

Analysis of Leakage Current Reduction Techniques in SRAM Cell in 90nm CMOS Technology

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ABSTRACT

Limited energy consumption in multimedia requires very low power circuits. In this paper we focused on leakage current minimization in single static random access memory (SRAM) cell in 90nm complementary metal oxide semiconductor (CMOS) technology. The leakage current mainly consists of sub threshold leakage current and gate leakage current in 90nm CMOS technology. So minimizing the sub threshold leakage current and gate leakage current is most important aspect in low power memory design. This work presents a technique based on dual threshold voltage (V_t), dual gate oxide thickness (t_{ox}) and dual power supply (V_{dd}) assignment together to minimize gate leakage and sub threshold current of SRAM cell. Simulation results using 90nm CMOS technology show that this technique can reduce the total leakage current dissipation of a single SRAM cell by more than 75% with less delay penalty.

Keywords

Leakage current, SRAM, high V_t , high t_{ox} , data retention voltage.

1. INTRODUCTION

As today's technology shrinking beyond 100nm deep submicron technology, leakage power becoming dominate to total leakage power [1]. The increasing demand for high density circuits and the exponential dependency of the leakage current on the t_{ox} and V_t is becoming a great challenge in deep-sub-micron CMOS technology. Mobile and multimedia applications need to be incorporating in one system. So there is a strong need to reduce the leakage current while keeping the memory cell data unchanged. There are several sources for the leakage current such as the sub-threshold leakage current due to low V_t and the gate leakage current due to very thin t_{ox} [2]. As technology scaling, this require not only very low V_t to maintain the device speed but also ultra-thin t_{ox} to keep the current drive and V_t variations under control when dealing with short-channels[3]. With scaling down of CMOS transistors gate leakage and sub-threshold leakage current increases [2]. The Sub-threshold leakage current is the drain-to source leakage current when the transistor is in the OFF mode. This occurs when the gate to source voltage of transistor is less than the V_t of the transistor. As V_t is scaled down with technology scaling there is exponential increase in sub-threshold leakage current. The gate leakage flows from the gate through the oxide to the substrate. Gate leakage current of transistor increases exponentially with the reduction of the t_{ox} over the active region of the transistor [4]. The gate leakage current is predicted to increase at a rate of 500x per technology generation whereas sub threshold leakage current is predicted to increase by 5x [5]. Since the leakage current depends on the number of transistors and given the large memory content of future system on chip devices, it is necessary to minimize the leakage current in SRAM cell [6]. Various

techniques have been proposed to reduce the SRAM leakage current. Method of reducing the sub threshold leakage current is to use higher V_t in some parts of a design and to reduce the gate leakage current multiple t_{ox} can be used [3]. To minimize the sub threshold leakage power consumption of a cell, the V_t of all or some of the transistors of the SRAM cell can be increased. When the V_t of all of the transistors within a cell is increased, then reduction in sub threshold leakage current is the highest but there is some delay penalty. So we can consider other configurations to reduce the gate tunneling leakage current of an SRAM cell, only the t_{ox} of the pull down NMOS transistors and pass-transistors need to be increased [3]. Leakage current reduces as V_{dd} decreases. So, the SRAM cell is put in the low-power drowsy mode when the data preservation is required and in the high-power mode before the access of the data [7]. In SRAM cell, the data retention voltage (DRV) defines the minimum V_{dd} under which the data in a SRAM cell can be preserved [8]. In this proposed work we have presented SRAM cell using high V_t , high t_{ox} and dual V_{dd} techniques together to reduce the leakage current of SRAM cell in 90nm CMOS deep-sub-micron technology.

The rest of the paper is organized as follows, Section 2 describes basic overview of the conventional 6 transistor(6T) SRAM Cell is presented. Section 3 describes leakage current component in 6T SRAM cell. Section 4 explains review of the related work. Section 5 describes the proposed work which is followed by the simulation results and Conclusion in Sections 6 and 7 respectively.

