◆◆ Scientific
◆◆ Research

Analysis of 8T SRAM Cell at Various Process Corners at 65 nm Process Technology

Shilpi Birla[1*], Neeraj Kumar Shukla[2], Kapil Rathi[3], Rakesh Kumar Singh[4], Manisha Pattanaik[5]
[1]*Department of Electronics & Communications, Sir Padampat Singhania University, Udaipur, India*
[2]*Department of ECE, ITM University, Gurgaon, India*
[3]*Texas Instruments, Bangalore, India*
[4]*Department of Electronics & Communications, Bipin Chandra Tripathi kumaon Engineering College, Almora, India*
[5]*VLSI Group, Atal Bihari Vajpayee Indian Institute of Information Technology and Management, Gwalior, India*
E-mail: [*]shilpibirla@gmail.com
Received June 7, 2011; revised July 22, 2011; accepted July 29, 2011

Abstract

In Present scenario battery-powered hand-held multimedia systems become popular. The power consumption in these devices is a major concern these days for its long operational life. Although various techniques to reduce the power dissipation has been developed. The most adopted method is to lower the supply voltage. But lowering the V_{dd} reduces the gate current much more rapidly than the sub-threshold current and degrades the SNM. This degraded SNM further limits the voltage scaling. To improve the stability of the SRAM cell topology of the conventional 6T Static Random Access Memory (SRAM) cell has been changed and revised to 8T and 10T cell, the topologies. This work has analyzed the SRAM's Static Noise Margin (SNM) at 8T for various process corners at 65 nm technology. It evaluates the SNM along with the write margins of the cell along with the cell size of 8T SRAM bit-cell operating in sub-threshold voltage at various process corners. It is observed that an 8T cell has 13% better write margin than conventional 6T SRAM cell. This paper analyses the dependence of SNM of SRAM memory cell on supply voltage, temperature, transistor sizing in 65 nm technology at various process corners (TT, SS, FF, FS, and SF).

Keywords: SNM, Sub-Threshold Current, Gate Current, Process Corners

1. Introduction

Due to increase in demand of wireless sensor nodes and mobile multimedia applications, the demand of small size SRAM memory on chips increases. However, as the voltage is scaled down to combat the rise in power and other issues, e.g., the lower noise margins (responsible for cell stability) arise in conventional 6T SRAM cells. Solutions involving additional transistors, *i.e.*, 7T, and 8T have been explored to lower power consumption while reducing these adverse effects in the cell performance. We will therefore look into one of these SRAM Cells topologies, the 8T SRAM cell which operates at sub-threshold voltages, successfully. The ultra-low leakage regime for static random-access memories (SRAM) designs imposes unique constraints on the cell design in many ways different from those imposed by performance-driven scaling concerns. The bit-cell size is of paramount importance regardless of the device threshold

voltage but beyond that the similarity ends. The high threshold voltage associated with the ultra-low leakage design point provides substantial relief to the static noise margin (SNM) for a given design, but the intrinsic threshold variation limits the performance available from the cell [1]. The intrinsic threshold variation affects the leakage as well, but in a less significant manner. In this paper we have analyzed the Static Noise Margin (SNM) of 8T SRAM cell at various process corners of the design environment at 65 nm.

This paper is organized as follows; SNM is described in section II. Section III deals with the working of 8T SRAM cell. Section IV shows the analysis of SNM, Write margin, Read Margin with respect to various process corners. Finally, conclusion is drawn in section V.

2. Static Noise Margin

The best measure of the ability of these inverters to

maintain their states is the bit-cell's SNM. The SNM is the maximum amount of noise voltage that can be introduced at the output of the two inverters, such that the cell retains its data. SNM quantifies the amount of noise voltage required at the internal nodes of a bit-cell to flip the cell's contents [2]. The static noise margin is a measure of the cell's ability to retain its data state. The worst-case situation is usually under "read-disturb" condition [3]. When the word-line device is turned on and connects the pre-charged bit-line to the low side of the cell. The state of the cell may flip if the internal node voltage rises to a high enough level. The problem is exacerbated if the ratio of the conductance of the pull-down and the word-line devices (often called beta) is too small.

