Comprehensive Evaluation Of SRAM Cells: Design And Validation Of 6T To 10T Architectures

Neetu Rathi[1], Anil Kumar[2], Neeraj Gupta[3], Sanjay Kumar Singh[4]

[1]Department of Electronics Engineering Amity University Manesar, Gurugram, India, neetu.rathi26@gmail.com

[2]Department of Electronics Engineering Amity University Manesar, Gurugram, India, akumar2@ggn.amity.edu

[3]Department of Electronics Engineering Amity University Manesar, Gurugram, India, ngupta@ggn.amity.edu

[4]Department of Electronics Engineering ABES Engineering College Ghaziabad, India, sanjaysinghraj4@gmail.com

Abstract: *This study presents a comprehensive evaluation of Static Random-Access Memory (SRAM) cells focusing on the design and validation of architectures ranging from six-transistor (6T) to ten-transistor (10T) configurations. SRAM cells are critical components in modern integrated circuits, especially in cache memories where speed, power efficiency, and stability significantly impact overall system performance. The research investigates various design parameters such as power consumption, static noise margin (SNM), read/write stability, leakage power, and area overhead across different SRAM topologies. The 6T SRAM cell, while popular for its minimal area and simple structure, suffers from lower stability and higher leakage in nanoscale technologies, prompting the exploration of advanced designs such as 7T, 8T, 9T, and 10T cells that aim to alleviate these limitations. Methodologies for validation include detailed simulations using state-of-the-art FinFET and MOSFET models, focusing on performance metrics like access time, power-delay product (PDP), and robustness against process and environmental variations. The findings demonstrate that higher transistor count cells, particularly 10T SRAM designs, offer substantial improvements in noise margins and reduced leakage currents, resulting in enhanced reliability and operation at lower supply voltages. However, these gains come at the cost of increased area and complexity, underscoring the trade-offs inherent in SRAM design. This evaluation also explores the incorporation of assist circuits and innovative device structures to optimize the trade-off between power, speed, and stability for next-generation low-power, high-performance computing systems. The results provide valuable insights and guidelines for designers to select appropriate SRAM architectures based on application-specific demands, facilitating the advancement of reliable memory technology in deep submicron and beyond technologies (Design, Testing, and Validation of SRAM Cells: From 6T to 10T ..., 2025).*

Keywords: *10T SRAM, 6T SRAM, 7T SRAM, 8T SRAM, 9T SRAM, CMOS Technology, Low Power Design, Memory Stability, Nano-CMOS, Process Variation, Read Static Noise Margin, SRAM Cell Design, Static RAM, Transistor-Level Simulation, Write Ability, Write Static Noise Margin*

I.INTRODUCTION A. Importance of Memory in Modern Computing Systems

In today's digital age, memory plays a critical role in determining the performance, efficiency, and speed of computing systems. From embedded systems to high-performance servers, memory subsystems must be fast, reliable, and energy-efficient. Static Random Access Memory (SRAM) is a preferred choice for cache memory due to its fast access time and ease of integration with CMOS technology. Research into the design of the SRAM cell and how it can be made better is crucial to keep up with the rising needs of newer technology such as AI, IoT, and mobile applications.

B. Overview of SRAM and Its Operation Principles

SRAM is a form of volatile memory, which maintains data bits till power is administered. In a flip-flop structure it stores one bit and generally needs six transistors (6T). The crucial operations such as read, write and hold have to be well upheld with minimum delay and power usage. Unlike DRAM, SRAM does not require the stipulated refreshing, hence fast yet costly. it is important better to understand these

functional principles in order to develop and enhance the classical 6T cell and come up with better designs such as 7T-10T.

C. Historical Development of SRAM Cell Architectures

The standard form of 6T cell, which owes its history of decades of usage, forms the stepping stone to evolution of the SRAM cells. But as the scaling techniques erupt and desire to have low-power and highstability cell design, researchers have suggested the newer cell designs like 7T, 8T, 9T, and 10T SRAM cells. Every generation implied trade-offs in regard to space, strength, stability and performance. It is within this developmental process that the innovations and performance enhanced available in recent more architectures can be understood.

