International Journal of Research in Engineering, Science and Management
Volume-2, Issue-10, October-2019
www.ijresm.com | ISSN (Online): 2581-5792

High Speed Low Power SRAM with Enhanced Data Dependent Leakage

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***Abstract*: The regular six-transistor static irregular access memory (SRAM) cell permits high thickness and quick differential detecting yet experiences half-select and read-bother issues. In spite of the fact that the ordinary eight-transistor SRAM cell unravels the peruse irritate issue, regardless it experiences low exhibit effectiveness due to crumbling of read bit-line (RBL) swing and I on/I off proportion with increment in the quantity of cells per section. Past methodologies to tackle these issues have been beset by low execution, data dependent spillage, enormous territory, and high vitality per get to. In this manner, in this paper, we present three cycles of SRAM bit cells with NMOS-just based read ports intended to incredibly lessen data dependent peruse port spillage to empower 1k cells/RBL, improve peruse execution, and lessen territory and control over traditional what's more, 10T cell-based works. We contrast the proposed work and different works by account measurements from the recreation of a 128-kb SRAM built with separated word line-deciphering design what's more, a 32-piece word size. Aside from huge enhancements watched over traditional cells, up to 100-mV improvement in read-get to execution, up to 19.8% sparing in vitality per get to, and up to 19.5% sparing in the territory are additionally seen over other 10T cells, along these lines extending the structure and application range of memory fashioners in low-control sensors and battery-empowered gadgets.**

***Keywords*: 10T SRAM, help methods, E min, low power**

1. Introduction

STATIC Random Access Memory (SRAM) possesses critical part of a framework on-a-chip (SoC) and has a prominent commitment to the absolute power utilization and territory of the SOC. Since territory is a significant factor when structuring circuits, memory configuration Specialists intend to put the same number of cells as conceivable per segment to permit sharing of fringe hardware. The ordinary 6T and 8T cells are incredible restricted by their powerlessness to work in longer segments on the grounds that they experience the ill effects of information subordinate spillage and corrupted ION/IOFF proportion and read bit-line swing as more cells are set on a solitary segment. In this manner, there is a need to plan new circuits to address this issue. Past methodologies [1]-[3] have attempted to explain this issue by improving the ION/IOFF proportion to empower up to 1k cells per section. In spite of the fact that these methodologies have been fruitful at this errand, these still experience the ill effects of enormous region or fluctuating information subordinate execution. Some likewise come up short to represent the base vitality point in SRAMs and thusly, expend a great deal of vitality per access at ultra-low voltages. This work portrays three cycles of SRAM bit cells with NMOS-just based read ports planned to significantly diminish information ward read port spillage to empower 1k cells per RBL, improve read execution, and diminish zone and control over regular 6T and 8T cells and other novel read-port based cells. With a novel topology in every one of the three cells' perused port, we get improved read get to execution, low vitality per access, and low territory individually, in this manner developing the structure and application range for memory creators in low control sensors and battery empowered gadgets. SRAM's effect has turned out to be particularly significant due to the development of battery controlled convenient gadgets and low control sensor applications. Most SRAM structure exertion has been prompted encourage voltage scaling and improving yield. The routinely executed six transistor (6T) cell in SRAMs permits high thickness, bit-interleaving and quick differential detecting be that as it may, experiences half-select strength, read-irritate solidness, what's more, clashing read and compose measuring. Past endeavors to fathom these issues have incorporated the usage of help strategies, novel cell structure, design enhancements, or on the other hand innovative advancements. Half-select and read-irritate issues in SRAMs can be alleviated by improvement of word-line voltage level. This incorporates word-line under-drive helps utilizing procedure corner following [4] or on the other hand utilizing reproduction get to transistors [5]. Postponed word-line help [6] to coordinate the inside voltage of half-chose cells to that of the bit-line during a read activity improves their security yet requires tweaking build up the touchy tradeoff between read security and compose capacity. Cell supply lift help can likewise be utilized to improve half-select steadiness by expanding the drive quality of draw down NMOS Negative cell ground [7] implementation to improve read stability is that the only assist however has high energy to use of multiple GND rails [8]. Disturb issues can also be mitigated by partial pre charge of bit-lines to decrease the strength of access transistors [9] make use of regulators to reduce the pre charge voltage level of the bit-lines to around 70% of supply voltage to improve the read stability. Alternatively, the bit-line scan be pre charged using an NMOS instead of a PMOS to obtain a single VTH drop on the bit-lines [10]. A process variation tolerant selective pre charge assist

