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Development of Single Electron Transistor for Filter Applications

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***Abstract*—Field-effect transistors were the most often used electron devices in ultra-low-power integrated circuits. Recent SET research provides fresh concepts that will transform random access memory and digital data storage technology. A better gadget will be created by new technology that has a high operational speed and low power consumption and which has the potential to be the future of the electronics industry. The development of a technique for the electric modelling of hybrid MOS/SET circuits will be carried out. A functional model of the transistor will be developed as a result, and this model will be applied through construction of the Filter.**

Keywords*— *SET, MOSFET, Nano-Device, MOS, FET, Filters

I. INTRODUCTION

John Bardeen and William Shockley's development of the transistor in 1948 heralded a new era in electronics. Scientists realized that this solid-state technology, originally designed to just imitate the vacuum tube, may give a lot more. As well-regulated materials like pure single-crystal silicone were available; the transistor's immense potential to achieve speed, compactness and reliability has been extensively utilized.

During the last two decades several successor technologies were investigated based on new operating principles and higher scaling potential at the expected end of the CMOS era. Single Electron Tunneling (SET), fast single-flow (RSFQ), resonant tunneling diodes (RTD) and carbon nanotubes are further technologies. Single Electron Tunneling, which may be replaced by CMOS, is not subject to CMOS technological limits (power consumption and scalability) [1,2]. SET technology permits few or single electrons to be managed and is hence capable of calculating very low energy consumption. The single electron transistor, a novel nano-scaled switching technology, is even nuclear-scaling that can produce very low power consumption and greater operating speed.

SET has different interesting properties such as the unique oscillation property of coulomb and nano size. Energy quantification increases the blocking area and the periodical blocking of coulomb substantially, so altering the SET circuit performance [3,4]. In a world in which transistors continue to decrease, is it inevitable that the quantum nature of electrons and atoms will be revealed when it comes to how instruments are constructed? To put it another way, how can a transistor be reduced to a few atoms or a molecule in size and function. Scientists have created the so-called single-electron tunnelling transistor to address these issues [5].

This device makes advantage of quantum tunnelling processes to monitor and detect the motions of single electrons, and it has been widely used in military applications. Experiments have showed that charge flows in these devices not constantly but in each pattern. In fact, single electron transistors are sufficiently confident to be used as highly precise electrometers. Researchers have been exploring the possibilities of SET transistors for digital electronics for a long time. The Island, two tunnel junctions, and the gate condenser, comprised of one transistor electron in a single molecule, may also be a solution to this problem [6].

II. CONSTRUCTION OF SET

The single-electron transistor is a transit through a quantum point by a single electron. A quantum point is a semiconductor of nano-particulates that has electrons in all three spatial dimensions. The transistor structure varies significantly. The principal components of a single electron configuration are illustrated in the following figure.

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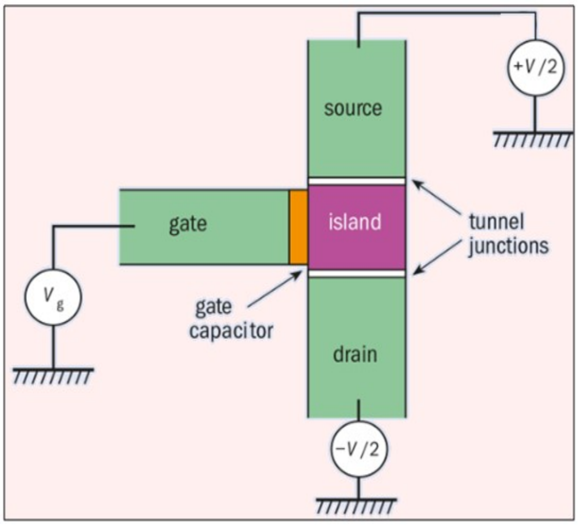

Fig.1. Single Electron Transistor

The island is the quantum point of the drainage terminals and of the source. Only the drain and source terminals attached to current and voltage meters are used for electron exchange. The gate terminal is electro statically or capacitive linked. If no link exists, the quantum point has an integer number N (island). The total charge is quantified on the island and equal to qN [7, 8].

III. FILTER APPROXIMATIONS

We have seen numerous instances of amplitude response curves for different filter type in earlier sections. The curve was always "ideal" to indicate that the border between the crossband and the stopband was abrupt, and the pitch was endlessly steep. This kind of reaction would be excellent since it would allow us to isolate signals fully at different frequencies. Unfortunately, a response curve of such magnitude is not physically feasible. We will have to take the best approach to satisfy our needs for a particular application. The optimal approach requires a balance between the different features of the transfer function of the filter [9, 10]. The following are the main qualities.

i. Filter Order

For various reasons, the order of a filter is essential. The number of components in the filter and its cost, its physical size and the difficulty of design work are closely connected to it. Higher-order filters are therefore more costly, take up more space and are harder to build. A higher order filter has the main benefit that it has a steeper roll off path than an equivalent lower order filter.