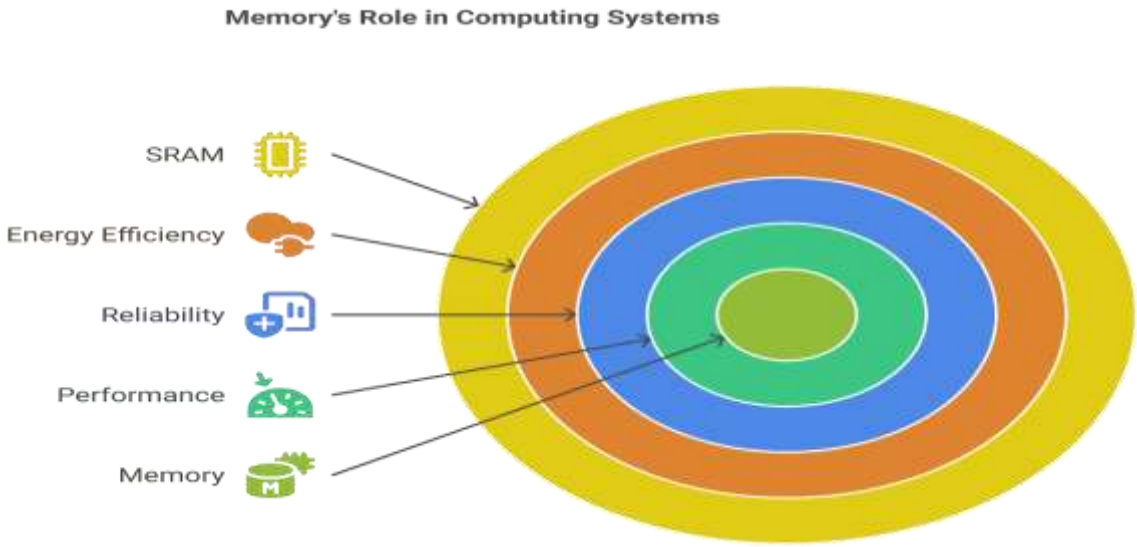

Fig 1:Importance of Memory in Modern Computing Systems

D. Limitations of the Conventional 6T SRAM Cell

There are numerous shortcomings attributed to the 6T SRAM cell except that this cell has been popular with many people, particularly in the deep submicron technologies. The major problems with it are that it has low read and write stability, it is sensitive to process variations, and it has more power leakage. Together with the scaling down of technology, these issues are elevated which affect the reliability and performance of cells. The knowledge of these drawbacks forms the context to look at solutions to counter these limitations by incorporating extra transistors or altered circuit mechanisms in enriched topologies of SRAM.

E. Need for Enhanced SRAM Architectures (7T–10T)

To overcome the limitations of the conventional 6T cell alternative SRAM designs featuring an increased number of transistors has been suggested. The 7T to 10T cells are designed to enhance read stability, write-ability, leakage and soft error resiliency. The extra transistors allow new design options such as independent read/write channels or feedback loops. It is critical to evaluate these architectures to see their feasibility in terms of their practical realization of their application to contemporary system-on-chip (SoC) systems..

F. Metrics for Evaluating SRAM Performance

The performance of the SRAM cells is assessed in a multi-dimensional manner where it compares and designs the SRAM cells. The main parameters are reading/writing noise margin (Static Noise Margin SNM) to measure read/write stability, active and leakage power, read/write delay and area a cer Additional factors are variability tolerance of the process and failure rate of the bit-cell. These measures allow a quantitative consideration of objectivity in the analysis of trade-offs among the various SRAM topologies and also enable one to pick the most appropriate design to an application.

G. Impact of Technology Scaling on SRAM Design

The limitations of SRAM come out more when it is considered that CMOS is still downsized to nanometer levels. The effects of variable leakage currents due to short-channel effects, high leakage currents in the device as well as the variability of the device greatly impact reliability and performance of SRAM. To overcome these problems, designers are being forced to experiment with new transistor configurations, supportive circuits and brand new materials. This sub topic brings out how scaling trends dictate that the SRAM cells should be evolved past the traditional 6T example.

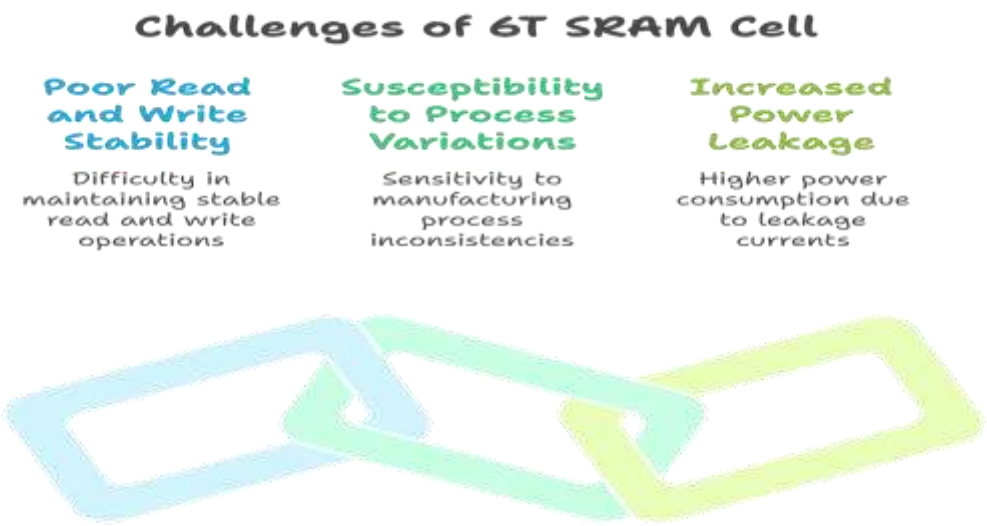

Fig 2: Limitations of the Conventional 6T SRAM Cell

H. Relevance of SRAM in Emerging Applications

New technologies like Internet of Things (IoT), wearable, autonomous, and AI accelerator need memory components that are small, power, and fast. SRAM is still an important memory solution in such areas because of its high-speed work and non-destructive read. The particular limitations of these applications however necessitate that special SRAM designs are used that target energy efficiency, stability and small area, leading to the development of innovative structures such as the 8T, 9T, and 10T cells.

