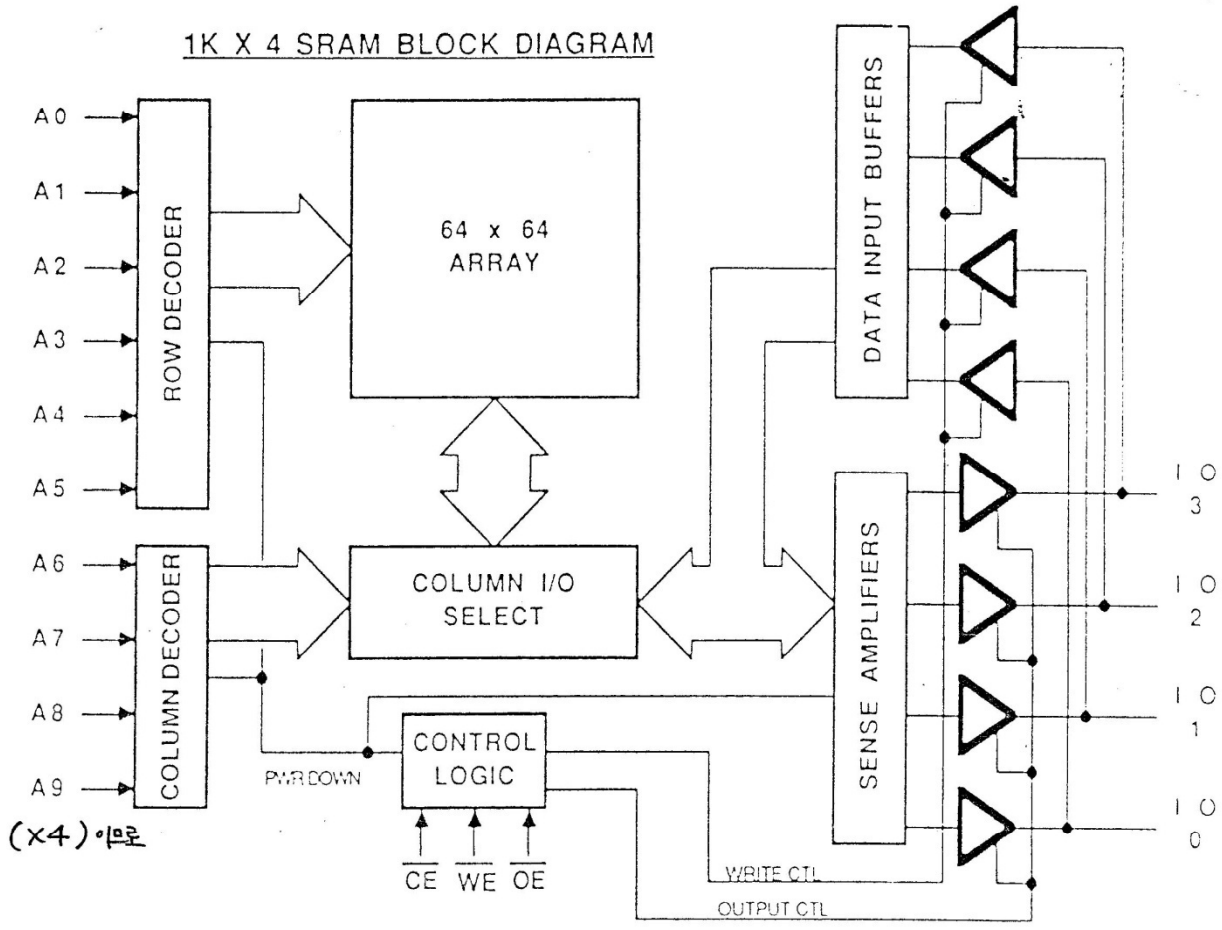
Static Random Access Memories (sRAM)