2. THE CONVENTIONAL 6T SRAM CELL

SRAM cell may be designed simply by using cross coupled inverters [5]. The leakage power consumption of the memory cell will be limited to relatively small leakage currents of both CMOS inverters. The only drawback of using the cross coupled inverters, is slightly larger area than resistive load and depletion-load NMOS SRAM Cell. The memory cell consists of a simple CMOS latch in which two inverters connected back to back and two complementary access transistors M1 and M2. The cell will preserve one of its two possible states, as long as the power supply is available. Conventional SRAM cell with 6T is shown in figure 1. There are mainly three states in SRAM cell the write, read and hold states [2]. In the following we describe the states in SRAM cell.

2.1 Hold State

When $WL = "0"$, M1 and M2 disconnect the cell from bit lines(Bit and Bit bar). The current drawn in this state from the V_{dd} is termed as leakage current.

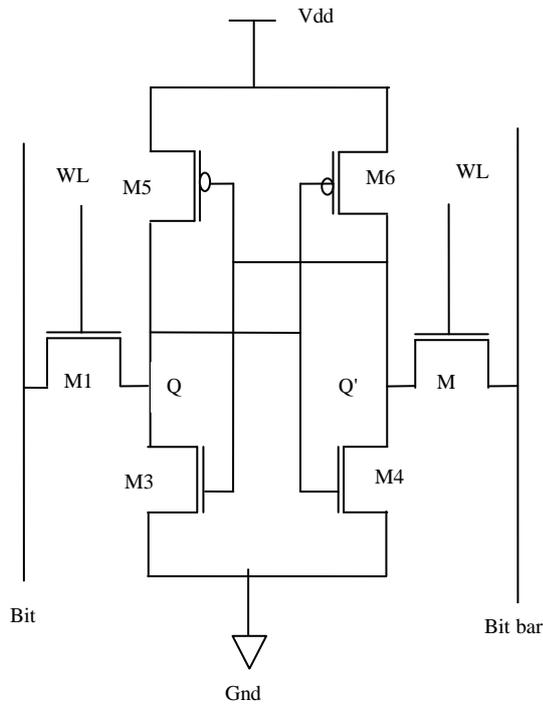


Figure 1: Conventional 6T SRAM cell

2.2 Read State

Read operation starts with pre-charging Bit and Bit bar to high. Within the memory cell M3 and M6 are ON. Asserting the word line, turns ON the M1 and M2 and the values of Q and Q' are transferred to bit-Lines. No current flows through M2, thus M2 and M6 pull Bit bar up to Vdd, i.e., Bit bar = "1" and Bit line discharges through M1 and M3. This voltage difference is sensed and amplified to logic levels by sense amplifiers[5].

2.3 Write State

The value to be written is applied to the bit lines and keep WL="1". Thus to write data "0", we assert Bit=0, Bit bar="1" and to write data "1", the Bit = "1", Bit bar = "0".

3. LEAKAGE CURRENT COMPONENTS

The leakage current in deep submicron CMOS Technology consists of three major components: junction tunnelling current, sub threshold current and gate leakage current. Since junction tunnelling current is a less contribution to the total leakage current in 90nm CMOS technology [3]. In this paper we do not tried to reduce this component of leakage in an SRAM cell. In the following, we describe the gate leakage, sub threshold leakage and junction tunneling leakage currents.

3.1 Sub Threshold Leakage Current

Sub threshold leakage current is the drain- to-source current of a transistor when the gate-to-source voltage is less than the threshold voltage of transistor [3]. The sub threshold current depends exponentially on threshold voltage, which results in large sub threshold current in short channel devices.

3.2 Gate Leakage current

Electrons (holes) tunneling from the bulk silicon through the gate oxide into the gate results in gate leakage current in an NMOS (PMOS) transistor. Gate leakage current consists mainly three components (1) gate to source and gate to drain overlap current (2) gate to channel current, some part of which goes to source and the rest of the part goes to drain (3) gate to

substrate current. In bulk CMOS technology, the gate to substrate leakage current is very less than the overlap leakage current and gate to channel current. On the other hand, the overlap leakage current dominates when the transistor is in off state; gate to channel leakage dictates the gate current in the ON state. Since the gate to source and gate to drain overlap regions are very small than the channel region, the gate leakage current in the OFF state is very small than that of gate leakage current in the ON state [3].