[11] has also been used to decrease bit-line voltage level victimization charge sharing to improve half-select disturb issues. However, such partial bit-line pre charge techniques reduce read ability and become less effective at lower voltages due to reduced VDS of the access transistors. Multiple supply line assist can also be used to improve read and write half-select stability issues in SRAMs. In [12], a column-based dynamic supply technique was proposed. By implementing different supply voltages for read, write and standby modes, it relieved half-select stability issues and allowed bit-interleaving. However, this resulted in increase in dynamic power, design and routing effort and area due to generation of multiple supply voltages. Although assist techniques can be beneficial in improving the performance and yield of SRAMs, they can often have a deteriorating complementary effect on write and read operations. They can also incur large area overhead, increase the energy per access, and have a limited and saturating effect on yield. Furthermore, since read and write stability is greatly dependent on temperature variations, an SRAM can either be write-limited at lower temperatures or read-limited at higher temperatures. Therefore, assists often require process and temperature tracking for effective yield improvement. Apart from assist techniques, improvements on the architectural front have additionally been created to handle half-select and read disturb stability issues. These include cross-point selection of words using both row and column word-lines to improve half select stability. Shorter bit-lines can also be used to improve read stability. These work by reducing bit line capacitance, thereby improving dynamic read margin. However, this comes at the expense of large area overhead due to greater number of cell banks. In another work, an array architecture with an area overhead of 12% was implemented in order to address the half-select disturb issue by decoupling the large bit-line capacitance from half-selected cells. Read and-write-back scheme [3] has also been used to alleviate the write-disturb in half-select cells. It allows data retention by writing back the stored data after each read. However, such techniques increase the dynamic power consumption since every column is subjected to full voltage swings. To boot, the sense electronic equipment cannot be shared amongst many columns and has to be integrated in each column, thereby incurring a large area overhead. With the 6T SRAM cell being afflicted by various stability issues, the 8T SRAM cell has been planned (shown in Fig. 1). It has a decoupled read path comprising of two NMOS transistors. though it eliminates the read-disturb issue, it is still harassed by a pseudo-read during a compose activity in half-chose cells on a similar column. In that capacity, the issue of loss of bit-interleaving capacity emerges Bit-interleaving is basic to low voltage SRAM activity since it is consolidated with Error-Correction Code (ECC) to battle delicate mistakes and accomplish required yield targets. Delicate mistakes, including Single Bit Upsets (SBUs) and Multiple Cell Upsets (MCUs) are brought about by barrage of alpha-particles, warm neutrons or then again high vitality vast beams. The pace of delicate blunders increments by 18% for each 10% decline in inventory voltage. Also, bit-interleaving able cell structures such as the section decoupled 8T.