Instructor - Bruce Bateman, Cypress Semiconductor

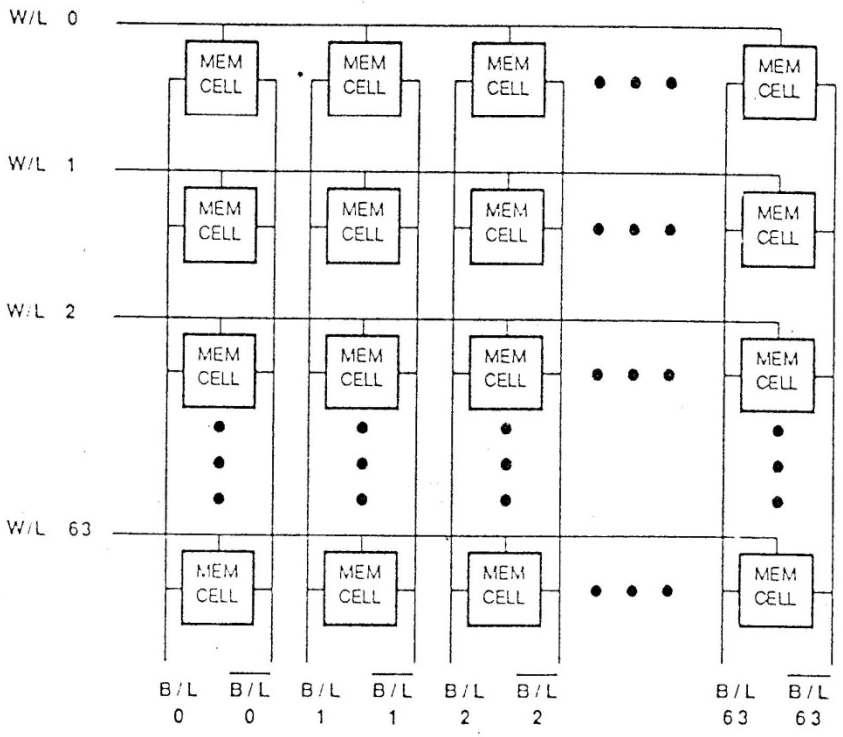
- Basic Architecture
- Storage Cell
- Address Decoding
- Data Sensing
- READ/WRITE Control

1K X 4 SRAM BLOCK DIAGRAM

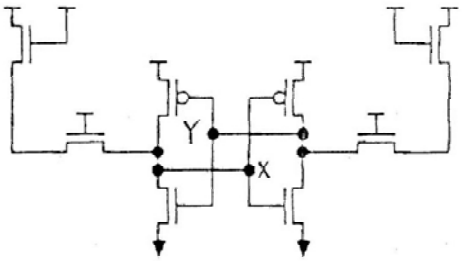


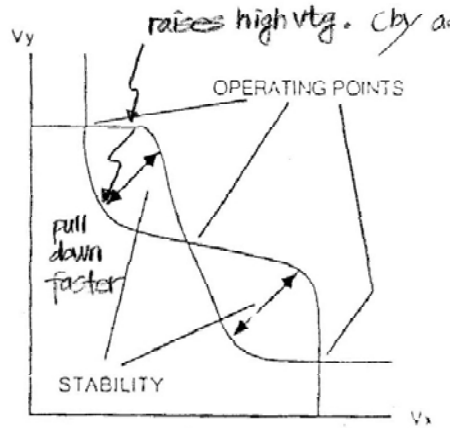
(x4)에로

4K SRAM MEMORY ARRAY



6T MEMORY CELL "READ" STABILITY



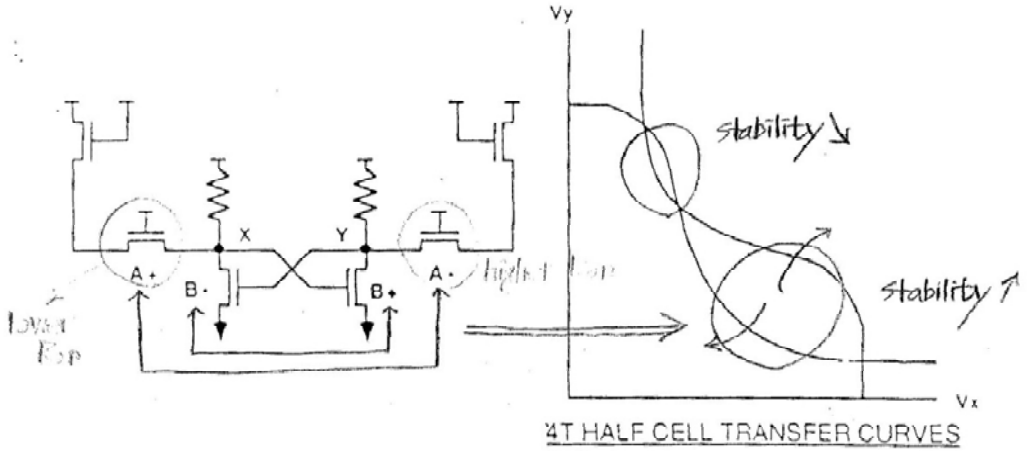


6T HALF CELL TRANSFER CURVES

compared to 4T cell

(Better stability, physical size ↗ due to well separation)

MEMORY CELL ASYMETRY



4T HALF CELL TRANSFER CURVES

CAUSES:

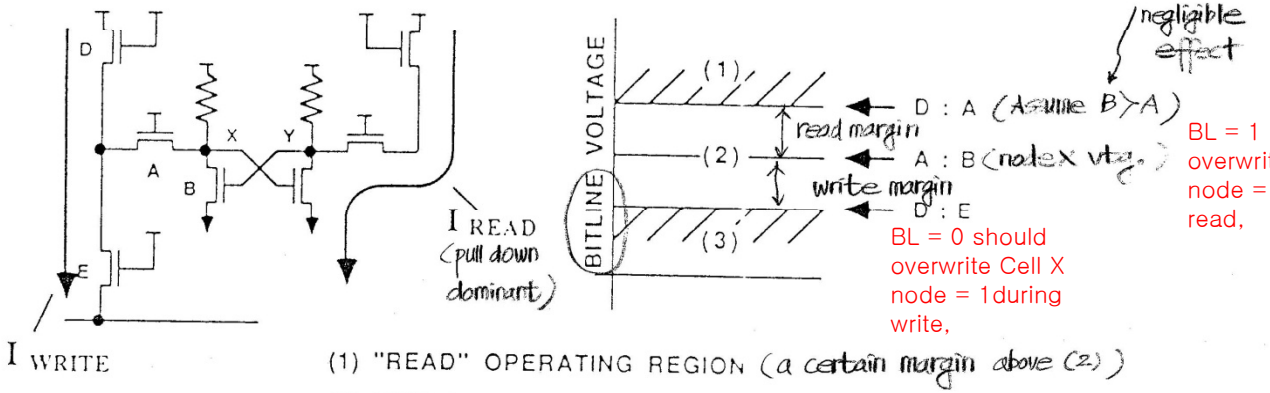
- DESIGN MISMATCH - DIFFERENT LAYOUT/SIZE
- PROCESS MISMATCH - Vt, CDs, ETC
- ALIGNMENT SENSITIVITY - WIDTH, LENGTH

critical dimension

SKIP

4T MEMORY CELL READ/WRITE OPERATION

Imagine voltage divider



BL = 1 should not overwrite Cell X node = 0 during read,

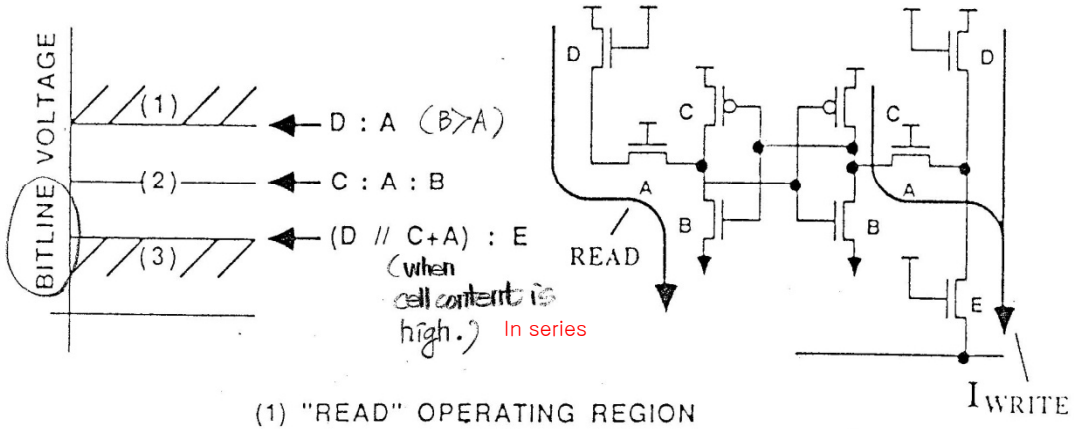
BL = 0 should overwrite Cell X node = 1during write,

(1) "READ" OPERATING REGION (a certain margin above (2))

(2) MEM CELL "TRIP" VOLTAGE

(3) "WRITE" OPERATING REGION (a certain margin below (2))

6T MEMORY CELL READ/WRITE OPERATION

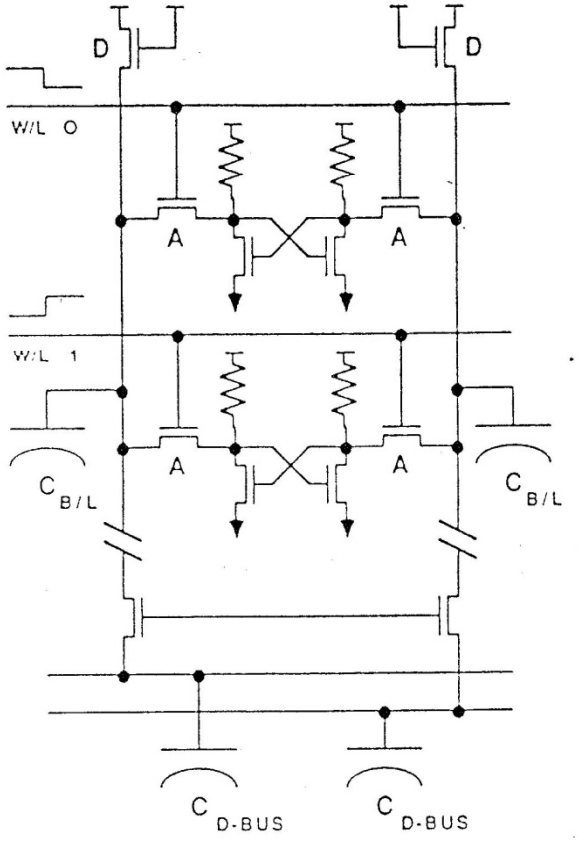


(1) "READ" OPERATING REGION

(2) MEM CELL "TRIP" VOLTAGE

(3) "WRITE" OPERATING REGION

MEMORY CELL SPEED VR. POWER



$Q = CV \longrightarrow I_{read} \cdot dt = C_{tot} \cdot dV$

$dt = [\ C_{tot} / I_{read}\ ]\ dV$

"SPEED"

