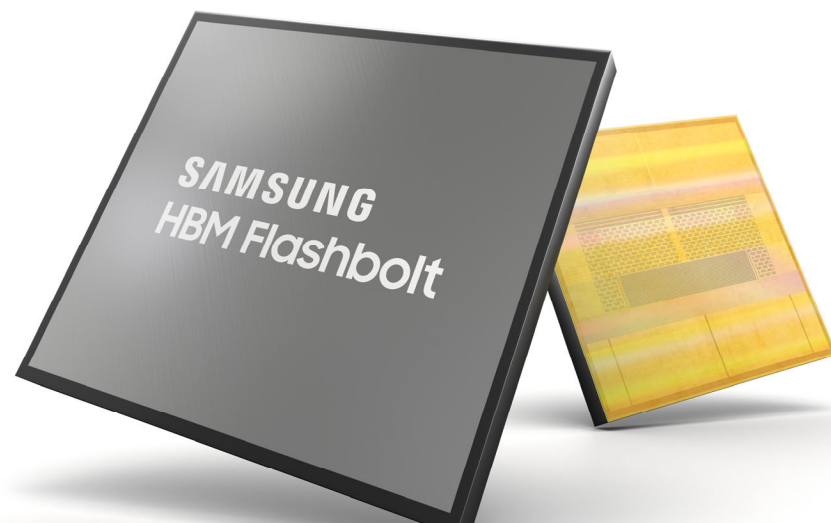


EE241B : Advanced Digital Circuits

Lecture 13 – SRAM

Borivoje Nikolić



March 4, 2020, EE Times

HBM Flourishes, But HMC Lives. While high bandwidth memory (HBM) is flourishing, hybrid memory cube (HMC) is finding life in applications that didn't exist when it was first conceived.

Announcements

- Assignment 2 due on Friday
 - Quiz 2 on Tuesday, March 10
- Please send me links to your project web pages