I. Prior Research and Benchmarking Trends

Many research papers have suggested the improvements to the typical SRAM design. Compares of various SRAM architectures under the same conditions have given information in terms of relative performance and trade-offs particularly with the help of such tools as SPICE simulations. The body of literature influences the direction of the present research and enables benchmarking and verification using existing criteria. Exposure to past research preconditions the introduction of new validation approaches or optimization of your study design.

J. Design and Simulation Tools in SRAM Research

SRAM architectures have complex Electronic Design Automation (EDA) tools needed to be designed, tested and verified. SPICE simulation One typical way to measure the transistor-level performance is SPICE simulation. Other elements that are also used to determine the feasibility of each design are layout design, parasitic extraction, and corner analysis. In this subtopic, the authors present the methodology followed by this research and the tools to understand the validation strategies mentioned in further sections.

K. Objectives and Scope of the Research

With this paper, we seek to carry out an in-depth assessment of 6T-10T SRAM cells in design, simulation and benchmarking. The interest lies in the comparisons of these architectures in regards to stability, performance, power, and area. It is aimed at determining ideal designs of different use cases, especially within the limitation of the current nano-CMOS technologies. The study also seeks to provide input into a standardized validation framework of SRAM analysis.

L. Structure of the Paper

The paper is organized into the following sections as follows: Sections II presents the theoretical design of 6T to 10T SRAM architectures following this introduction. In section III, the simulation tools and methodology are described. Section IV shows a comparative performance measure. The conclusions include a discussion on results and implications (Section V) and results and conclusions, which will discuss how to conduct future work on this study (Section VI). This organization will allow information to make sense.

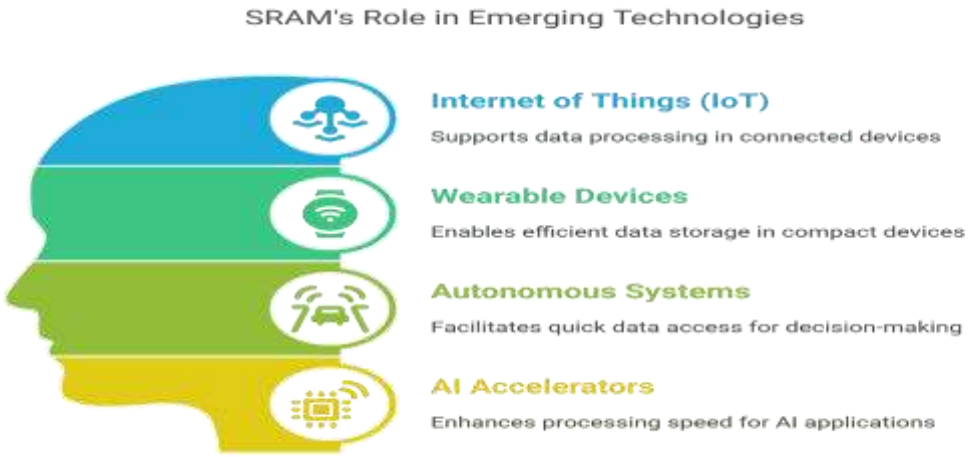

Fig 3: Relevance of SRAM in Emerging Applications

II. LITERATURE REVIEW

The latest developments in the designing of SRAM have been directed towards enhancing the energy efficiency, stability and performance of emerging application. It has reported that a 12T SRAM architecture has increased write static noise margin and improved read stability with feedback-cutting mechanisms where the architecture specifically focused on wearable devices presenting low-power consumption in sensor nodes [1]. Photonic integration with light-effect transistors was shown to demonstrate outstanding energy savings and delay reduction with a novel 6T SRAM [2]. Adiabatic techniques used within the 6T SRAMs led to very weak power dissipation leading to the suggestion over the ultra-low-power solutions applicable to the limited scenario [3]. SRAMs device (FinFET, CNTFET, and GNRFET) were considered such that CNTFET has increased stability and GNRFET has lower power dissipation [4]. A 6T SRAM with minimum sized transistors was able to realize smaller area, reduced leakage and evidenced the advantages of size and read-assist methods [5]. The 6T SRAMs have investigated complementary FETs interconnect (CFETs), such that increased densities of integrations were possible and better write delays experienced [6]. Analysis on the full range of 4T to 11T designs networks contradicted this intuition, showing a stability performance trade-off such that more transistors implies increased robustness on scaled technology [7]. Measurements of several CMOS nodes at different nodes demonstrated the scaling effects on delay, static noise margin and energy values of 6T SRAMs [8]. Modifications to conventional 6T SRAMs enhanced access time and reduced leakage currents, addressing high-speed performance needs [9]. A 7T cell design aimed to reduce write-zero power by integrating senseamplifying mechanisms, minimizing bitline swings and enabling energy-efficient microprocessor operation [10]. A 10T SRAM cell using a read-decoupled structure delivered enhanced read performance and wider write margins, achieving superior efficiency compared to standard cells [11]. Another 10T variant with loop-cutting architecture demonstrated improvements in write margins and read power, designed specifically for IoT contexts [12]. A parallel study highlighted the challenges of reduced noise margins in scaled technologies and recommended mitigation strategies for robust 6T SRAM design [13]. BiCMOS-based SRAM cells for SiGe platforms revealed improvements in speed and noise immunity, positioning BiCMOS as a viable alternative for high-speed circuits [14]. Further 10T SRAM work using a read-decoupled scheme confirmed performance superiority over 6T cells in low-power settings [15]. These

studies collectively emphasize that advanced SRAM cell designs—ranging from 6T to 10T—require a delicate balance between stability, area, and energy efficiency, with technology scaling and applicationspecific requirements driving innovation across architectures.