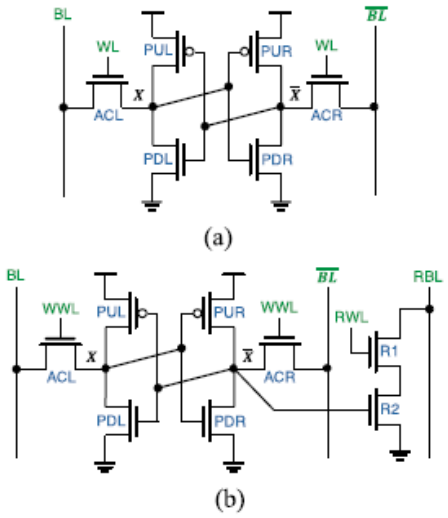

Fig. 1(a). Schematic of 6T and (b) schematic of 8T

Still harassed by a pseudo-read during a compose activity in half-chose cells on a similar column. In that capacity, the issue of loss of bit-interleaving capacity emerges. Bit-interleaving is basic to low voltage SRAM activity since it is consolidated with Error-Correction Code (ECC) to battle delicate mistakes and accomplish required yield targets. Delicate mistakes, including Single Bit Upsets (SBUs) and Multiple Cell Upsets (MCUs) are brought about by barrage of alpha-particles, warm neutrons or then again high vitality vast beams. The pace of delicate blunders increments by 18% for each 10% decline in inventory voltage. This is particularly tricky for low voltage SRAMs, since in sub-limit activity area, the basic charge in hubs is fundamentally decreased, prompting regular MCUs. MCUs have been moderated by actualizing and consolidating bit-interleaving structure with ECC. Also, bit-interleaving able cell structures such as the section decoupled 8T cell. Bother free 9T cell., two-port irritate free 9T cell, multi-port 9T cell, and the differential 10T cell have been proposed to empower bit-interleaving and expel half-select bother issues by utilizing both line and segment word-lines. For cell structures without interleaving capacity, for example, the single finished 8T cell, extra equality or ECC bits can be interleaved per word for delicate mistake rectification. Regardless of whether the read and compose irritate issues are lightened utilizing the strategies depicted over, an exhibit executed utilizing the 8T cells has low cluster productivity. This is since, its single finished instrument requires a progressive detecting design which actualizes as few as eight cells per neighborhood RBL and different nearby RBLs per worldwide RBL. Moreover, in contrast to the quick differential detecting in the 6T cell, the single finished detecting has a moderate full swing activity. As more prominent number of cells are put on a similar neighborhood RBL .so as to improve exhibit productivity, both postponement and the read bit-line voltage swing are significantly influenced. Thusly, this type of various leveled detecting doesn't come close to differential detecting as far as both execution and exhibit

productivity. Albeit numerous methods have been proposed to improve the single finished read detecting execution, the region overhead still stays huge. So as to improve the cluster proficiency what's more, read bit-line voltage swing of single-finished read cells, many changed read ports have been proposed [1]-[3].