3.3 Junction Tunneling Leakage Current

In the reversed biased p-n junction leakage has two main components: one is minority carriers, diffusion near the Edge of the depletion region and the other is due to electron hole pair generation in the depletion region of the reverse biased junction. The junction tunneling current is an exponential function of junction doping and reverse bias voltage across the junction [7]. In 90nm CMOS this is less contribution to the total leakage current so this paper don't consider to reduce this component in this work. Figure 2 shows the sub threshold leakage current and gate leakage current in SRAM cell storing 0 and when WL=0 [7].

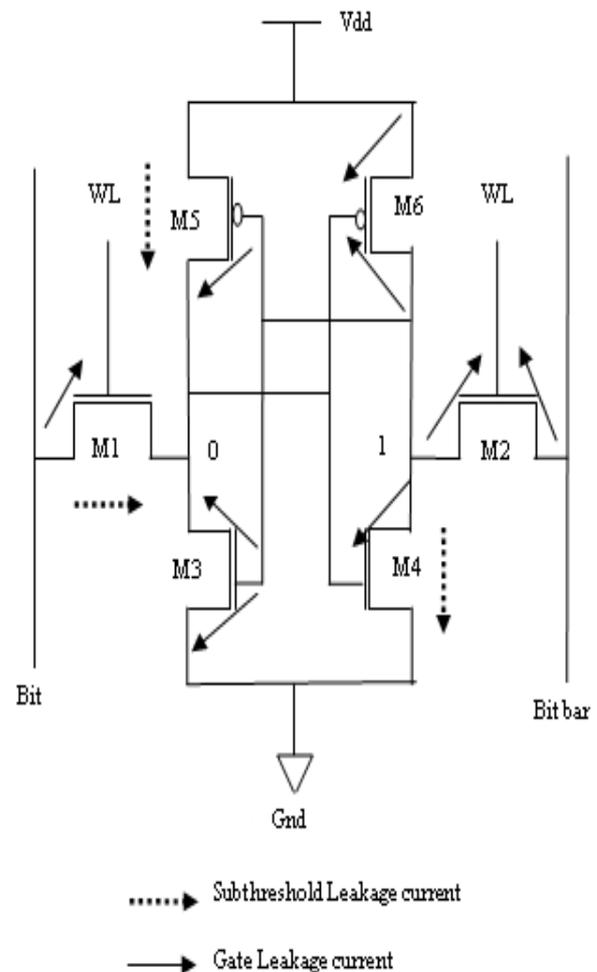


Figure 2: Leakage currents in 6T SRAM cell

4. RELATED WORK

4.1 Drowsy Cache

In the SRAM cell there are mainly two operations. One is read and other is write operation. It can be assumed as active mode when read and write operation is done. On the other hand when there is no read & write operation, only information preservation is done by the latching phenomena of memory. It is found that there is very low V_{dd} needed for preservation of data [8]. Drowsy cache method puts memory in a low V_{dd} when only data preservation is needed. It uses multiple V_{dd} sources. It supplies high V_{dd} when actual transmission of data takes place. Leakage current is reduced as V_{dd} decreases. Thus, the memory core is put in the low-power drowsy mode when the information preservation is required and in the high-power mode before the access of the contents [9]. The leakage current reduces with the voltage scaling. This reduced leakage current and V_{dd} results in a much reduction in the leakage power [8]. Figure 3 shows the diagram of drowsy cache.