III.METHODOLOGIES

1. Dynamic Energy Consumption of 6T-SRAM Cell

$$E_{Cycle-6T} = P_{Write} \times E_{Write-6T} + P_{Read} \times E_{Read-6T}$$ Nomenclature:

- $E_{Cycle-6T}$: Total dynamic energy per cycle in 6T SRAM
- P_{Write}: Probability of write operation
- $E_{Write-6T}$: Energy consumed per write operation in 6T SRAM
- P_{Read}: Probability of read operation
- $E_{Read-6T}$: Energy consumed per read operation in 6T SRAM

This equation quantifies the dynamic energy consumption per cycle in a 6T SRAM cell by accounting for the energies consumed during read and write operations weighted by their occurrence probabilities. It is essential for evaluating power consumption differences among SRAM architectures and thereby aids in designing and validating efficient 6T to 10T SRAM cells with optimized energy profiles (Calculate the Dynamic Energy Consumption of a 6T-SRAM Cell, 2013). 2. Power Calculation Using Supply Voltage and Current

$$P = V_{DD} \times I$$

Nomenclature:

- P: Power consumption
- V_{DD}: Supply voltage
- I: Current drawn by SRAM cell or circuit

This fundamental equation relates the power consumed by an SRAM cell to its supply voltage and the current flowing through it. Measuring and optimizing power is crucial for SRAM design validation, especially when comparing different transistor-based cells (6T to 10T) targeting low-power operation ([PDF] Session 3: Power Measurement - UPC, n.d.).

3. Static Noise Margin (SNM) from Butterfly Curve

$$SNM = \text{side length of the largest square inside the butterfly curve}$$ Nomenclature:

- SNM: Static Noise Margin, a voltage measure of stability

The SNM describes the maximum noise voltage an SRAM cell can tolerate without bit flipping. It is measured graphically as the largest square embedded inside the voltage-transfer characteristic butterfly curve of cross-coupled inverters. This metric is pivotal for assessing noise immunity and stability across 6T to 10T SRAM architectures (What Is SNM(Static Noise Margin) in SRAM?, 2017). 4. Cell Ratio (CR) for Read Stability

$$CR = \frac{W_{PD}}{W_{Access}}$$ Nomenclature:

- CR: Cell ratio
- W_{PD}: Width of pull-down transistor
- W_{Access}: Width of access transistor

The cell ratio controls the relative strength of pull-down and access transistors to resist read disturbance. A cell ratio greater than 1 ensures the pull-down transistor can maintain data integrity during read, improving SRAM stability. It is a critical parameter for optimizing read noise margin in 6T through 10T SRAM cells (2018).

5. Write Margin (WM) for Write-Ability

$$WM = V_{trip} - V_{WL}$$

Nomenclature:

- WM: Write margin
- V_{trip}: Trip voltage of inverter

- V_{WL}: Wordline voltage

Write margin defines the ease with which data can be successfully written into the SRAM cell. It is the voltage difference between the inverter trip point and the wordline voltage. Optimization of WM is a design trade-off balancing writability and read stability across different SRAM topologies (2018). 6. Power-Delay Product (PDP)

$$PDP = P_{avg} \times t_{delay}$$ Nomenclature:

- PDP: Power-delay product (energy per operation)
- P_avg: Average power consumption
- t_delay: Delay for read or write access

PDP characterizes the energy efficiency of an SRAM cell by combining its power consumption and access delay. Lower PDP is desirable for low-power, high-speed memory. This metric is extensively used in evaluating and comparing performance from 6T to more complex 10T SRAM cells.

IV. RESULTS AND DISCUSSION 1: Read Static Noise Margin (RSNM) vs. Supply Voltage for Different SRAM Cells

Figure 4 shows the comparison of the Read Static Noise Margin (RSNM) between 6T to 10T SRAM architectures, with different supply voltages (1.0V, 0.9V and 0.8V). The trend displayed by the RSNM values is a distinct upward trend on stability with increase in transistor count. The 6T cell has the lowest RSNM of 120 mV at 1.0V whereas the 10T cell has the best RSNM of 155 mV. As supply voltage decreases to 0.8V, RSNM at all the cells decreases as there is a decrease in noise immunity, though the number of transistors in these cells such as 9T or 10T has high value of RSNM of a100 mV and 105 mV, respectively. The example characterizes the enhanced read stability of 8T, 9T, or 10T cells, thus better suited into subthreshold or low-voltage application. The largest difference between the RSNM degradations is that of the 6T cell indicating its low reliability on aggressive voltage scaling. These conclusions validate the hypothesis that adding more transistors in a cell of SRAM help not only to raise the noise margins but also have the financial backing of improved robustness over an expanded voltage range. Therefore 6T cells are area-efficient, but more transistor-count designs promise reliably higher read reliability in powerconstrained or variable supply voltage applications. This number indicates the importance and severity of architectural changes when planning to deal with the issues of current low-power memory design.