CAP LOAD FIXED BY RAM DENSITY

POWER FIXED BY PASS GATE SIZE - A

VOLTAGE SWING FIXED BY RATIO D : A

During read,
B effect is negligible
since it is large

DRAM - Dynamic Random-Access Memory

1988 IEDM Short Course on Microprocessor and Memories

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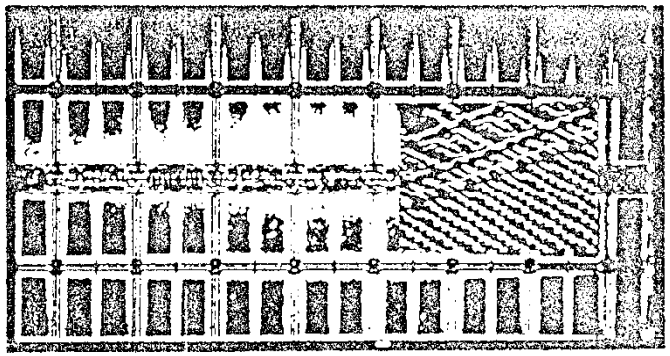
Thomas J. Watson Research Center, Yorktown Heights, NY 10598

1. DRAM And Its Development

1.1 Background And Definition
1.2 DRAMs in Systems: Examples
1.3 Product Environments And Trends

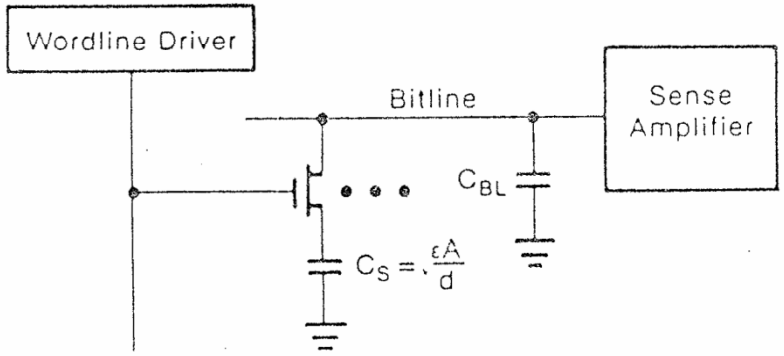
DRAM Chip

- Cell Arrays And Peripheral Circuits
- Array Utilization = (Cell Area × Total Bits)/(Chip Area)
- Key: Small Cell Area



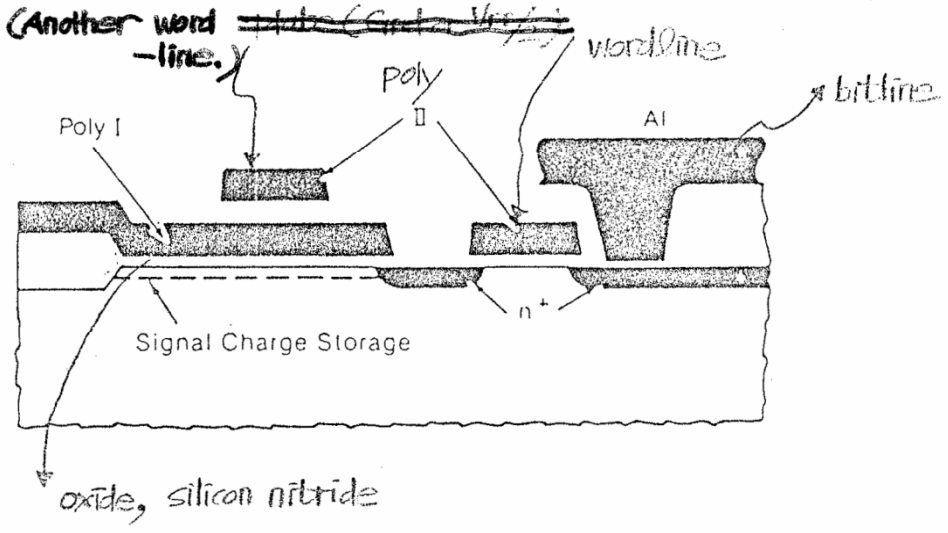
One-Transistor Cell

- An Access Transistor Plus A Storage Capacitor
  - — Selected By Wordline
  - — Signal Developed on Bitline