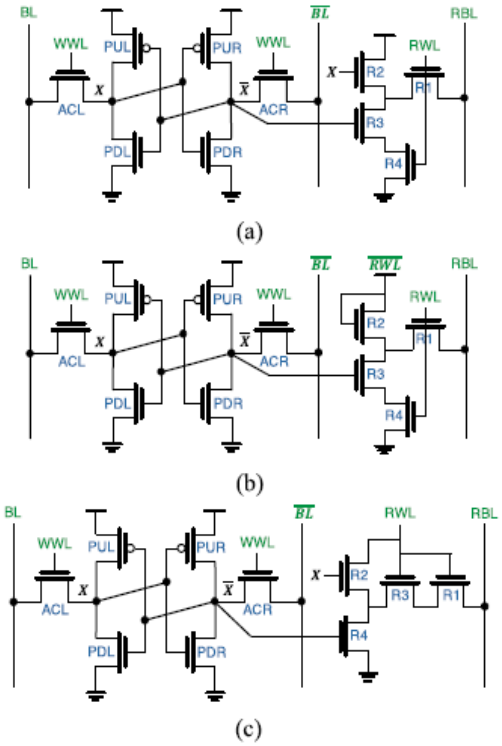

Fig. 2. Schematic of the proposed (a) 10T-P1, (b) 10T-P3, (c) 10T-P2 cells

These structures plan to set up to 1k cells per bit-line by improving the ION/IOFF proportion of SRAM read ports. This methodology serves to extraordinarily improve the cluster proficiency as fringe hardware can be shared among more noteworthy number of cells. Despite the fact that these methodologies have been fruitful at this errand, these still experience the ill effects of enormous zone, shifting information subordinate execution what's more, high vitality utilization. In this work, we propose three emphases of SRAM bit cells with NMOS-just based peruse ports and contrast them and traditional 6T and 8T cells and past 10T cell-based works by estimating measurements from reenactment of a 128kb cluster on the 32nm innovation hub. We process least vitality per access for all cells considering distinctive movement factors for different degrees of stores and ascertain dynamic disappointment rate dependent on working recurrence and procedure varieties. The paper has been built as pursues. Segment II portrays the proposed cells and their working standard and Segment III incorporates the presentation assessment of different piece cells based on read bit-line swing, vitality per get to, dynamic disappointment likelihood and zone. Segment IV abridges what's more, closes the paper.

2. Proposed SRAM bit cell

A. *Topology of proposed bit cells*

The schematic of the proposed 10T SRAM cells is appeared in Fig. 2. Every one of them involves cross coupled inverters (PUL-PDL and PUR-PDR) and two access transistors (ACL and ACR). The read port of every cell comprises of four NMOS (R1, R2, R3 and R4). The read port in Fig. 2(a) has improved information ward read bit-line spillage and is pointed at elite. The read ports in Fig. 2(b) and (c) have total information autonomous perused bit-line spillage and are gone for low power and high thickness individually. The working of each port has been clarified in the following segment

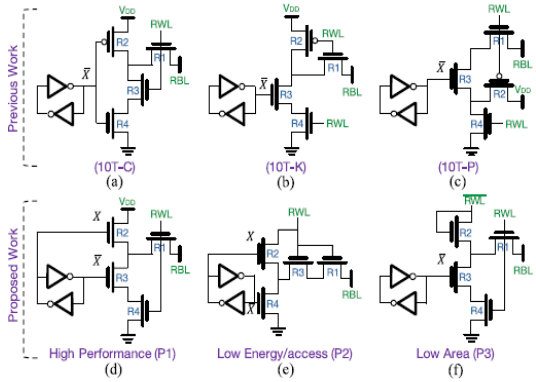

Fig. 3 Schematic of read port of (a) Calhoun and Chandrakasan [1], (b) Kim *et al*. [3], (c) Pasandi and Fakhraie [2], (d) Proposed 10T-P1, (e) 10T-P2, (f) 10T-P3 cell.

B. *Bit Cell Working Mechanism*

When working in close and sub-edge area, the Particle/IOFF is seriously debased and it turns out to be progressively hard to actualize more noteworthy number of cells on a solitary section. As the quantity of cells increment, the joined pass gate spillage ends up equivalent to the read current, in this way appearing well and good speaker to accurately assess the read bit-line voltage level. Moreover, the information put away in the cell additionally influences the read bit-line spillage subsequently making the off-state read bit-line spillage current to vary exceptionally. This is exacerbated at ultra-low voltages, where the most pessimistic scenario information example can prompt the RBL voltage level of 'zero' getting to be more prominent than the RBL voltage level of 'one'. So as to improve the ION/IOFF proportion, the read port appeared in Fig. 3(a) was proposed in [1]. At the point when the cell stores 'one,' the R2 PMOS charges the halfway hub, in this manner significantly decreasing the read bit-line spillage through R1 NMOS. Be that as it may, this additionally prompts stream of spillage current from middle hub into the RBL. The joined spillage of all cells on a similar segment can raise the low rationale level of RBL to a few hundred mV, along these lines prompting decreased voltage swing and detecting edge. The reasonable situation of the powerful perused bit-line voltage swing. Then again, when the cell stores 'zero,' the RBL spillage is diminished through the