ii. Ultimate Roll off Rate

Usually stated as dB attenuation for a particular frequency ratio. The main units are dB/octave and dB/decade. In the case of a low pass or high pass filter and 20 dB/decade for each pair of poles in the bandpass filter, the ultimate roll-off rate will be 20 dB/decade; certain filters have higher attenuation slopes close to the cut-off rate than others in the same sequence.

iii. Attenuation Rate near the Cut-off Frequency

If a filter is designed to reject a signal extremely near to that signal, a strong cut-off characteristic between these two frequencies is desired. Note that this steep path may not continue to extreme frequencies.

iv. Transient Response

The amplitude response curves demonstrate how a filter reacts to the sinusoidal steady-state input signals. Since a genuine filter has far more complicated signals on its input terminals, it is frequently worth knowing how it acts under temporary situations. A step function input signal offers a good indicator of this.

v. Monotonicity

A filter has a monotonic amplitude reaction when its gaining path never varies, in other words when the gain grows with a rising frequency or lowers constantly with an increasing frequency. This can only, of course, occur with a low-pass or high-pass filter. On either side of the central frequency, however, a bandpass or notch filter can be monotonous.

vi. Passband Ripple

If the filter is not monotonous within its passband, one or more "bumps" will be present inside the passband. These bumps are called "ripple." Some systems do not need monotonicity, but the ribbon ribbon must be restricted to some maximum value (usually 1 dB or less).

vii. Stopband Ripple

Some filter answers are also rippling in the stopbands. We are usually unaware of the number of ripples in the stopband as long as the signal to be rejected is diminished enough. Since the "perfect" filter amplitude response curves cannot be physically implemented, we must pick an acceptable approximation to the ideal response. In various contexts, the term "acceptable" may have multiple connotations.

viii. Butterworth

Butterworth or the maximum flat response is the first and most definitely best-known filter approximation. It has an almost flat ribbon without ribbon. The rolling is smooth and monotonous with a rolling rate of 20 dB/decade (6 dB/octave) for every pole. A Butterworth 5th-order low-pass filter would therefore have a 100 dB attenuation rate for each factor of 10 increases in frequency beyond the cut-off frequency.

ix. Chebyshev

The Chebyshev response or equal ripple response is another approximation of the ideal filter. As the latter term indicates, this kind of filter will have an amplitude reaction in the passband. The ribbon quantity is one of the parameters used to design a Chebyshev filter. In comparison with Butterworth, the Chebyschev characteristic has a steep roll off at the cutting frequency, but at the price of the monotony of the passband and the lesser transient response.

x. Bessel

The phase shift of all filters varies with frequency. This is a typical and anticipated property of filters, although issues may arise in some circumstances. If the phase rises linearly, it merely delays the output signal by a fixed length of time. However, when the phase shift is not exactly proportional to the frequency, the components of the input signal must appear at one frequency at a shifted output in phase (or time) compared to other frequencies. The overall effect is to deform waveforms not sinusoidal.

xi. Elliptic

The elliptical filter cut-off pitch is steeper than the Butterworth, the Chebyshev or the Bessel one, but both the passband and the stopband ripple off the amplitude response and the phase response is extremely non-linear. However, in the absence of phase shifts or rings, the elliptical response will accomplish that job with a lowest-order filter, assuming there is main concern to pass frequencies falling within a specific frequency range and reject frequencies beyond that band. By inserting notches into the stopband, the elliptical function produces a crisp cut. These cause the transfer function to fall to nil at one or more stopband frequencies [11, 12].

IV. PROPOSED METHODOLOGY

Single-electron devices operate at a faster rate than conventional MOSFETs. Furthermore, because to its very tiny capacity, it consumes extremely little power (four decades lower than the CMOS). Despite the unrivalled advantages of SET, low current drivability limitations, minimal gain, the absence of room temperature working technology, and the background charge effect have all emerged as obstacles in the development of future silicone technologies. To compensate for the basic constraints of SET, the benefits of CMOS technology, such as high gain and rapid drive rates, must be used. According to the findings of the literature review, many studies into the hybrid SET-CMOS circuit have been conducted. It is expected that hybrid systems based on nano-metric CMOS transistors and nano-devices, such as SET, would be required to develop a counterpart from their own design and verification pathways in the not-too-distant future [14].

The downscaling of CMOS was the most important technique for improving the performance of the VLSI circuit. Studies have shown, however, that the transistor of the MOS cannot be reduced any farther than the limits imposed by its working principle. In recent years, this understanding has prompted us to explore future technologies, such as single electron device technology, that have more promise than they now have. One of the most effective technologies is improving the density, performance, and power dissipation needs in future VLSI circuits while simultaneously decreasing the power dissipation requirements. As a result, for efficient circuit design and analysis, it is necessary to run both SET and CMOS simulations at the same time. In this research effort, the aim is to model, and construct switched capacitor filters using a single transistor to decrease power consumption via the utilization of block and background charges generated by the SET coulomb signal. The planned work is created and carried out in accordance with the necessary processes to reach the intended result.