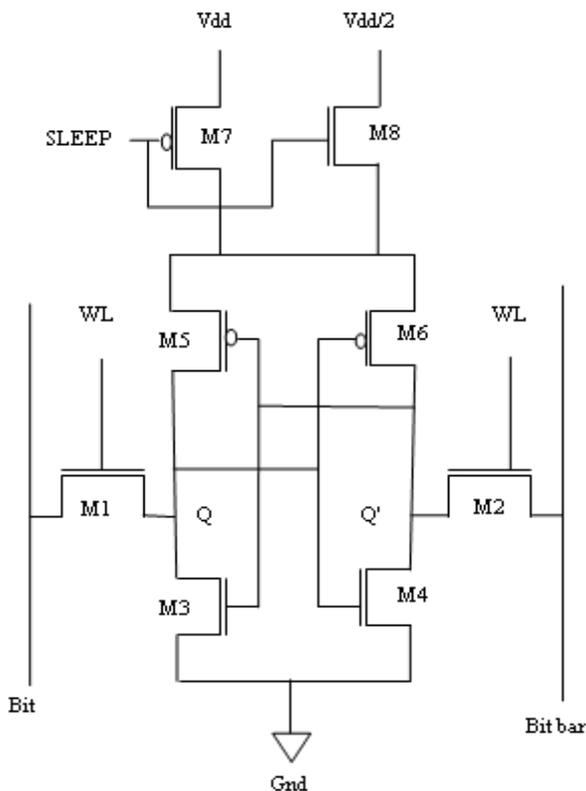


Figure 3: Drowsy cache 6T SRAM cell

4.2 Hybrid SRAM Cell

To reduce the sub threshold leakage current of a SRAM cell, the V_t of all or some of the transistors of the SRAM cell can be increased [3]. When the V_t of all transistors in SRAM cell are increased, the sub threshold leakage current reduction is the highest. However, this has the worst effect on the read delay of the cell. Thus, other configurations which have smaller sub threshold leakage reductions but lower delay penalties. On the other hand, to reduce the gate leakage current of an SRAM cell only the t_{ox} of the pull down NMOS transistors and pass-transistors need to be increased. Since increasing the t_{ox} also increases the V_t of a transistor, in this paper the t_{ox} and V_t of a

transistor is not increased at the same time because the delay penalty will be too high [3]. Figure 4 shows the diagram for hybrid SRAM cell. In this work high V_t pull up transistors and high t_{ox} pull down transistors are used for low leakage and high performance SRAM cell.