stacking impact of NMOS. Subsequently, such a topology makes the viable RBL swing to a great extent subject to the information design in the section. In another work [3], the information reliance was evacuated by making an information free spillage way between the cell peruse port and the RBL. This prompted a huge voltage swing on the RBL even at lower voltages. The read port what's more, the comparing successful RBL swing for the equivalent has been appeared in Fig. 3(b). An ongoing work [2], likewise proposed a changed read port [shown in Fig. 3 (c)], to improve the ION/IOFF proportion. In any case, it is too burdened by the information subordinate spillage way issue. Depending upon the information put away in the cell, the spillage from middle of the road hub to RBL can change radically, along these lines prompting fluctuating low rationale voltage levels of RBL. In spite of this issue, it is capable to keep up a RBL swing. From here on, the cells in Fig. 3(a), (b) and (c) will be alluded to as the 10T-C, 10T-K and 10T-P cells individually. Like the proposed cells, these cells additionally have a similar topology for the compose port and vary as far as the read port as it were. The schematic of the proposed read ports is appeared in Fig. 3(d)– (f). The proposed 10T-P2 and 10T-P3 cells are pointed at low power and low region separately while all the while keeping up an information free ION/IOFF proportion. The standard behind their working is delineated. The greatness of I leak winds up equivalent in both read 'zero' and read 'one' case. This keeps up the required distinction in greatness between got to cell current in both cases. All things considered, a critical successful RBL swing can be watched. This is beyond the realm of imagination in the instance of regular 8T cell detecting, on account of the huge reliance of spillage current on the information design. Despite the fact that the proposed 10T-P1 cell diminishes its information reliance in contrast with the 10T-C cell. It to a great extent stays unequipped for playing out a read activity at ultra-low voltages. In any case, in the accompanying subsection, we demonstrate that working at ultra-low voltages builds the vitality per access and working close to the edge point is ideal for most minimal vitality utilization. All things considered, the 10T-P1 cell is worked close to the sub-limit locale for most reduced vitality utilization and best. At close limit and super-edge voltages, the read bit-line swing isn't an issue for the 10T-P1 cell. A progressively far reaching examination of RBL.

3. Evaluation of SRAM cells

A. Cluster Design

To gauge the exhibition of proposed cells and analyze them with past works, we executed a 128kb cluster utilizing every cell. Since every one of the cells which have been thought about are inclined to compose exasperate issue, the cluster was built in a non-interleaved engineering without section select hardware. The exhibit contains four 32kb sub-obstructs each with 1024 cells for every section and a 32-piece word size. High speed Limited Switch Dynamic Logic (LSDL) was used to build the pre decoders and decoders. Ten location bits were utilized as contributions to make sixty-four NOR based pre decoders, whose yields were then utilized as self-planned heartbeats to drive the decoder-driver for each line. Various leveled- Word-Decoding (HWD) brings about lower control utilization also, quicker access time in contrast with Divided-Word line- Deciphering (DWD). This is on the grounds that the HWD design actualizes extra degrees of word-lines to diminish the general capacitance per line select way. Be that as it may, the favorable circumstances are insignificant for littler clusters (< 256kb). Since the cluster limit is just 128kb, the DWD plan was utilized. Particular pre charge utilizing BS (Block-Select) was utilized to empower the pre charge of bit-lines of just the got to square to diminish dynamic power utilization. Four metal layers were utilized to course VDD, GND, bit-lines furthermore, the nearby and worldwide word-lines. The transistor estimating for all cells thought about in this work is appeared in Table 1. The proposed 10T-P1 cell, with its extraordinary topology and format, had the option to build the estimating of R3 NMOS, along these lines prompting enormous upgrades in read performance. While this change didn't prompt an expansion in the region of cell, it did bring about somewhat expanded reserve control

Table 1
Transistor width sizing (nm)