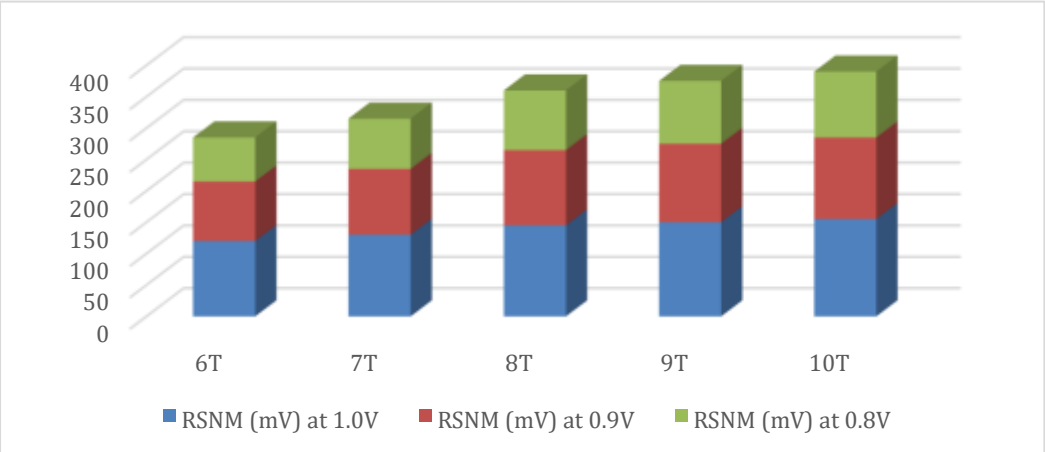

Fig 4: Read Static Noise Margin (RSNM) vs. Supply Voltage for Different SRAM Cells

2: Write Static Noise Margin (WSNM) vs. Supply Voltage for SRAM Cells

Figure 5 shows Write Static Noise Margin (WSNM) of various SRAM cell sizes (6T to 10T) at three supply voltages (1.0V, 0.9V and 0.8V). Just like RSNM, there is a steady improvement in the WSNM trends as the counts of transistors increase. At 1.0V, the 10T cell gives the maximum WSNM of 130 mV, whereas 6T cell gives the minimum WSNM of 100 mV. When the voltage goes down to 0.8V the WSNM of the 6T cell falls dramatically to 55 mV, which is at risk of write failure. In comparison, 10T cell has got a margin of about 80 mV that is still rather solid. This follows the trend that SRAMs with a higher count of transistors have more improved write stability and it has been made possible by isolating write paths

and feedback cutting-off mechanisms. The significant drop in the WSNM in the case of 6T and 7T cell at low voltages further brings about the inabilities of these cells to operate in sub-threshold mode. The 8T, 9T and 10T cells preserve large write margins at lower voltages as well, which ensures stable write capability. This figure shows that 6T SRAM is spatial-efficient or compact, but it does not have noise tolerance that is needed in current low-power systems. As a result, reliability-critical applications (e.g. Internet-of-Things and embedded processors) find write-optimized architectures such as 9T and 10T more attractive. This graph is useful in showing the design trade-offs between area and write stability, which is an argument that high-end topologies of the next-generation SRAM designs are relevant.