Planar Cell Structure

- Planar Transistor Plus Planar Capacitor in Silicon
- Uses Two Polysilicon Layers
- Storage-Node Leakage Requires Refreshing Data Periodically

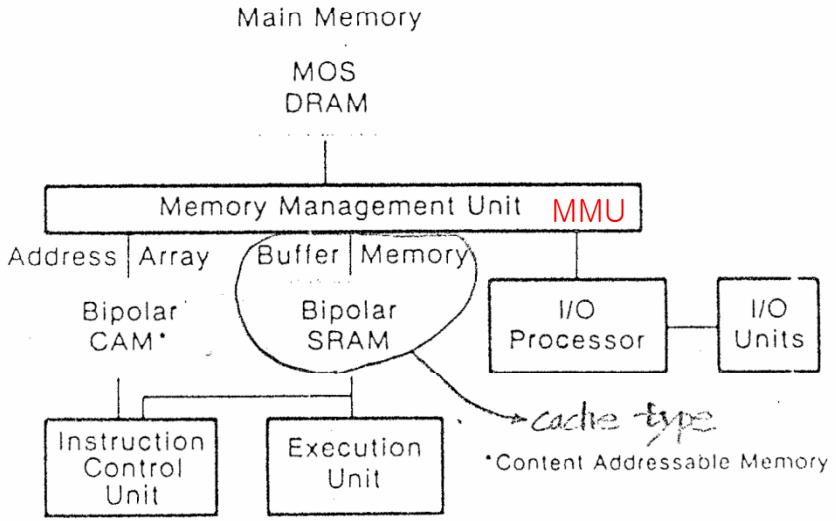


DRAM Definition

- Randomly Addressable Memory (Versus Serial Memory)
- Electrically Read and Write Data at Will in Any Sequence
- Needs Refresh Periodically
- Volatile (Unless By Battery Backup)

DRAM in Mainframe

- Today: ≃1GB (8,000 1Mb DRAM Chips)
- By 1995: ⩾64GB (Needs 8,000 64Mb DRAM Chips)



(Figure from Ref. B-6)

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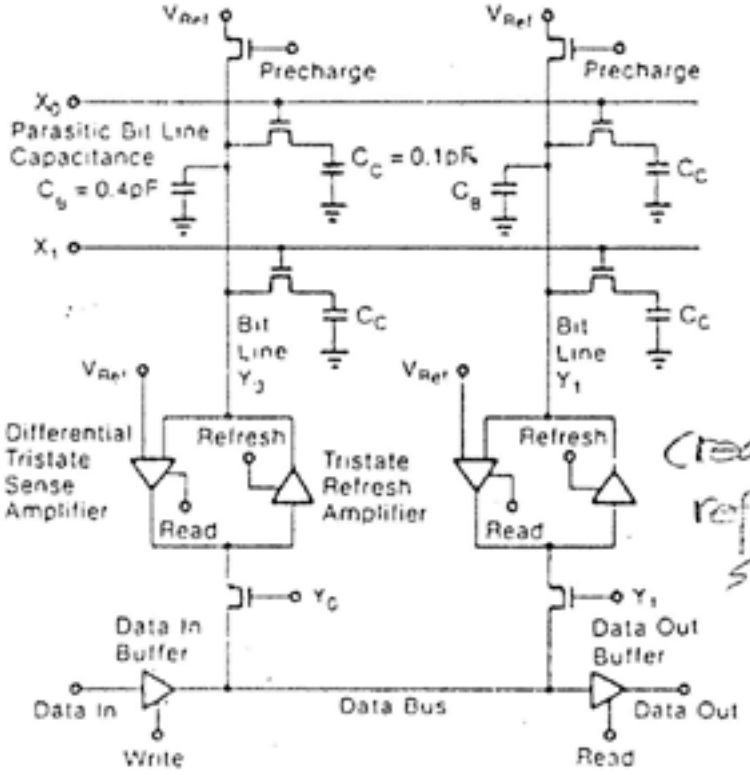
2. Chip/Circuit Design