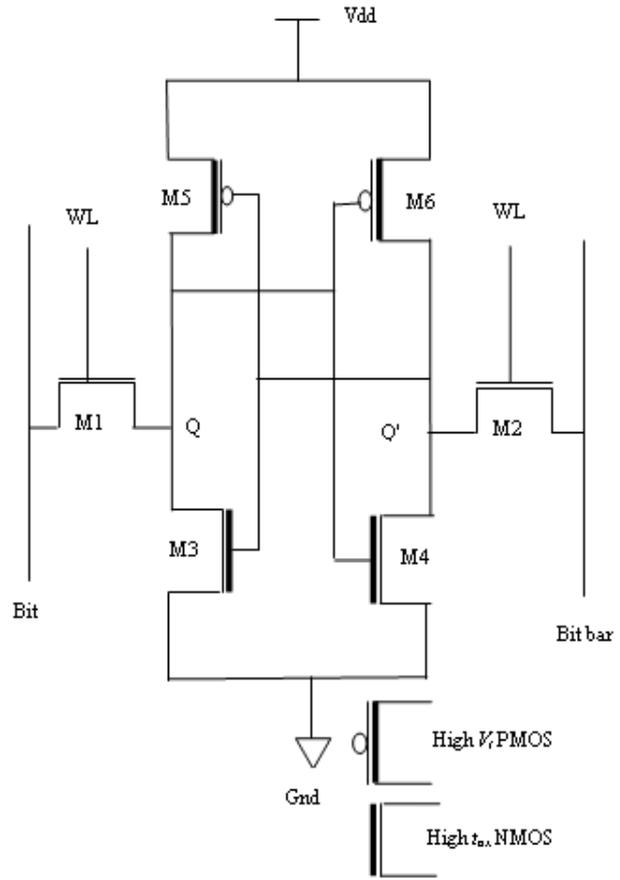


Figure 4: Hybrid SRAM cell

5 PROPOSED WORK

The proposed SRAM cell using dual V_{dd} , high V_t and high t_{ox} together is shown in figure 5. The proposed work shows that when dual V_{dd} , high V_t , high t_{ox} are combinately used, there is great reduction in the total leakage current. Using high V_t transistor in SRAM cell sub threshold leakage current of SRAM cell is reduced but delay of read and write operation of SRAM cell is increased. When the V_t of pull up PMOS transistors is increased, write delay is increased, because in write operation, access transistor and PMOS pull up transistor is involved. When the V_t of access transistors is increased both read and write delay of SRAM cell is increased, since access transistor are involved in both read and write operation. When the V_t of pull down NMOS transistors is increased, the read delay of SRAM cell is increased. Since write delay is very less compare to the read delay of SRAM cell so V_t of pull up transistors is increased [3]. To reduce the gate leakage current the SRAM cell t_{ox} of transistors of SRAM cell is increased, since the gate leakage in PMOS transistor is less compared to the NMOS transistor, so in this work the t_{ox} of pull down transistors is increased. To reduce the sub threshold and gate leakage when no read and write operation V_{dd} is used for data retention[9]. In this work we have used 1 volt V_{dd} for normal operation and 500 milli volt V_{dd} for data retention.