3. Analysis of 8T SRAM Cell

This topology was originally proposed for a sub-threshold SRAM design. It is optimized for functionality and performance over a large voltage range in this design. Two NMOS devices (N3 and N2), **Figure 1**, constitute the read-buffer. A write operation is performed through WWL, WBL and WBLX ports, whereas single-ended read operation is exercised through RWL and RBL ports. RBL is pre-charged at the end of each read cycle and kept pre-charged during a write cycle [4]. In this bit-cell, read and write ports are decoupled in contrast to the traditional 6T cell so that the,

1) read-SNM (RSNM) problem is eliminated;

2) 6T SRAM part can be sized for better write-ability without trading-off RSNM and;

3) 2T read-buffer can be sized for larger read-current independently.

This makes the voltage drop across unaccessed read-buffers zero and hence leakage on read-bit-lines is highly reduced. V_{dd} is the virtual supply nodes for the cross-coupled inverters and its voltage can be brought down during a write access to weaken PMOS load devices (P1 and P2), **Figure 1**, and ease write-ability problem at low voltages. Since all the bit-cells on a row are written and
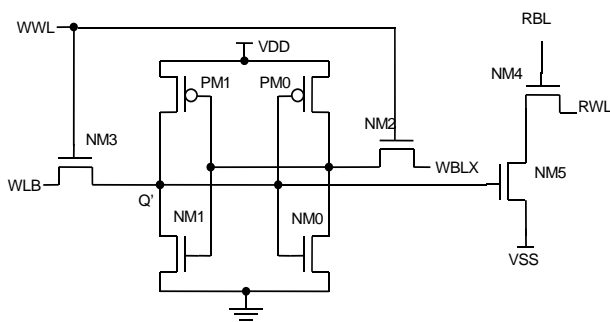
read at the same time, V_{dd} is shared across one row of memory cells [5].

4. Analysis at Different Process Corners

Process Corners (PCs) represent the extremes of these parameter variations within which a circuit that has been etched onto the wafer must function correctly. A circuit running on devices fabricated at these process corners may run slower or faster than specified and at lower or higher temperatures and voltages, but if the circuit does not function at all at any of these process extremes the design is considered to have inadequate design margin.

There are therefore five possible process corners: typical-typical (TT), fast-fast (FF), slow-slow (SS), fast-slow (FS), and slow-fast (SF). The first three corners (TT, FF, SS) are called even corners, because both types of devices are affected evenly, and generally do not adversely affect the logical correctness of the circuit. The resulting devices can function at slower or faster clock frequencies, and are often binned as such. The last two corners (FS, SF) are called "skewed" corners, and are cause for concern. This is because one type of FET will switch much faster than the other, and this form of imbalanced switching can cause one edge of the output to have much less slew than the other edge.

4.1. Analysis of Static Noise Margin at Various Process Corners

A simulation and analysis has been performed on the static noise margin at 65 nm at various process corners. The results shows that at SF corner the SNM is the maximum and at FS corner the SNM is minimum, **Table 1**. TT corner shows moderate value. As we measure the SNM at varying temperature at 40°C and 100°C, we found that as the temperature increases and the SNM decreases. As the V_{dd} increases the SNM has also increased but this increase in V_{dd} leads to increase in leakage current.

4.2. Analysis of Write Margin at Various Process Corners

Write SNM (WSNM) is measured using butterfly (or VTC) curves. For a successful write, only one cross point should be found on the butterfly curves, indicating that the cell is monostable. WSNM for writing "1" is the width of the smallest square that can be embedded between the lower-right half of the curves. WSNM for writing "0" can be obtained from a similar simulation. The final WSNM for the cell is the minimum of the margin for writing "0" and writing "1". A cell with lower

Figure 1. 8T SRAM Cell.

Table 1. SNM at various V_dd and PCs for 8T SRAM Bit-Cell at 65 nm.

V_{dd} (V)	SNM (V) (TT Corner)		SNM (V) (SS Corner)		SNM (V) (FF Corner)		SNM (V) (FS Corner)	
	100°C	40°C	100°C	40°C	100°C	40°C	100°C	40°C
1.2	0.207	0.192	0.232	0.242	0.142	0.157	0.117	0.137
1.1	0.187	0.202	0.217	0.227	0.137	0.152	0.112	0.132
1	0.177	0.187	0.202	0.207	0.132	0.147	0.107	0.122
0.9	0.162	0.172	0.182	0.187	0.127	0.137	0.096	0.107
0.8	0.147	0.152	0.162	0.167	0.117	0.127	0.081	0.086
0.7	0.127	0.132	0.137	0.142	0.107	0.117	0.061	0.066
0.6	0.107	0.112	0.117	0.117	0.091	0.096	0.041	0.046
0.5	0.086	0.067	0.091	0.096	0.076	0.081	0.021	0.026
0.4	0.066	0.066	0.071	0.071	0.057	0.061	0.004	0.009
0.3	0.041	0.041	0.046	0.046	0.041	0.011	failed	failed