S. No.	Bit Cell Topology	PUL/PUR	PDL/PDR	ACL/ACR	R1/R4	R3	R2
1	6T Cell	72	144	72	-	-	-
2	8T Cell	72	72	72	108	-	-
3	10T-C Cell	72	72	72	108	108	72
4	10T-K Cell	72	72	72	108	108	72
5	10T-P Cell	72	72	72	108	108	72
6	10T-P1 Cell	72	72	72	108	180	72
7	10T-P2 Cell	72	72	72	108	108	72
8	10T-P3 Cell	72	72	72	108	108	72

Length of all transistors: 36nm

While nearby RWLs and WWLs were actualized in each push for all cells, the RWL for the 10T-P3 cell was shared among two contiguous lines. Such a usage was made because of the restricted vertical pitch of each column and the wiring necessity of a few flat neighborhood and worldwide lines in each push. At whatever point a read activity is played out, the RWL goes to low level for two columns. Despite the fact that the spillage current from the half-chose column expands, the general increment in IOFF for each RBL is very little and doesn't affect read execution. The planning chart for the memory activity. The WL (word-line), RD (read) and WR (compose) are certain edge synchronized with the clock signal. Both the nearby RWL and WWL are empowered with the negative edge of clock signal. The WL is joined with the yield of each pre decoder to empower new address unraveling, just at the start of every activity. The bit-lines are pre charged at the start of each compose activity, after which the information is stacked onto them before the empowering of WWL. Also, all the neighborhood bit-lines of the got to square and worldwide RBLs are pre charged during the main portion of the read clock cycle. The RWL is empowered during the second 50% of the clock to permit the RBL to grow restrictively. The voltage level on the RBL is recognized by the sense speaker, which is then

utilized to assess the worldwide RBL. The DIDO (Data-In-Data-Out) produces coherent yield as indicated by worldwide RBL level

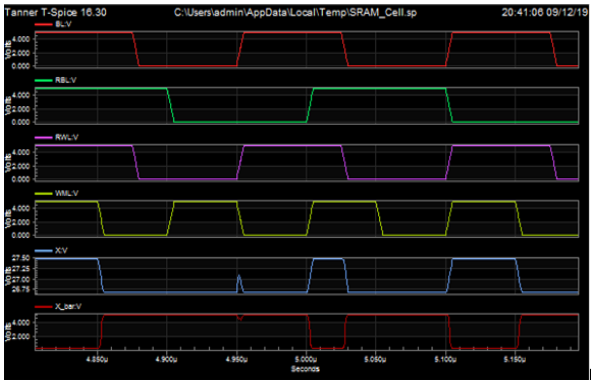

Fig. 4. Results

B. Peruse Bit-Line Swing

When playing out a read activity, an adequate read edge is required for right assessment by the sense enhancer. This edge is guaranteed by an enormous RBL swing, which is in a perfect world the distinction among VDD and GND. In any case, the joined spillage from all cells into the RBL or from RBL into the cells, can seriously corrupt the low and high rationale levels individually, in this way prompting decreased edge for right detecting at lower voltages. The crumbling in RBL swing is additionally exacerbated at higher temperatures because of increment in spillage current. At times, the RBL swing is additionally influenced by the information subordinate spillage way in the read ports of SRAM cells. The successful RBL swing, as a level of VDD, and regarding differing voltage, temperature and information design is appeared for all cells. The following three cases have been viewed as when estimating the RBL swing –

1) All cells in the section store 'zero.'
2) All cells in the section store 'one.'
3) 'One' and 'zero' are conveyed similarly in the segment.

As found in Fig. 8, the 10T-C cell's successful RBL swing is most minimal among all cells thought about and shifts incredibly agreeing to the information design. The 10T-K cell has an information autonomous spillage way in its read port, which prompts an information autonomous RBL swing. The 10T-P cell likewise has an information subordinate RBL swing, but with a lower level of variety. The viable RBL swing in the proposed 10T-P1 cell has a much lower reliance on the information design in contrast with the 10T-C cell. In spite of the fact that it is information subordinate, it is gone for elite what's more, close/super-limit activity, where RBL swing isn't an issue. Both the 10T-P2 and 10T-P3 cells have a data independent RBL swing, with the 10T-P2 displaying the most elevated RBL swing.