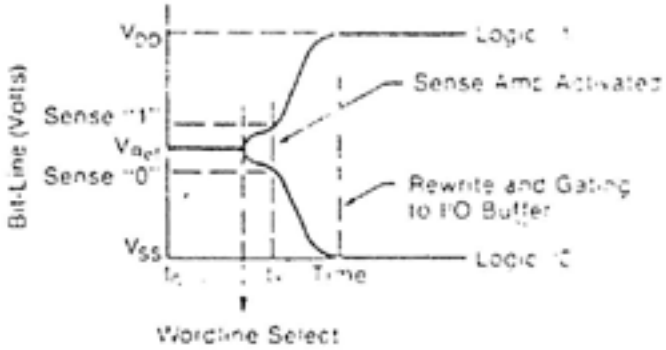
2.1 Basic DRAM Operations

2.2 Design Example: A 512Kb CMOS High Speed DRAM

2.3 Notes on NMOS and BiCMOS DRAMs

Basic Array Design

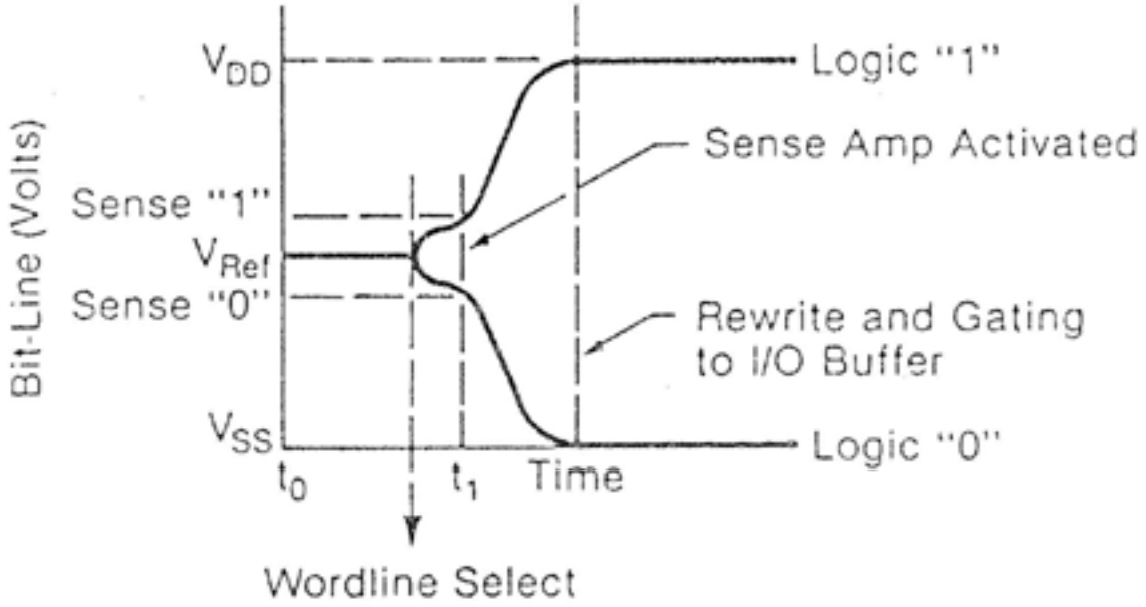




read & refresh simultaneously.)

(After Ref.)

Signal Development



Charge Transfer Ratio Concept (During Read)

- $V_R(1) = \dfrac{C_s V(1) + C_B V_{ref}}{C_s + C_B}$ (charge sharing)

  C_s ; cell cap.
  C_B ; bit-line cap.

- $\Delta V_{sen}(1) = V_R(1) - V_{ref} = \dfrac{C_s}{C_s + C_B}\,[V(1) - V_{ref}]$

  $\Delta V_{sen}(0) = V_{ref} - V_R(0) = \dfrac{C_s}{C_s + C_B}\,[V_{ref} - V(0)]$

- $V_{sen} = \dfrac{1}{2}\,[\Delta V_{sen}(1) + \Delta V_{sen}(0)] = \dfrac{1}{2}\,\dfrac{C_s}{C_s + C_B}\,\underbrace{[V(1) - V(0)]}_{V_s}$

  (average value)

- Transfer Ratio $T = \dfrac{C_s}{C_s + C_B}$ $\approx C_B$ (1 : 10)

- Storage Charge Capacity $Q_s = C_s V_s = 2(C_s + C_B) V_{sen}$

$V_{sen} = \dfrac{C_s V_s}{2(C_s + C_B)}$

Cell Design Basics

- $V_{sen} + \Delta V = \frac{1}{2(C_S + C_B)} \cdot \frac{\varepsilon A V_S}{d}$