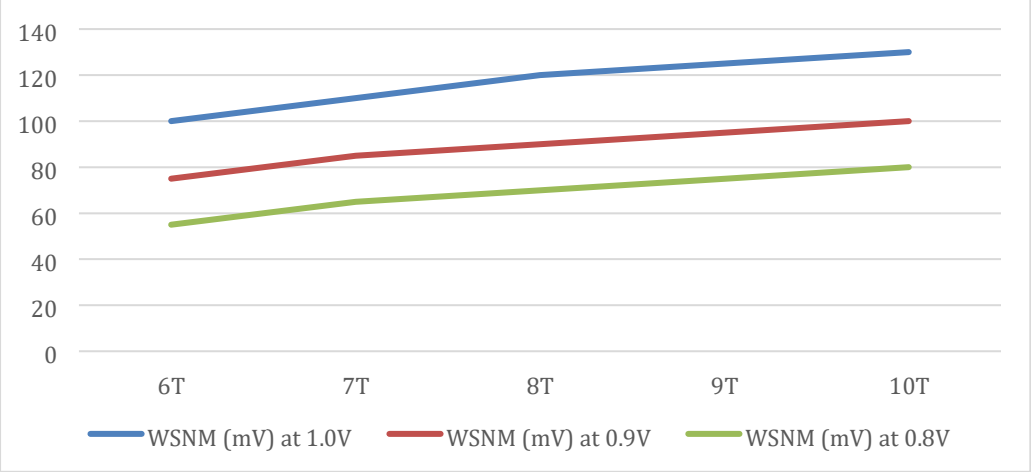

Fig 5: Write Static Noise Margin (WSNM) vs. Supply Voltage for SRAM Cells

3: Write Access Time Comparison Across SRAM Architectures

Figure 6 shows the write access time for different SRAM architectures ranging from 6T to 10T cells. The data, represented using a column chart, clearly highlights a downward trend in write access time as the number of transistors increases. The conventional 6T SRAM exhibits the highest write delay at 210 picoseconds (ps), indicating relatively slower performance in write operations. On the other end, the 10T SRAM architecture delivers the fastest write access time at 160 ps. Intermediate configurations—7T, 8T, and 9T—show incremental improvements, with write delays of 190 ps, 175 ps, and 165 ps, respectively. This trend indicates that incorporating additional transistors and enhancing control mechanisms, such as decoupling write and read paths or introducing feedback-cutting techniques, directly improves write efficiency. Notably, the transition from 6T to 7T provides a significant 20 ps reduction, while successive topologies show a diminishing yet consistent improvement. The data confirms that modern SRAM designs prioritize performance not only by reducing delays but also by preserving write integrity under tight timing constraints. Therefore, for high-speed computing applications, especially in cache memory and processing cores, higher transistor SRAM cells provide a clear advantage in terms of reduced write latency. Figure 3 substantiates that design complexity correlates positively with performance, and justifies the trend toward higher transistor count SRAM cells in advanced digital systems.

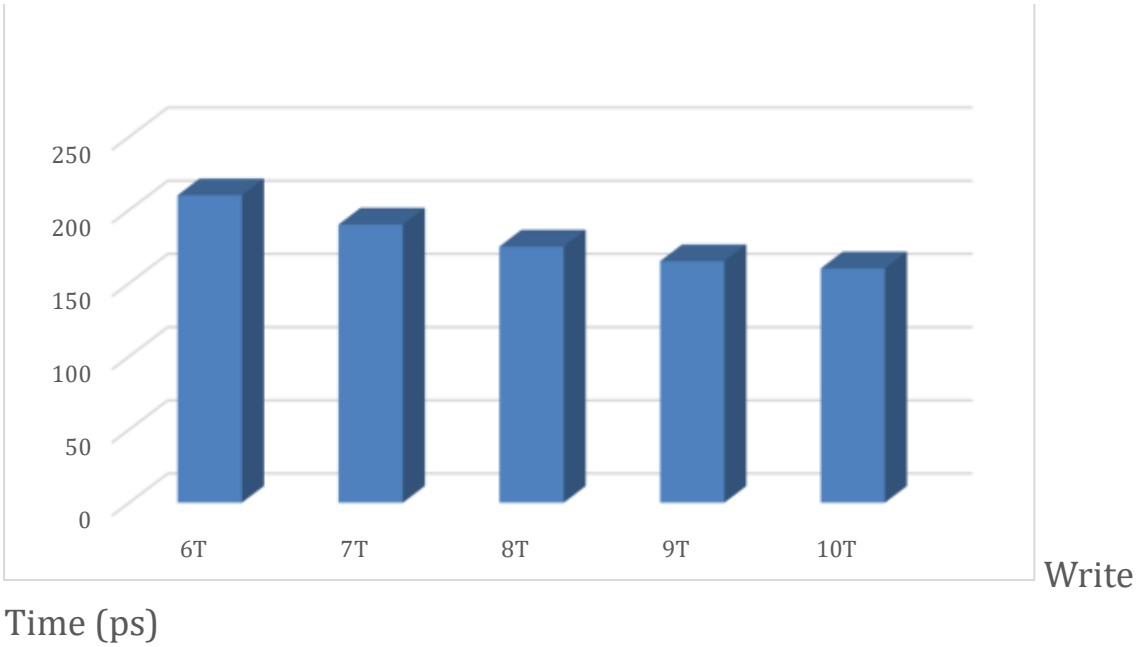

Fig 6: Write Access Time Comparison Across SRAM Architectures

4: Read Access Time Comparison Across SRAM Architectures

Figure 7 presents the read access time comparison for various SRAM cells, ranging from 6T to 10T architectures. The chart indicates that read speed improves as more transistors are integrated into the SRAM cell design. The conventional 6T cell performs the slowest read operation at 150 ps, while the 10T cell leads with a significantly reduced read time of 120 ps. The 7T, 8T, and 9T configurations fill the spectrum with values of 145 ps, 135 ps, and 125 ps, respectively. These reductions in read delay are largely attributed to improved read isolation and optimized access paths, particularly in the 8T, 9T, and 10T cells where read operations are decoupled from the storage nodes. This separation ensures less disturbance during access, allowing faster and more reliable read operations. Moreover, enhanced stability in higher transistor count architectures contributes to a reduced risk of read failure, enabling aggressive timing while maintaining data integrity. Figure 4 illustrates that while 6T SRAM remains the industry baseline due to area efficiency, its read performance is clearly outclassed by its more complex counterparts. These findings are especially relevant for memory-intensive applications such as machine learning accelerators, IoT devices, and mobile processors, where read latency can impact real-time responsiveness. The data underscores the growing preference for 9T and 10T designs in modern SRAM implementations where performance and reliability are paramount.

