as a process of setting the electric charge on the Coulomb Island. A simplistic view of a SET circuit is shown in Fig.1 below along with its complete schematic in Fig.2.

The "*orthodox*" theory of single-electronics was proposed by Kulik and Shekhter [25] which plays a very significant role in single electronics. This theory was further generalized to other systems. The simplicity of the structure of SET increases its popularity in next generation nano scaled electronics.

3. The Conditions for Tunneling

The circumstances required for tunneling are -

- The Tunneling Circuit should comprise of tunnel junctions, capacitors and voltages sources.
- Electron should tunnel in from one point of a tunnel junction to an opposite point of the tunnel junction, during this time the charge distribution of the respective circuit changes.
- All the tunnel resistances R_T must be greater than the fundamental resistance Rq. i.e., $R_T > Rq = h/e^2 = 25.818\ K\Omega$.
- The Coulomb Energy E_C is required to charge an island with an electron $E_c = e^2/(2C) > K_T$, where C is the overall capacitance of an island and K is Boltzmann's constant (K=1.38×10-34 J/K)
- If Coulomb energy is much greater than the available thermal energy, with the help of the supplied voltage source we can manipulate the movement of electrons by controlling the available energy.

These are the prior conditions that are required to be fulfilled for SET operation [26-32]. For real time applications it is utmost necessary to design SET based various logic gates. Few prominent research publications in this category are referred in this work[33-36]. Some of these designs are now in laboratory use to realize commercial SET products. It is to be noted that room temperature operation, background charge like hindrances need to be overcome at the earliest so that such designs can be brought into massive productions in electronic industrial houses in near future. Such SET based 2 input AND, OR, NOT, NAND, NOR gates and D-Flip Flop are shown below in Fig 3 to Fig.8 respectively.

4. Need of Advanced Traffic Signaling System

Such systems assist road authorities in maximizing the operational performance and reliability of all aspect of the road network keeping pace with safety and security of the common man.Failure of conventional systems recorded massive number of accidents causing major losses of lives and also to the automobiles. One of the pioneering bodies to survey the road accidents, World Health Organization (WHO) published a Global status report on road safety'2013 taking records from road accidents from 182 countries, which accounts for almost 99% of the world's population; indicates that worldwide the total number of road traffic deaths remains excessively high at 1.24 million per year [37]. The World Road Statistics (WRS) in its issue of 2010 published by the International Road Federation, (IRF) Geneva, declared USA as the highest number of road accidents occurring country [38]. Astonishingly only 28 countries, covering 7% of the world's population, demonstratedbetter and comprehensive road safety system.Beside this International Transport Forum also expressed greater concern in lacking to develop easy, sophisticated advanced traffic signaling system[39]. India too has a very high rise in recording road accidents causing deaths as in every 3 minutes an Indian dies in a road accident [40]. In such circumstances the authors emphasized in designing this novel advanced traffic signal model as a sincere service to the nation and mankind.

5. Circuit Realization of the Proposed SET Advanced Traffic Signal Model

The complete architecture is shown in Fig. 9 and its operational methodology is depicted in the following sections.

6. Operation of the Advanced Traffic Signal Model

The model consistsof six lights to operate. The Red, Amber, and Green lights in the North-South direction arelabeled as R1, A1, G1. Similarly, the lights in the East-West direction are named R2, A2, and G2 accordingly. As soon as thedigital signals are in the Logic-1 state they turn their respective lights on, or else the lights remains off. A digitalclock signal is attached to supply clock pulses at each time when the lights change as per schedule. For simplicity of the design we have not included the design of the circuit that produces the clock pulses at appropriate times.Considering that there are two types of road crossing: (i)some crossings use a simple sequence, and (ii) few busy crossings require a longer sequence i.e., a delayed green signal. Further, it is assumed that selected junctions possibly will use the busy sequence during the day and the quiet sequence at night. One specific digital input signal called J that refers the junction type indicates if the road crossingis considered quiet. When J=0 it denotes a busy junction and forJ=1 a quiet one. Combining all such it appears that we have a one-input, six-output synchronous system to operate as the advanced traffic signal model.

7. Gains of Replacing CMOS by SET in this Circuit

Amid the real pain in constructing this SET based circuit we have briefly studied the improvements achieved so far in substituting CMOS for this circuit. The power consumption factor compared to CMOS is $(1/10^3)$ times and the power dissipation per gate is ~1μW which is significantly low. Besides, the SET circuit is twice faster than the CMOS circuit and the propagation delay per

gate is noted as merely 6ns. This increases the compactness of the SET circuit. Above all, being nanoscaled the circuit is feasible to be implemented on one single chip which is economical and user friendly.

8. Conclusion

SET device based advanced traffic signal model efficiently transmits and controls the signaling system and consumes considerably less power compared to other existing conventional traffic control hardware models. Additionally, owing to its less complicated architecture the cost of the device can be reasonably low. Other concerned aspects like time-delay, integration density, speed and robustness of the model is of far better standard when matched to present day CMOS-TTL logic circuits. With the steady increase in SET fabrication technology such type of model will be designed efficiently by the nano device engineers in near future. Thus this model can be considered as a successful competent in next generation Digital Communication and Signaling System.