C. Reserve Leakage Power

At some random voltage and temperature, the total intensity of the cell ought to be as low as would be prudent. Accordingly, a total correlation of normal reserve spillage control per cell with regard to voltage, temperature and information design varieties. The accompanying three cases have been thought about when estimating backup control

1) All cells in the exhibit store 'zero.'
2) All cells in the exhibit store 'one.'
3) 'One' and 'zero' are conveyed similarly.

The proposed cells expend least spillage control in contrast with past work at most voltages and temperatures. It can likewise be watched that an equivalent conveyance of 'zero' and 'one' information prompts the most pessimistic scenario spillage control if there should be an occurrence of 10T-C, 10T-P, 10T-P1 furthermore, 10T-P2 cells. The 10T-K and 10T-P3 for the most part have the most noteworthy spillage control when they store 'zero.' However, this pattern doesn't keep up over all inventory voltages and temperatures. The 10T-P2 cell, which devours most minimal power in close and sub-edge area, has an unexpected increment in power utilization at higher voltages because of increment in stream of entryway burrowing spillage current. At 27°C, the 10T-P3 cell goes from devouring lower control than the 10T-C cell in super-edge locale to higher power utilization in sub-limit area. Despite the fact that this pattern remains constant at lower temperatures (−10°C) too, at high temperatures (80°C), the 10T-P3 cell consistently The absolute power is additionally influenced by the recurrence of activity, exchanging action, format ward interconnect supply voltage. Since all cells thought about in this work have critical contrasts in interconnect wiring due to changing perspective proportions, the complete dynamic power will likewise fluctuate enormously. Thusly, in the following subsection we assess the aggregate vitality per access for all cells.

4. Simulation results

To gauge the exhibition of proposed cells and think them with past works, we actualized a 128kb cluster utilizing every cell. Since every one of the cells which have been analyzed are inclined to compose bother issue, the cluster was developed in a non-interleaved design without section select hardware. The cluster contains four 32kb sub-hinders each with 1024 cells for each section and a 32-piece word size. High speed Limited Switch Dynamic Logic (LSDL) was used to build the pre decoders and decoders. Ten location bits were utilized as contributions to make sixty-four NOR based pre-decoders, whose yields were then utilized as self-planned heartbeats to drive the decoder-driver for each column. Various leveled-Word-Decoding (HWD) brings about lower control utilization also, quicker access time in contrast with Divided-Word line-Deciphering (DWD). This is on the grounds that the HWD engineering executes extra degrees of word-lines to diminish The general capacitance per column select way.

5. Conclusion

In this work, we exhibited three specialties explicit read ports

with improved information free read port spillage for SRAM cells went for superior, low power and low region individually. Each of the three proposed read ports didn't execute any PMOS, along these lines prompting littler n-well size, which thus prompted littler vertical measuring and shorter piece lines in the dainty structure formats. This diminished the territory per cell and vitality per get to. Every one of the SRAM cells with the proposed peruse ports improved the successful read bit-line voltage swing what's more, empowered 1k cells per read bit-line, permitting extraordinary potential for zone sparing as far as sharing fringe hardware. With a one of a kind topology in every one of the three cells' perused port, we get a best-case get to Vmin of 483mV for the 10T-P1 cell, an E min of 7.19pJ/acc for the 10T-P2 cell, and a low territory of 0.55728μm^2 for the 10T-P3 cell. In examination to regular cells, this makes an interpretation of to up to 180mV improvement in read get to execution and up to multiple times decrease in vitality per access at their individual V min. At the point when contrasted with past 10T cell-based works, about 100mV improvement in read get to execution, up to 19.8% sparing in vitality per get to, and up to 19.5% sparing in region can be watched, in this manner growing the structure and application range for memory originators in low power sensors and battery empowered gadgets.

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