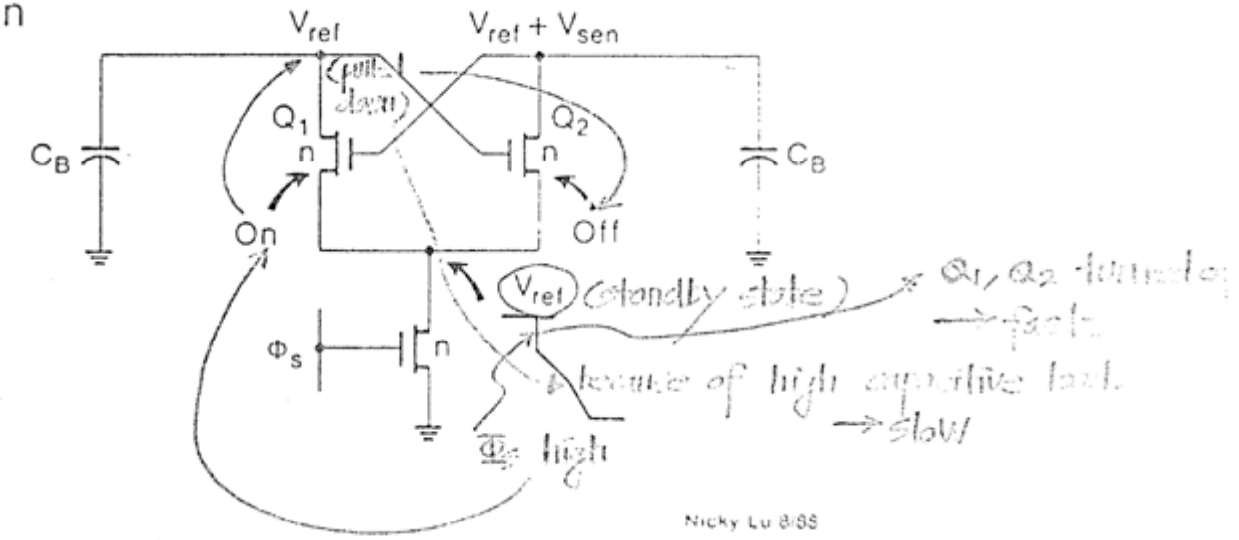
  C_S

  Where ΔV : Noise
  ε : Dielectric Constants
  A : Storage Area
  V_S : Storage Signal
  d : Dielectric Thickness