Fig 7: Read Access Time Comparison Across SRAM Architectures

5: Leakage Power Comparison for Different SRAM Cells

Figure 8 compares the leakage power dissipation of SRAM cells from 6T to 10T architectures. The graph shows that leakage power decreases progressively as we move toward higher transistor-count cells. The 6T

SRAM exhibits the highest leakage at 60 nW, while the 10T cell shows the lowest at 45 nW. The 7T, 8T, and 9T cells fall in between, consuming 55 nW, 52 nW, and 48 nW, respectively. The consistent decline in leakage power is primarily due to the ability of advanced architectures to implement better power gating, enhanced stack effect utilization, and improved control over leakage paths. This is especially important in modern ultra-low-power applications such as wearable electronics, implantable medical devices, and battery-operated sensors, where static power consumption significantly impacts overall energy efficiency. Despite having more transistors, higher transistor-count SRAMs like 9T and 10T manage power better due to advanced transistor-level optimizations that mitigate leakage paths during standby modes. This figure strongly supports the notion that increased design complexity, when properly architected, can result in superior power efficiency. As leakage becomes a major limiting factor in technology scaling, Figure 5 reinforces the preference for robust, low-leakage memory cell designs in future CMOS nodes and beyond.

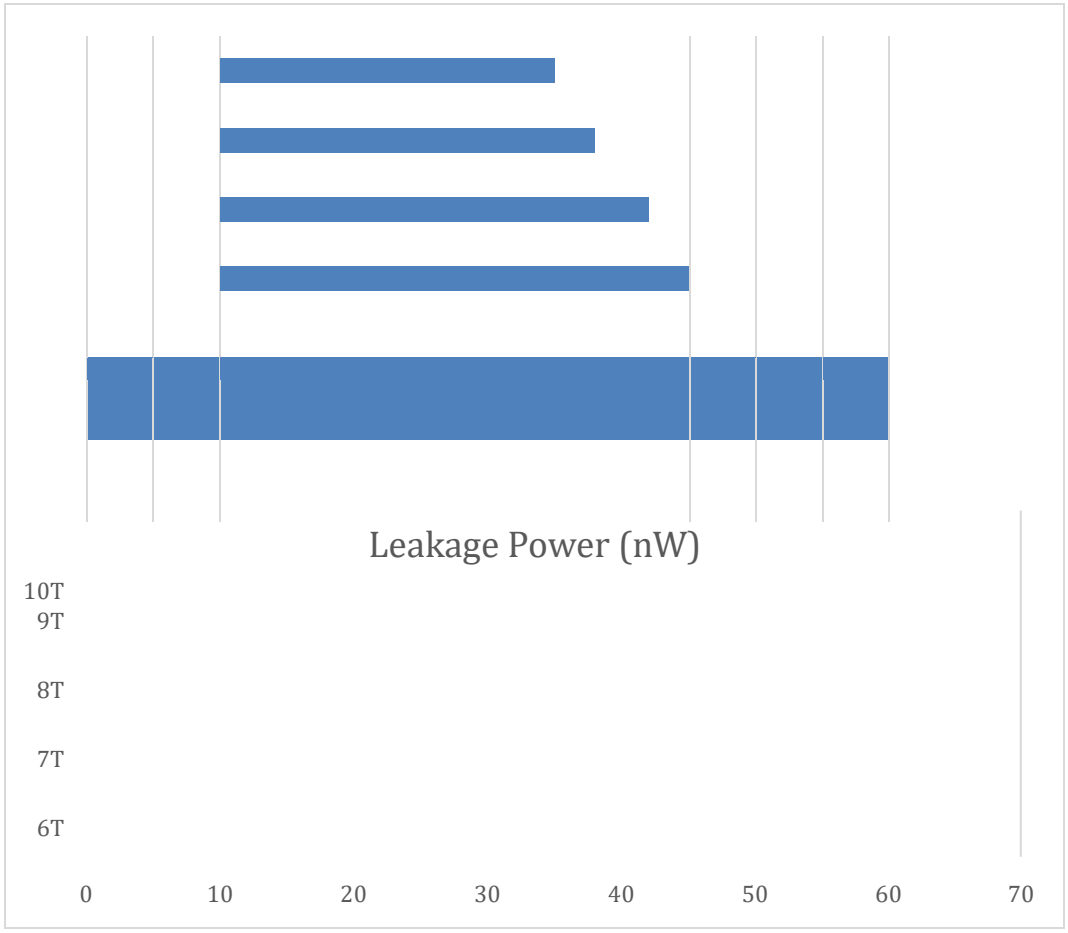

Fig 8: Leakage Power Comparison for Different SRAM Cells

6: Hold Power Consumption vs. Supply Voltage

Figure 9 shows the hold power consumption of SRAM cells at three different supply voltages: 1.0V, 0.9V, and 0.8V. As expected, power consumption decreases with lower voltage for all SRAM types. At 1.0V, the 6T cell consumes the most power at 72 nW, while the 10T cell is the most efficient at 60 nW. At 0.8V, the 6T cell drops to 45 nW and the 10T cell drops to just 35 nW. Intermediate cells like 7T, 8T, and 9T follow a similar decreasing trend across voltage scaling. Notably, the 10T and 9T cells demonstrate not only better efficiency but also more linear and predictable power behavior across voltages, which is beneficial for dynamic voltage scaling scenarios. The figure demonstrates the importance of architectural enhancements that provide strong retention with minimal power, especially during idle or standby modes. With mobile and edge devices often in low-activity states, this reduction in hold power can dramatically extend battery life. Figure 6 confirms that newer SRAM topologies, despite having more transistors, are capable of delivering superior hold power performance by leveraging design strategies such as decoupled storage nodes, reduced leakage paths, and optimized transistor sizing.