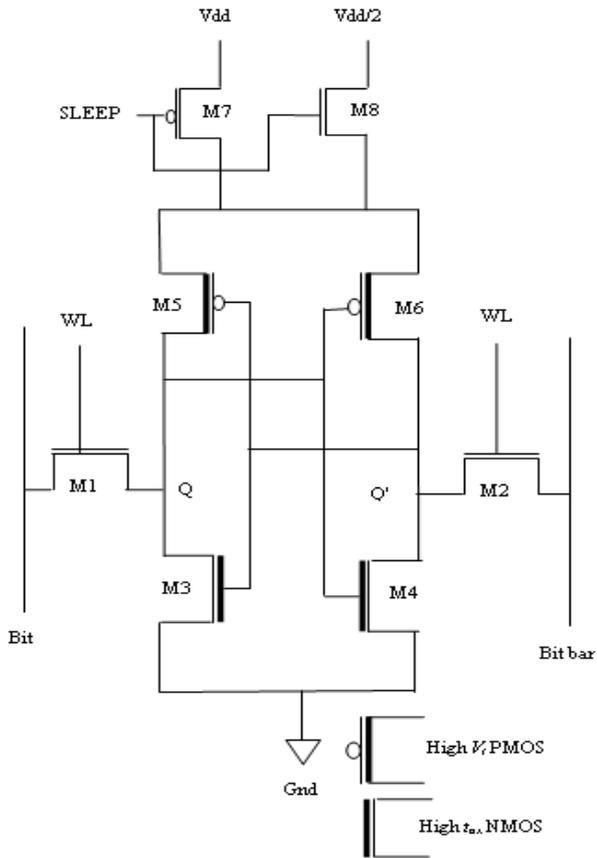


Figure 5: Proposed SRAM cell

6. SIMULATIONS AND RESULTS

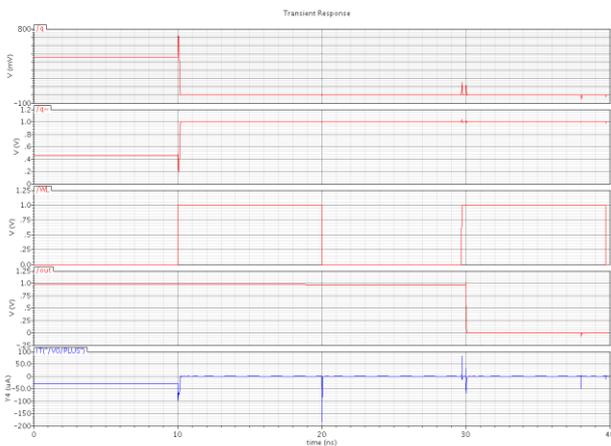


Figure 6: Simulation result for conventional SRAM cell

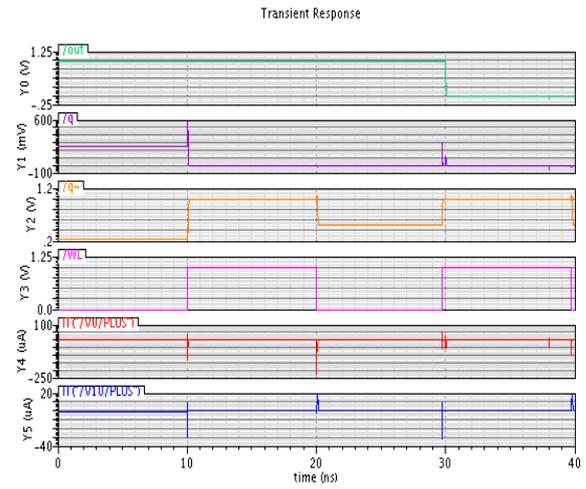


Figure 7: Simulation result for drowsy cache SRAM cell

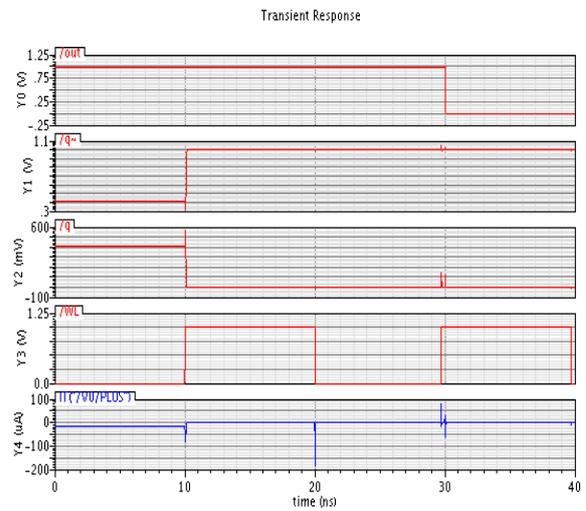


Figure 8: Simulation result for hybrid SRAM cell

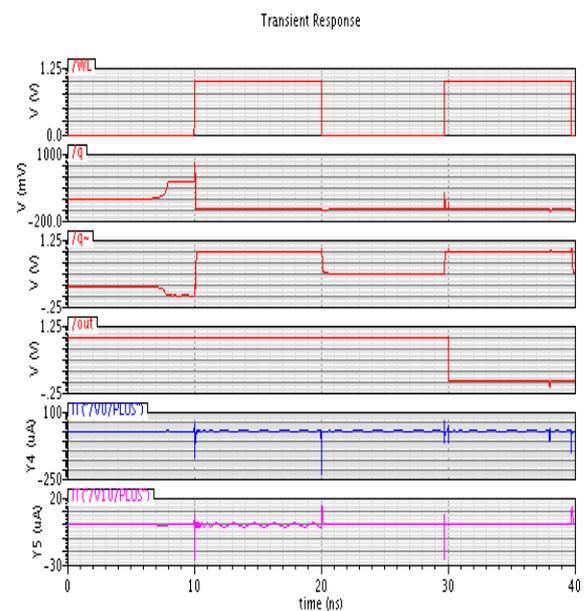


Figure 9: Simulation result for proposed SRAM cell

Table 1: Leakage current in different SRAM cell structures

Structure	Total Leakage Current (nano ampere)
Conventional 6T SRAM cell	27.89
Hybrid SRAM cell	15.24
Drowsy cache SRAM cell	10.39
Proposed SRAM cell	6.02

By the experiment result this is found that total leakage current in conventional SRAM is 27.89 nano ampere, in hybrid SRAM cell 15.24 nano amperes, in drowsy cache it is 10.19 nano ampere, while in proposed work this is 6.02 nanoampere. So proposed work is best in terms of leakage power saving in comparison to the other configurations.

7. CONCLUSIONS

In this paper, a structure of the SRAM cell, using high V_t , high t_{ox} and dual V_{dd} SRAM cell structure is presented. In comparison to the conventional 6T SRAM cell, the total leakage power is reduced by 45% while the cell is storing data "0" in hybrid SRAM cell, in drowsy cache SRAM cell total leakage saving is 63%, while in proposed SRAM total leakage power saving is 78%. In future this work can be extended to reduce delay penalty and can be applied to larger designs.

8. REFERENCES

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