- V_S/d Limited By Maximum Dielectric Strength

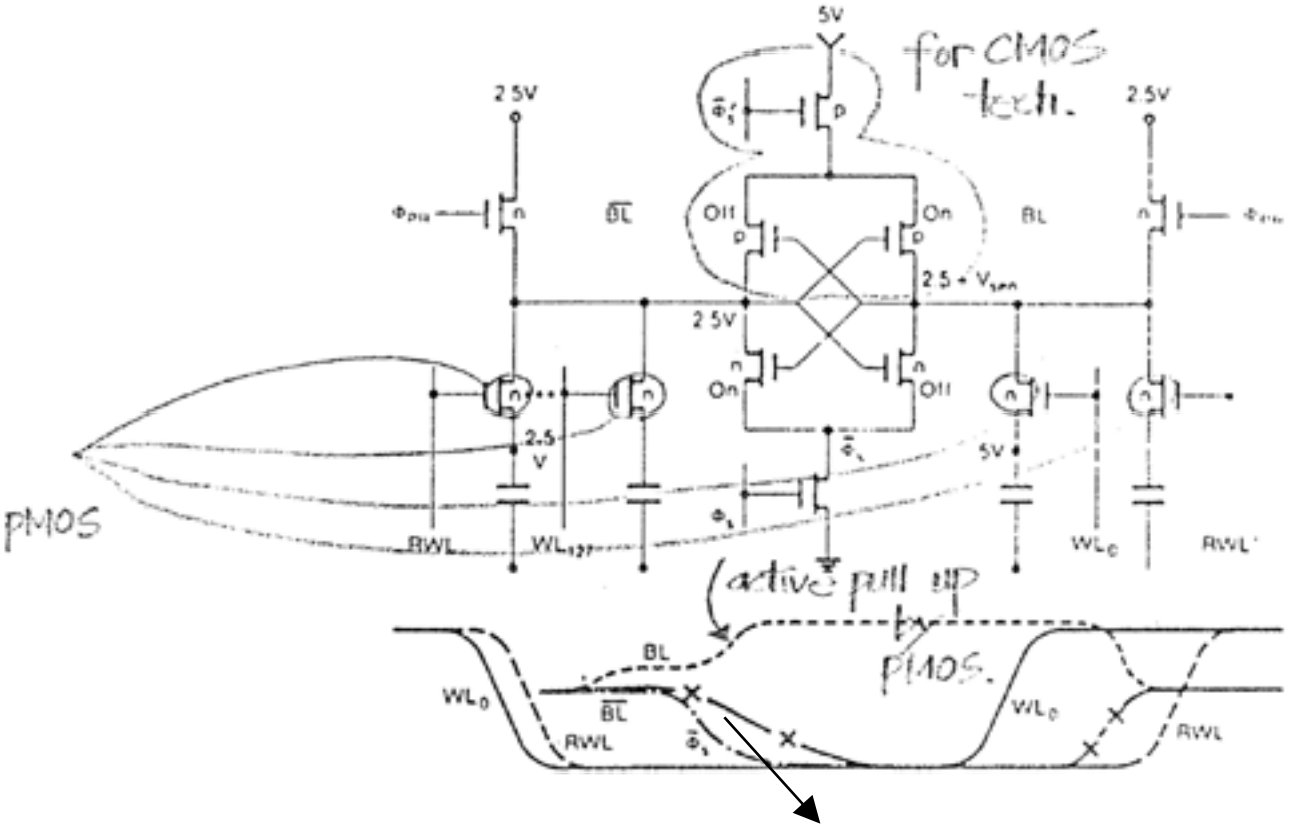
Cross-Coupled Sense Amplifier

- Differential Signal Established
- Latching
- Amplification



Sensing Circuits

- CMOS Cross-Coupled Latch



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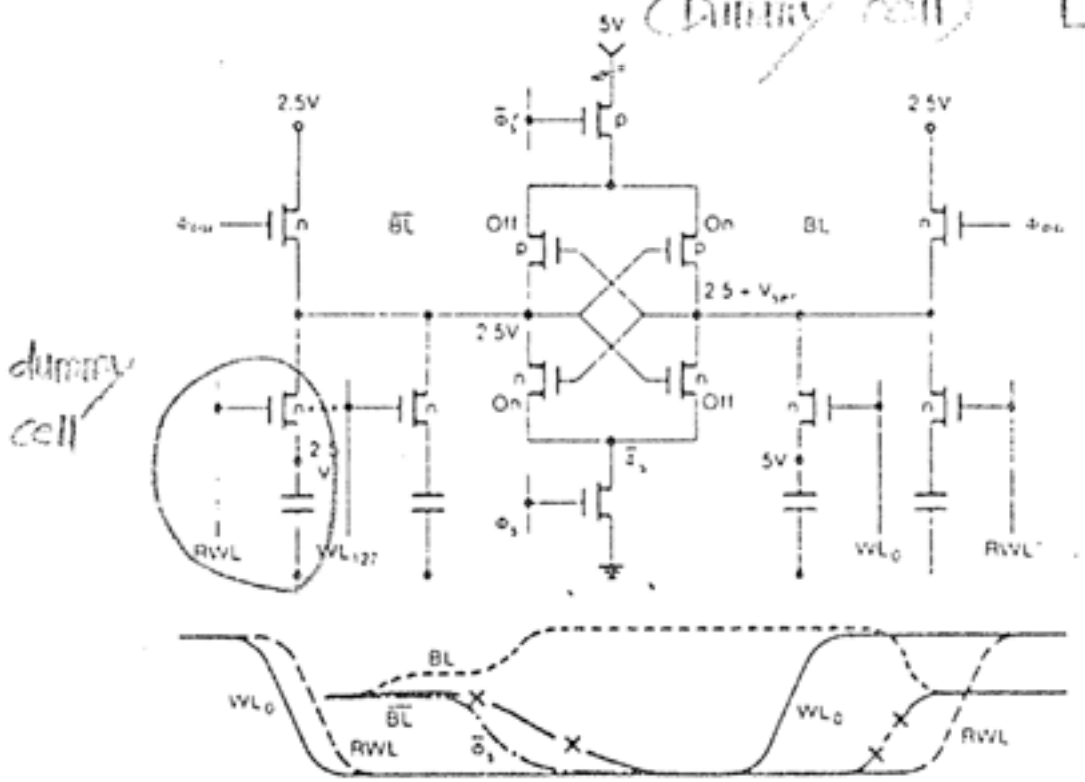
Phi pulled down then bit line change

Sensing Circuits

- Bitline Precharge
- Reference Cell Concept



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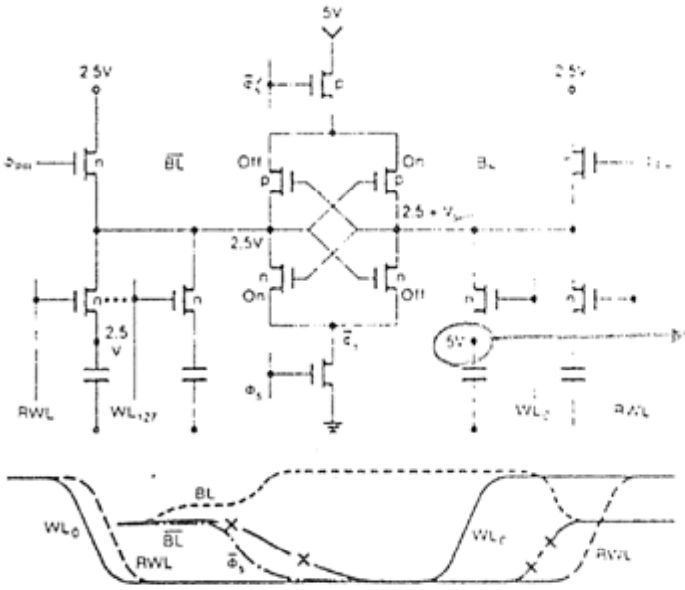
Sensing Circuits

- Self Restore
- Refresh



degraded while reading
(write back necessary)