

# Low Power DP SRAM Design in VLSI Implementation

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**Abstract** Static Random Access Memory (SRAM) is a major part of System on Chip (SoC) and more than half of the silicon area were filled with it. Nowadays, portable digital devices such as cell phones have a long lifespan in order for the humans to be able to rely on it and performing similar tasks as the desktop or laptop. Thus, it is important to design a low power SRAM. In this paper, a conventional Dual-Port SRAM (DP SRAM) of 2-Read/Write cell type compared with design with low power Complementary Metal Oxide Semiconductor (CMOS) techniques in terms of overall power consumption and the performances. The simulation and comparison has been designed and carried out by using Tanner Tools EDA using 0.25 $\mu$ m CMOS technology with 1V power supply. It shows that the Multi-threshold CMOS (MTCMOS) technique is the offer the lowest power consumption in the circuit, about 8% reduced as being compared with the conventional DP SRAM, while the Full Stack technique reduced about 6% as compared to the conventional DP SRAM. The time delay measured for the both low power techniques also have improved the conventional DP SRAM. It showed that by using MTCMOS technique greatly improve the overall design of SRAM array architecture.

**Keywords** DP SRAM, 2-Read/Write, CMOS, Power gating, Low power techniques

## 1. Introduction

Nowadays a Very Large Scale Integration (VLSI) technology has allowed the growth of System on Chip (SoC) and implemented in modern devices such as cell phones, digital devices and others micro-watt applications. It consists of an electronic systems that integrates into a single integrated circuit (IC) embeds with a multiple processors (Central Processing Unit (CPU) and Graphic Processing Unit), memories, power management circuits, various wireless radios (Wi-Fi, 3G, 4G LTE).

SoC is designed in different CMOS technology (from bigger to smaller nanometer technology) in order to increase the IC performances. However, the power consumption has to be kept low as the CMOS technology of SoC evolve [1]. Memory subsystem in SoC plays a major part in the silicon area. According to the research, about 70% of the SoC silicon area are occupied with the SRAM as it provides a link with CPU [2]. Figure 1 shows the embedded SoC architecture, where the blocks that has been shaded in yellow colour are the memory part.

SRAM is a type of memory that does not to be periodically refreshed. The main design issues are to design the low power and high-stability of SRAM as it required the high number of the transistors used in the memory chip to

store data compared to other subsystems [3]. The existing SRAM design in [4] has done the maximization by using the Multiple-threshold CMOS (MTCMOS) technique that plays with different threshold voltage (Vt). In research article [5] and [6], both improved the conventional design of DP SRAM with 2-Read/Write (2-RW) memory cell type.

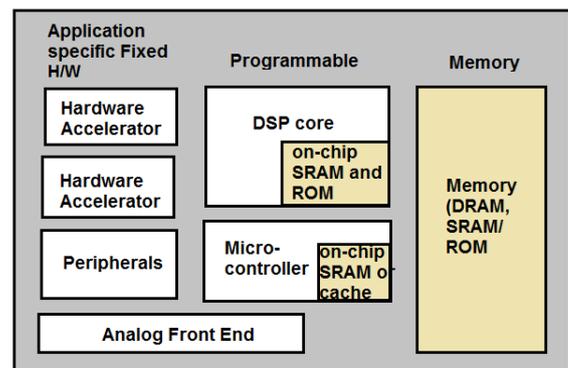


Figure 1. Embedded memory architecture [1]

Besides MTCMOS technique, there are other techniques have been applied to the SRAM such as Full Stack, Reverse Body Bias (RBB) and Multi-threshold Voltage (MTVC MOS) cell swapping. This paper focused on designing the conventional DP SRAM and two DP SRAM with low power CMOS techniques of MTCMOS and Full Stack in order to compare the power consumptions and performances of the circuit.

Overall, this paper is divided into five sections. The rest of the sections will be organized as follow. In Section 2, we

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discussed the Conventional 2-RW DP SRAM. A low power design techniques are presented in Section 3. The simulation results and discussions in Section 4. Finally, the conclusion is in Section 5.

## 2. Conventional DP SRAM

Dual port RAM cells is used to achieve a higher RAM density. As each port must be able to access the cell independent of each other the basic access lines; bit line, bit line bar and word line need to be duplicated.