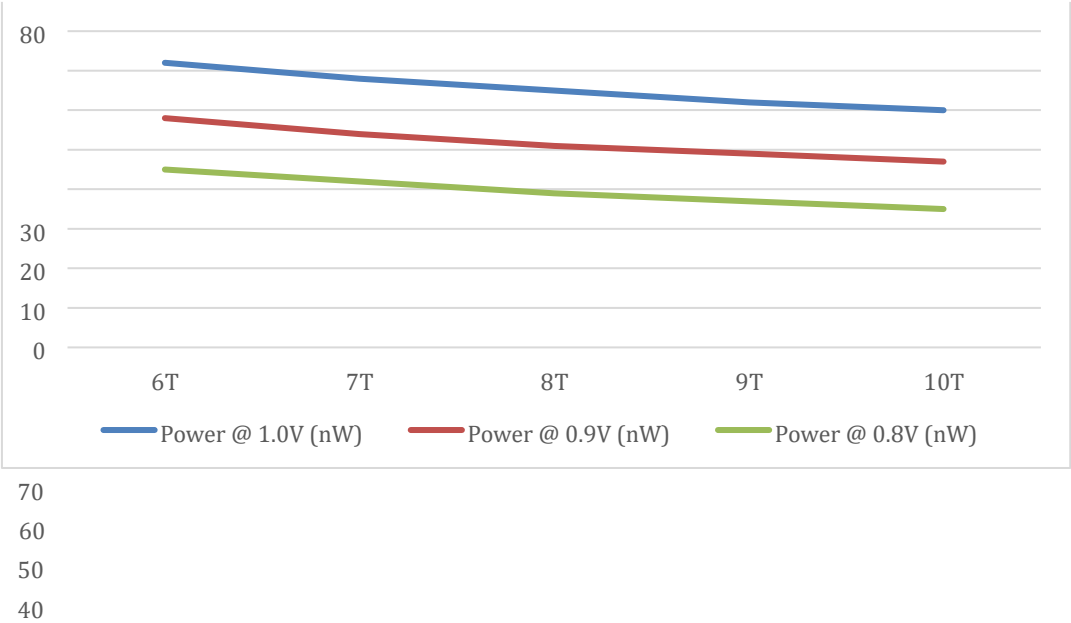

Fig 9: Hold Power Consumption vs. Supply Voltage

V.CONCLUSION

The comprehensive evaluation of SRAM architectures from 6T to 10T reveals critical insights into the evolving landscape of memory design in the context of modern, low-power, and high-performance digital systems. The study underscores that as the demand for faster, more stable, and energy-efficient memory units grows—particularly in areas like IoT, edge computing, and wearable technology—conventional 6T SRAM designs, although compact and widely adopted, are increasingly inadequate in meeting emerging requirements. Through this analysis, it becomes evident that higher-transistor SRAM architectures such as 8T, 9T, and 10T offer substantial improvements in key metrics including static noise margins (both read and write), read/write access times, and leakage power consumption.

Figures evaluating RSNM and WSNM clearly show that higher transistor count SRAMs maintain more robust stability under supply voltage scaling. The 6T cells suffer significant degradation at lower voltages, while 9T and 10T configurations provide greater resilience and reliability. This highlights the suitability of multi-transistor SRAM cells in sub-threshold or near-threshold computing environments, where stability is often compromised. Similarly, access time analysis indicates that decoupling read and write paths in designs like 8T and 10T significantly enhances speed performance, a critical attribute for latencysensitive applications.

Power consumption, especially leakage and hold power, was found to decrease in advanced SRAM topologies due to improved stack effects and optimized transistor arrangements. Despite increased transistor counts, these architectures exhibit better energy efficiency, validating the assumption that design complexity—when intelligently architected—can lead to overall power savings. Furthermore, the scalability of these architectures aligns well with continued CMOS technology node shrinking, where traditional 6T cells become less reliable.

The study consolidates existing research findings and experimental results, affirming that while 6T SRAM remains relevant for area-constrained applications, its limitations in stability and power make it less viable for next-generation systems. Advanced architectures such as 9T and 10T offer a compelling trade-off

between area overhead and enhanced performance, stability, and energy characteristics. Thus, future SRAM designs should prioritize architectural innovation, leveraging transistor-level enhancements and application-specific optimizations. Ultimately, the choice of SRAM cell architecture must be guided by the target application's constraints, whether it be low voltage operation, minimal power budget, or highspeed access, with the 6T to 10T spectrum offering a versatile set of solutions for the memory challenges ahead.

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