WSNM has poorer write-ability. The BL voltage can also be used as a measure of write margin [6]. The 6T cell is configured for a write "1" case. The voltage of BLB the bit-line connected to the node holding "1" initially is swept downward during simulation. The write margin is defined as the BLB value at the point when Q and QB flip, which we will call VBL. The lower that value is, the harder it is to write the cell, implying a smaller write margin. From **Figures 2** and **3**, it can seen that as the V_{dd} increases the write margin increases, this trend of increasing write margin can be seen in each process corner. As the temperature increases the write margin increases too, as we can see that at 40°C (**Figure 2**), the write margin at TT is 0.148 V and at 100°C it is 0.167 V, (**Figure 3**), an increase in 0.19 V.

4.3. Analysis of Read Current at Various Process Corners

In some sense, stability can be viewed from write ability and read access time. The more stable the cell, the more difficult it will be to write the cell into a different state. A cell design with a narrower word-line device is more stable, but as the current through such a device is smaller, it will require more time to develop a signal of a given magnitude on the bit-line. The rate at which the cell can pull down the bit-line is limited by the series combination of the pull down device and the word-line device, and is increased by increasing the conductance of either or both devices [7]. The relative importance of the two devices to the read current is a consequence of the details of the device design and the operating conditions, and may not be precisely equal. For minimum read delay the widths of both devices should therefore be as wide as possible. While SNM evaluate cell functionality, the cell read current, "I_{read}" is a major component in designing array access time.
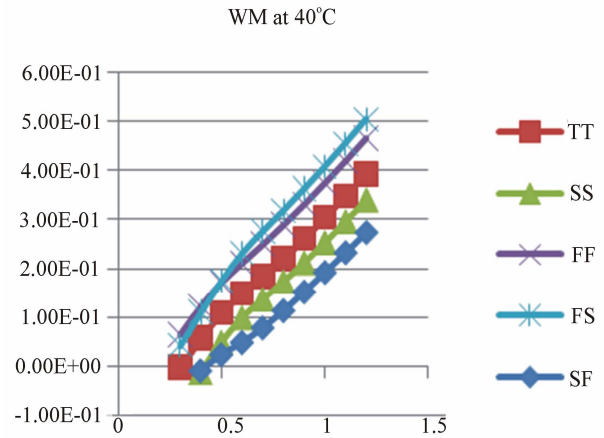

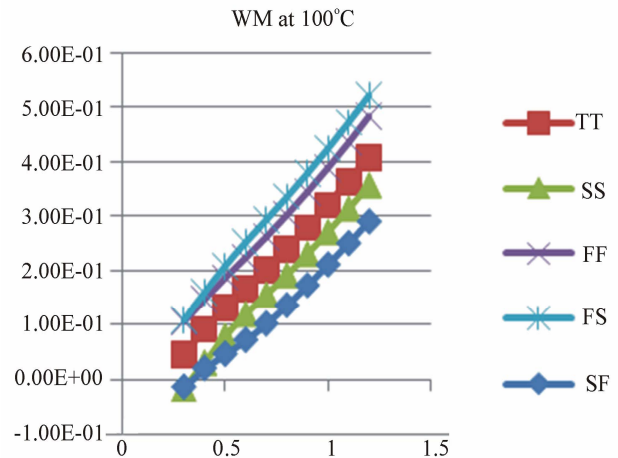**Figure 2. Write margin at 40°C measured at various process corners.**

Figure 3. Write margin at 100°C measured at various process corners.

The correct write operation requires that stored data be overwritten by the access devices; however, the relative

device strengths necessary to ensure this cannot practically be guaranteed. Further, the increased sensitivity to variation also results in extremely low worst case read-current. The resulting effect on performance is drastic, but, even more importantly; the effect on functionality can be fatal, where the read-current can be exceeded by the aggregate bit-line leakage-current. As shown in **Figures 4** and **5**, we can analyze, as the temperature increases the read current decreases and it is the highest for FF corner. So, increase in temperature degrades the read current which degrades the stability.

5. Conclusions

Voltage scaling enables energy minimization and leakage power reduction in micro-power systems. However, the design techniques and circuit peripherals are nece-

Figure 4. Read current at 40˚C measured at various process corners.