There are two types of memory cells used for the DP SRAM, the 1-Read/Write (1-RW) memory cell and 2-RW memory cell [9]. Both of the memory cells have eight transistors (8T) in common. However, the drawback of 1-Read/Write is its single ended read bit line structure [6]. This paper focused in 2-RW cell type as shown in Figure 2 comprises two cross-coupled inverters (flip-flops) from M1 until M4 that are used to store the data, the rest M5 until M8 are used to access the stored data in the cell. 2-RW type as compared to 1-RW, both of the ports are able to do the read and write operation at the same time. Besides, it also can be operated as 1-RW type.

## 3. Low Power DP SRAM CMOS Design Techniques

The conventional 2-RW cell has to be modified in order to observe the techniques that offer the most low power consumption and improve the performances of the DP SRAM. These techniques increased the number of the transistors in the low power design more than the conventional 2-RW cell.

### 3.1. Multi-threshold CMOS (MTCMOS)

Low power and high stability has become the main issues in designing the SRAM. Therefore, by using the MTCMOS process, leakage current would be minimized and a large scale (macro) of SRAM are divided into multiple sub-macros to improve the read and write stability and ability and reducing the dynamic power. In MTCMOS technology, low, normal and high threshold voltage ( $V_t$ ) transistor were used in designing a CMOS. Low- $V_t$  (LVt) will give a high performance in the circuit design because the propagation delay could be reduced in the critical path and can be used whenever high performance is required. However, the LVt could caused the leakage current to be increased in the sub threshold. For the High- $V_t$  (HVt) transistor, to be compared with the LVt, the HVt can be used to reduce leakage currents and the power consumption in the shortest path [7]. Mitra [10] proposed 8T 1-RW DP SRAM using MTCMOS technique in 90nm CMOS technology with power consumption of 1.71uW, read and write delay of 15.93ps and 8.9ps, respectively.

MTCMOS power gating technique has been introduced in [3]. The sleep transistors that is applied between the supply voltage and the LVt gate, and between the ground line and the HVt device is known as “power gating”. The 9T SRAM in [3] consumed power of 88.22uW and propagation delay 0 and Figure 3 shows the MTCMOS with power gating technique. The sleep transistors will reduce the subthreshold leakage during sleep mof 340ps for 1-bit cell.

The technique concept is divided into two modes. During active mode, the SLEEP signal is deactivated by supplying the SLEEP transistors with LOW signal (0V). The HVt, which are the SLEEP transistors is turned ON and causes the LVt to be connected to the virtual VDD (supply voltage) and GND (ground). The LVt, which is the conventional 2-RW cell is utilized, allow the cell to be operated at low voltage with sufficient speed. While during standby mode (inactive), the SLEEP signal is activated by supplying the signals with HIGH signal (1V etc.). The HVt is turned OFF and causes the virtual VDD and GND to float, hence limiting the leakage current. This allowing the LVt transistors to work normally, at low leakage current. Figure 4 shows the working principle during active and standby mode.

### 3.2. Full Stack CMOS (FSCMOS)

Stack effect is the condition when two or more stacked transistors are turned off together, thus able to reduce the leakage power consumption [8]. Two PMOSs were stacked on the top of the pull-up transistors, M1 and M2 of the conventional memory cell and the other two NMOSs will be stacked at the bottom of pull-down network, M3 and M4. These PMOSs and NMOSs will be named as the PMOS stacking transistors and NMOS stacking transistors respectively. The reverse bias will be induced between the stacked transistors and the memory cell and the two cross-coupled inverters, thus resulting a lower sub-threshold leakage current. However, this would increase the delay and affect the circuit performances. Figure 5 shows the circuit diagram of FSCMOS technique.

The working principle of memory cell in this technique were the same as the conventional memory cell. During both of word lines is inactive (0V), the flip-flops will be isolated with the access transistors, which will not allowing any read and write operation occurs. Therefore, node ‘0’ value will be connected to the GND through the two series of pull-down network and NMOS stacking transistors. Similarly, at node ‘1’ value will be connected to the VDD (1V etc.) through the two series of pull-up network and PMOS stacking transistors. These will causes the leakage current reduction due to the stack effect. The power consumption in this technique could be further lowered by applying the HVt at the stacking transistors and normal- $V_t$  (NVt) at the conventional memory cell. This could optimize both power consumptions and delay in the circuit.