9. Acknowledgement

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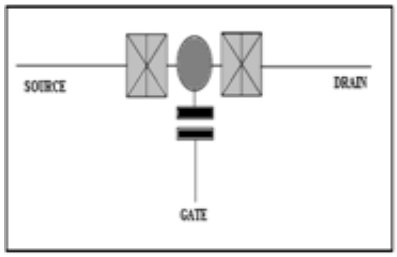

Figure 1: Block diagram of SET

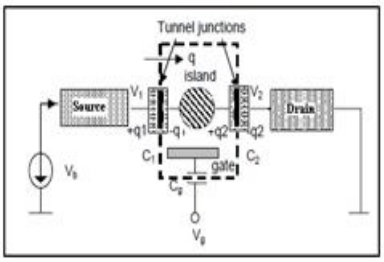

Figure 2: Schematic structure of SET

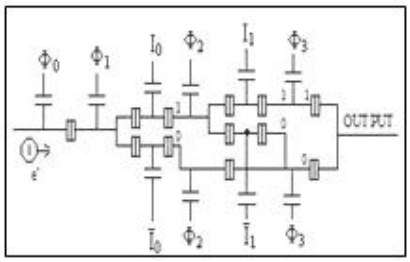

Figure 3: 2 i/p SET based AND Gate

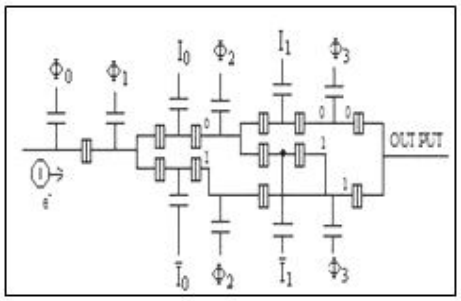

Figure 4: 2 i/p SET based OR Gate

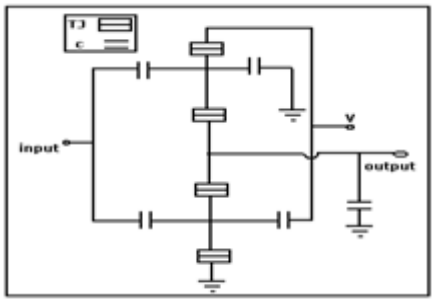

Figure 5: 2 i/p SET based NOT Gate

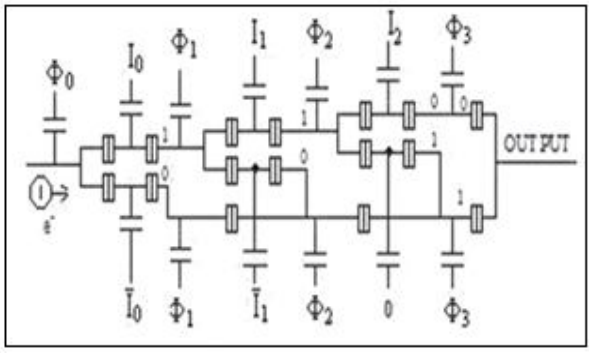

Figure 6: 2 input NAND gate realization using SET

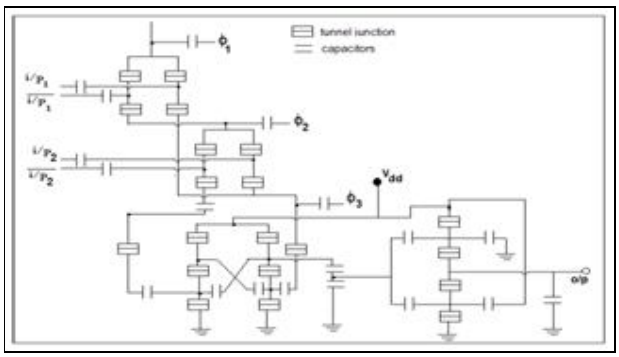

Figure 7: 2 input NOR gate realization using SET

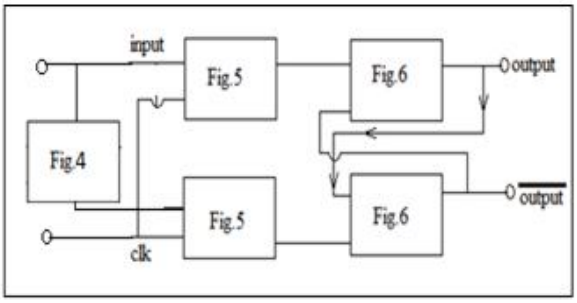

Figure 8: SET based D-Flip Flop

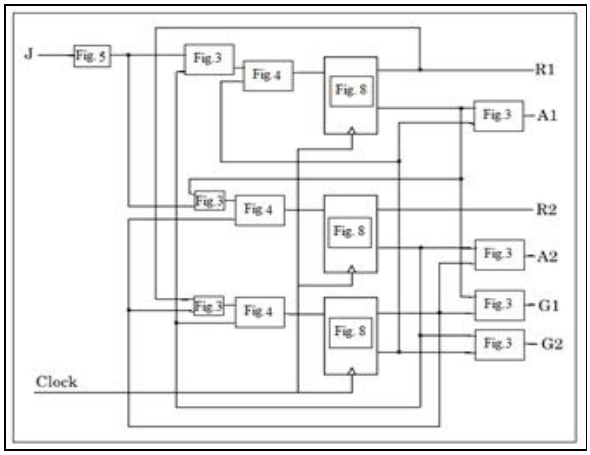

Figure 9: Complete SET Structure of On Chip IC for Novel Traffic Control

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