Figure 5. Read current at 100˚C measured at various process corners.

ssary to overcome the process variations in the ultra-low voltage regime. This work analyzed the SRAM Bit-cell's stability of the 8T cell at the 65 nm technology. The cell size of the 8T cell is 0.525 μm^2 and it is seen that as the voltage decreases, the SNM decreases. The temperature also affects the stability when it is at the higher side. On the other side, if the supply voltage V_{dd} increased, it increases the leakage and may lead in exceed in the read current. To minimize the V_{dd}, other low-voltage techniques may be used, so that the leakage can be minimized with maximized stability. It is also observed that the stability is the best with FF process corner and it has intermediate stability at the TT process corner.

6. Acknowledgements

7. References

[1] S. Birla, N. Kr. Shukla, M. Pattanaik and R. K. Singh, "Device and Circuit Design Challenges for Low Leakage SRAM for Ultra Low Power Applications," *Canadian Journal on Electrical & Electronics Engineering*, Vol. 1, No. 7, 2010, pp. 156-167.

[2] B. H. Calhoun and A. P. Chandrakasan "Static Noise Margin Variation for Sub-Threshold SRAM in 65 nm CMOS," *IEEE Journal of Solid-State Circuits*, Vol. 41, No. 7, 2006, pp. 1673-1679. doi:10.1109/JSSC.2006.873215

[3] Y. Chung and S.-H. Song, "Implementation of Low-Voltage Static RAM with Enhanced Data Stability and Circuit Speed," *Microelectronics Journal*, Vol. 40, No. 6, 2009, pp. 944-951. doi:10.1016/j.mejo.2008.11.063

[4] N. Hiroki, S. Okumura, Y. Iguchi, *et al.*, "Which Is the Best Dual Port SRAM in 45 nm Process Technology? 8T, 10T Single End and 10T Differential," *IEEE International Conference on Integrated Circuit Design and Technology and Tutorial*, Austin, 2-4 June 2008, pp. 55-58.

[5] B. H. Calhoun and A. P. Chandrakasan "A 256-kb 65-nm Sub-Threshold SRAM Design for Ultra-Low-Voltage Operation," *IEEE Journal of Solid-State Circuits*, Vol. 42, No. 3, 2007, pp. 680-688. doi:10.1109/JSSC.2006.891726

[6] Koichi Takeda, *et al.*, "A Read Static Noise Margin Free SRAM Cell for Low V_{dd} and High Speed Applications," *IEEE Journal of Solid-State Circuits*, Vol. 41, No. 1, 2006, pp. 113-121. doi:10.1109/JSSC.2005.859030

[7] R. Keerthi and H. Chen, "Stability and Static Noise Margin Analysis of Low Power SRAM," *IEEE International Instrumentation & Measurement Technology Co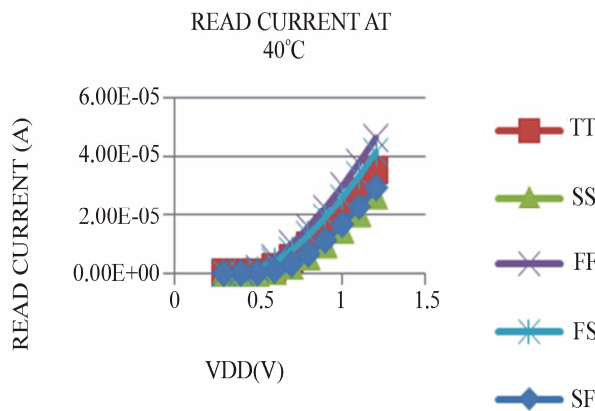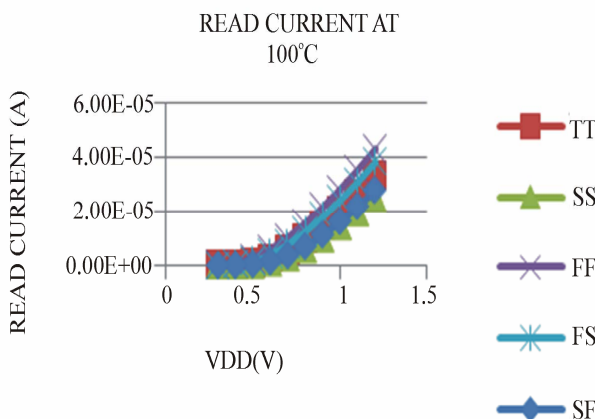nference*, Victoria, May 2008, pp. 1541-1544.