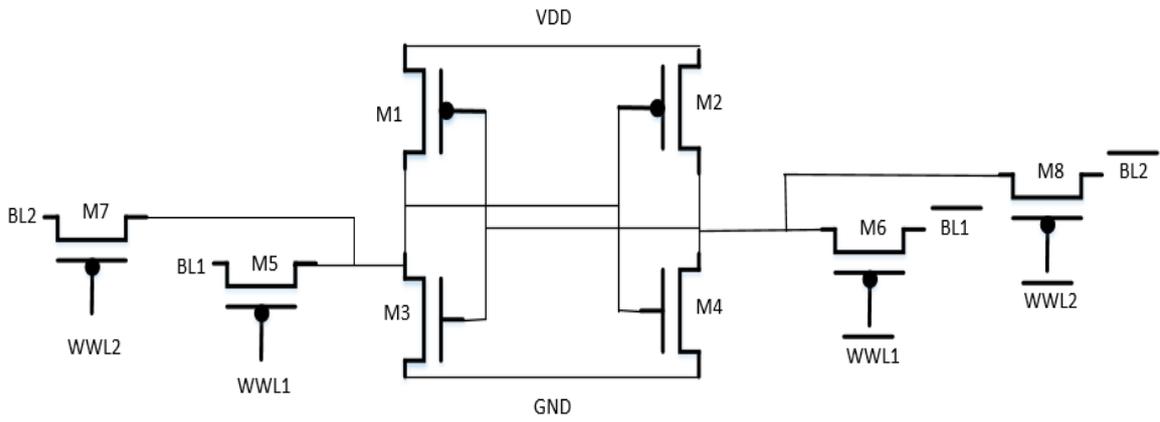


Figure 2. Circuit diagram of 2-RW memory cell

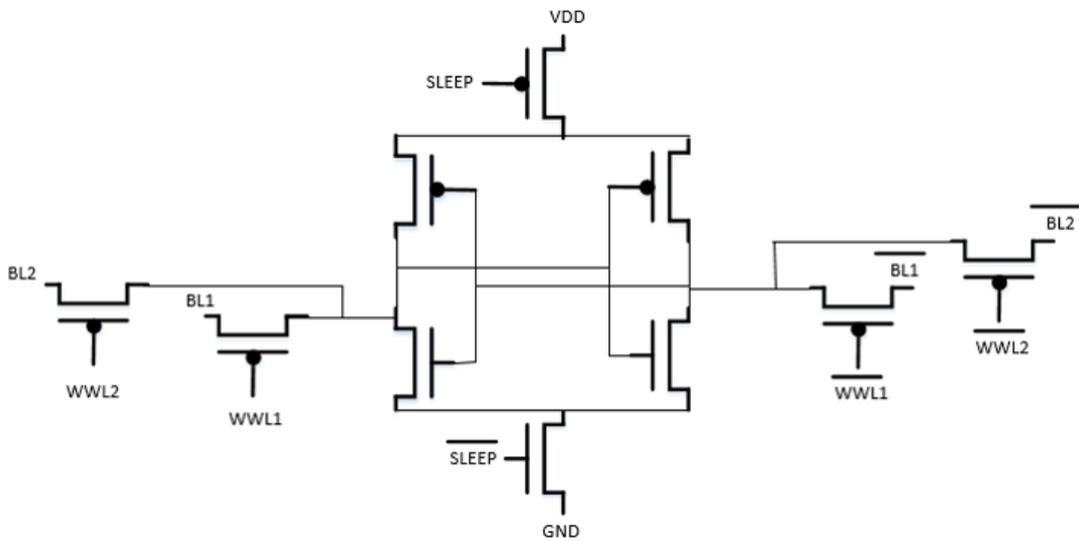


Figure 3. MTCMOS power gating technique

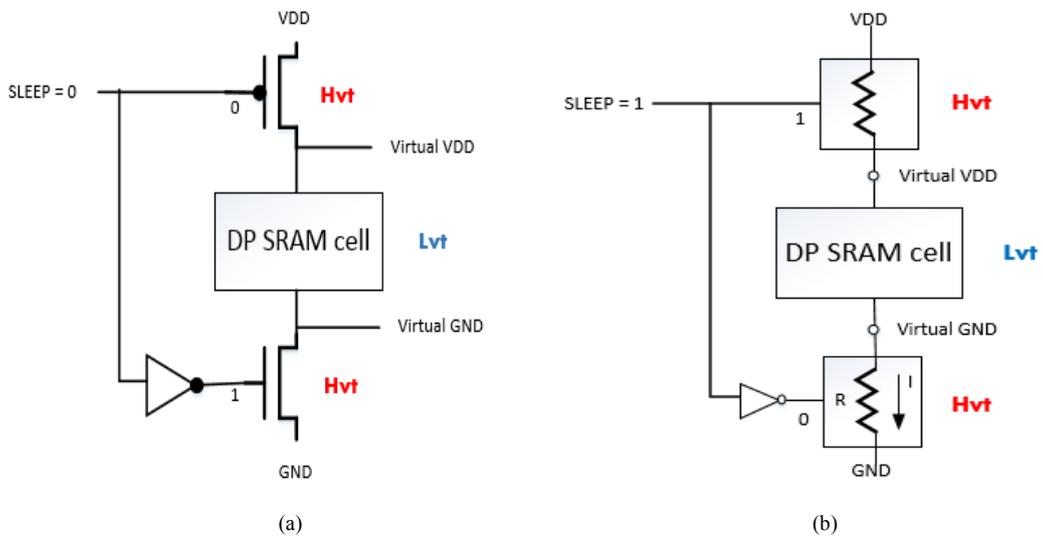


Figure 4. Power gating; (a) during active mode; (b) during standby mode

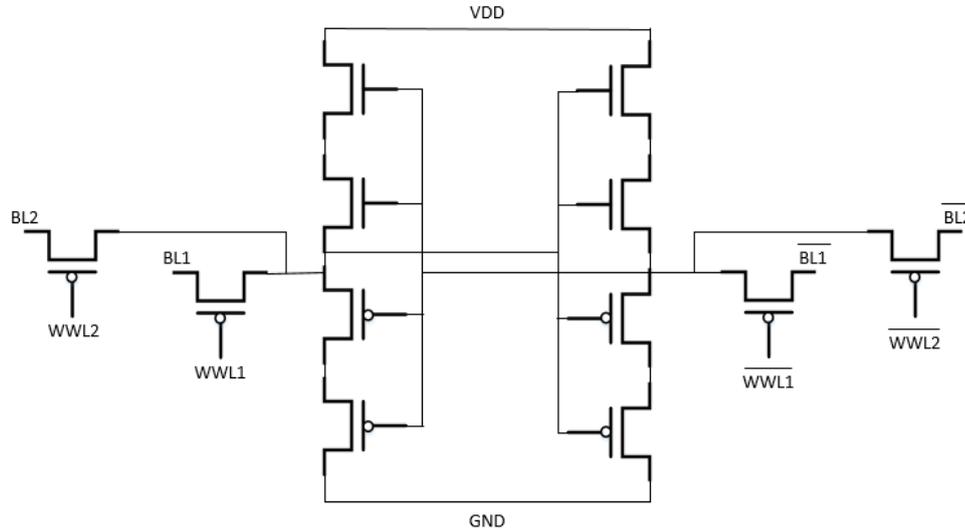


Figure 5. FSCMOS technique

## 4. Results and Discussions

DP SRAM circuit have been simulated at different voltage levels in range of 0.6V to 5V implemented in 0.25 $\mu$ m CMOS technology using Tanner Tools. Result showed that reducing the voltage level affecting the power consumption to be decreased. But as using 0.25 $\mu$ m CMOS technology, the minimum threshold voltage of the transistor might be higher for the voltage below 1V, the output waveform is degraded. Thus, 1V is chosen to be supplied in this memory cell. Table 1 shows the range of voltage supply of the circuit and its corresponding power consumptions.

Table 1. Power consumption in various voltage level

VDD (V)	Measured Power ( $\mu$ W)
0.6	3.36
0.8	13.36
1	35.11
3	1383.12
5	4646.52

The conventional 2-RW circuit have been simulated in 1V power supply. Two DP SRAM with low power design MTCMOS power gating and FSCMOS technique were simulated with the same parameters.

The power consumption and propagation delay of the circuit for proposed designs including the conventional 2-RW memory cell, the MTCMOS power gating technique and FSCMOS technique are tabulated in Table 2. It also show the area of each design. By applying the low power technique, it proves that the power consumption is reduced about 8% and 6% for the MTCMOS power gating and FSCMOS techniques respectively. MTCMOS shows the least power consumption as compared with the other two designs.

Table 2. Comparison result of DP SRAM design with different techniques

Circuit Design	Power ( $\mu$ W)	Delay (ns)	Area (in number of transistor)
Conventional 2-RW memory cell	35.11	40.07	8
MTCMOS power gating technique	32.25	40	10
FSCMOS technique	32.97	40	12

## 5. Conclusions

As a conclusion, DP SRAM with MTCMOS power gating technique has proven to reduce the power consumption in a memory cell, and overall of DP SRAM design. Using FSCMOS also reduced the conventional DP SRAM but required more number of transistors used in the cell that cause larger area of SRAM design compared to the MTCMOS and conventional design. Time delay also has been measured and proved that by applying these low power techniques, the speed performances of the conventional DP SRAM could be improved. The delay measurement involves both process during read and write operation.

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