The circuit that was utilized to build the switched condenser filter is illustrated in the diagram. The proposed clock circuit is shown in the diagram without any overlapping elements. The clock frequency in mixed signal systems is increasing all the time, allowing for the processing of signals with a wider range of bandwidth. Because of the high frequency values, designers face a number of challenges. The op-amp circuit is shown in the figure, while the high-pass filter circuit has been depicted in Figure. The suggested low-pass filter circuit includes fewer circuits than those used in the proposed non-overlapping clock circuit, as well as fewer components than is typically used in this kind of circuit. As a result, the circuits that have been proposed will take up less area and thus produce less heat. It is necessary to transmit the appropriate low pass filter and high pass filter in real time.

$$H_l(s) = \frac{K_2}{s^2+\frac{\omega}{Q}s+\omega^2} \qquad H_h(s) = \frac{K_2.S^2}{s^2+\frac{\omega}{Q}s+\omega^2}$$

If Hl(s) is a low-pass filter transfer feature, Hh(s) is a high-pass filter transfer feature, the 3-dB cut-off frequency of each filter [15].

The suggested low-pass filter circuit contains fewer components than traditional low-pass filters. It will thus dissipate little power. The lower-pass filter and high-pass filter circuits operate on power supply in the range ±1.8V.

V. RESULTS

To validate the suggested approach, we simulate an improved type counter using the input condenser array and phase adjustment system structure. All simulation parameters have been established in advance, and the design process is as follows. Electrons flow to a quantum dot via a tunnel junction between the source and drain in this device (conductive island). Furthermore, the electrical potential of the island may be adjusted by a third electrode called the gate, which is capacitive linked to the island. The conductive island is wedged between two tunnel junctions, who are represented by parallel capacitors C_d and C_s and resistors R_d and R_s.

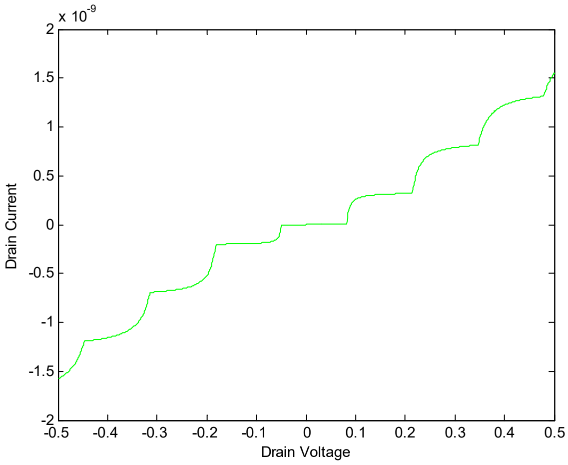

Fig.2. Drain current vs. Drain voltage plot at Vg =0.5

I-V characteristic of the SET is plotted, as shown in Fig. 2. The staircase distribution reveals the occurrence of Coulomb blockade. Simulation parameters are selected like that, obtained characteristics becomes uniform and symmetric. In this situation it may also be acknowledged that when reducing the value of C_1 threshold point will be reached.

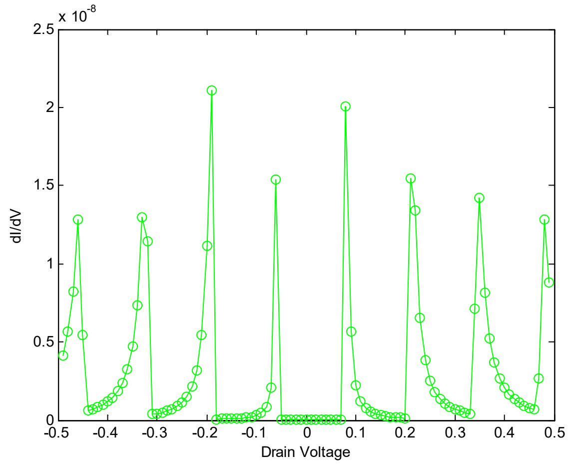

Fig.3. dI/dV vs. Drain voltage plot at Vg =0.5

The dI/dV curve with the gate voltage =0.5 is shown in fig3 where circle is shows that the change in the value of dI/dV and Drain Voltage.

VI. CONCLUSION

In this study we have examined in detail the feature of Coulomb oscillation blockade of SET and used these characteristics completely for the construction of circuits, including supplements and multipliers. Since pure SET circuits suffer from low current drive abilities, modest voltage gains and low-temperature operations, the thesis has utilized hybrid SET designs as the main building blocks for viable nano-meter integration solutions. To improve the system resilience against BCs, the SET hybrid design has been developed to provide adaptive feedback that balances the background charging impact by providing the proper voltage through an extra SET gate.

VII. FUTURE SCOPE

In our research, we focused primarily on single-electron transistor. We have studied the concepts, operating conditions, and boundaries of this device in detail. We wish to continue with our efforts to build a two-port single electron twist model similar to one, to compute impedance and admission parameters and to see the replies.

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