Outline

- **Module 4**
 - SRAM margins

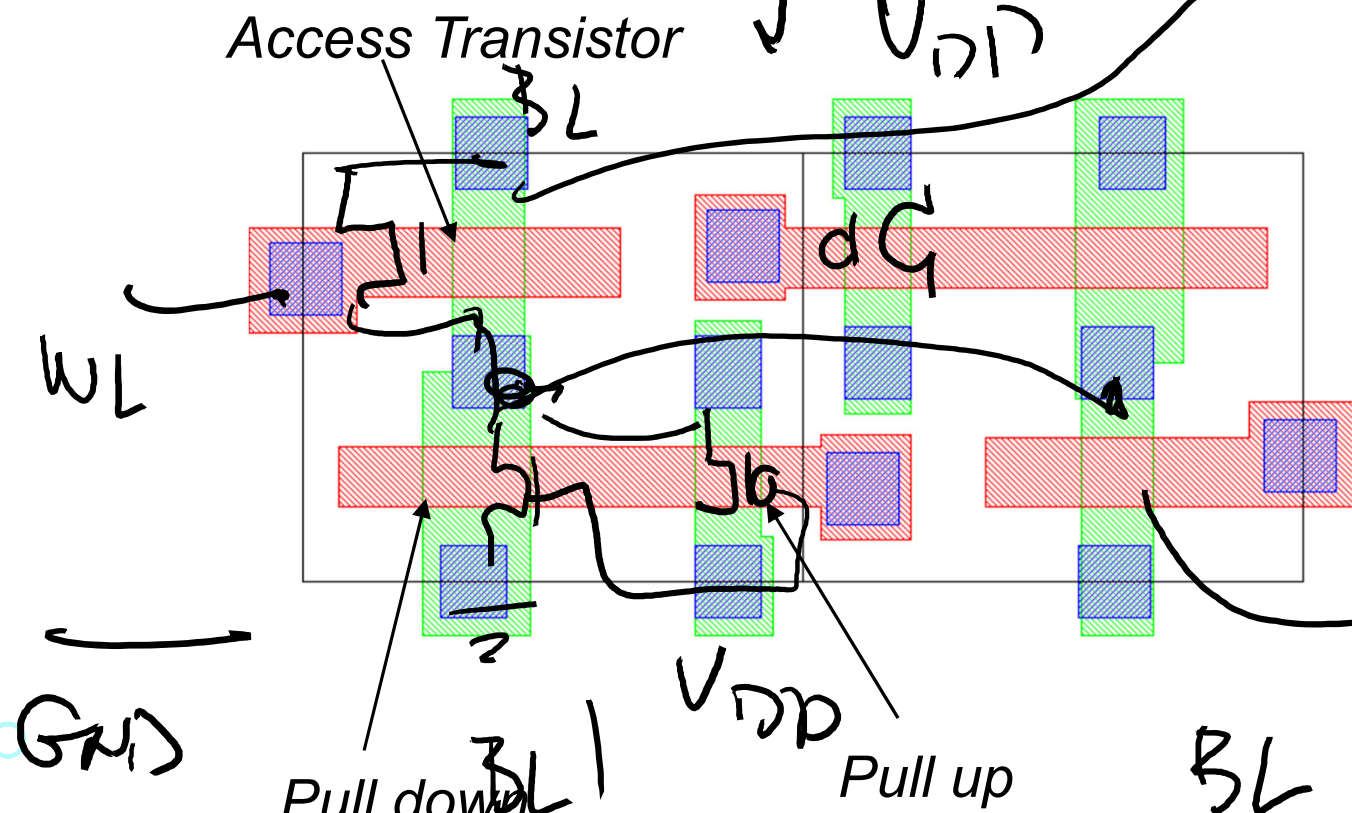
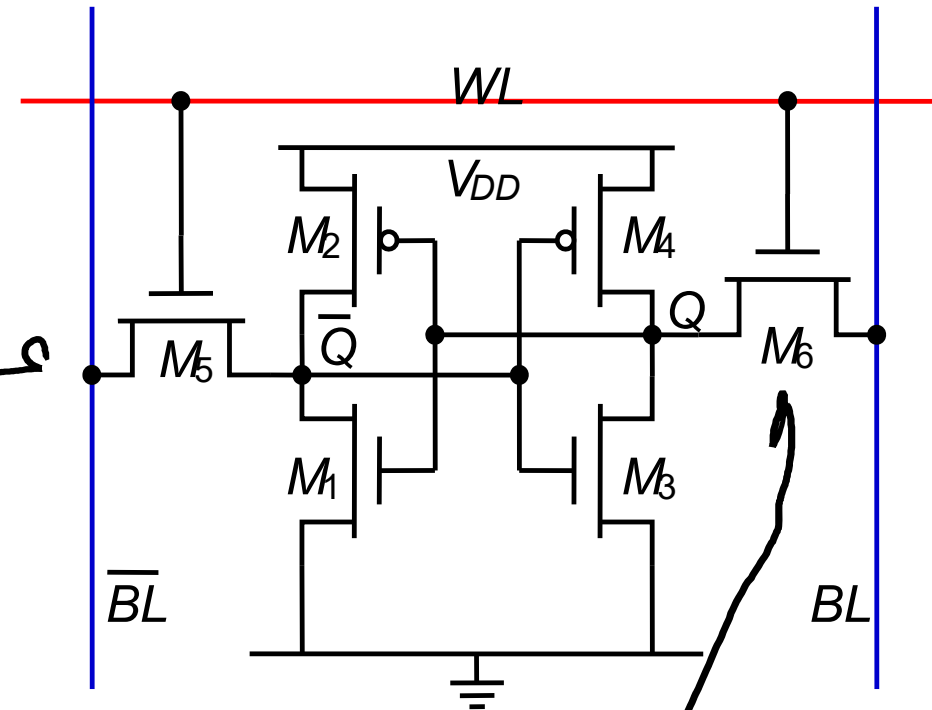


4. Memory

4.B SRAM Static Retention Margin

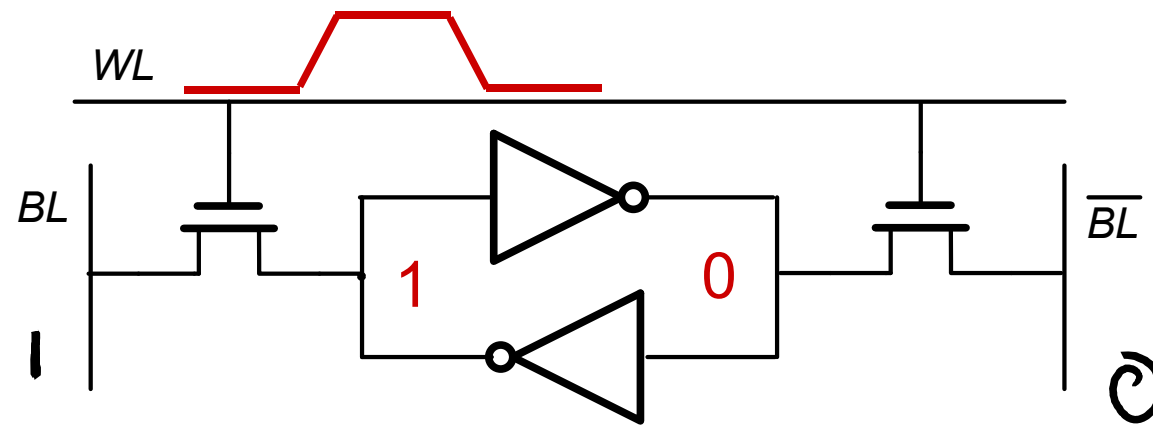
SRAM Cell/Array

- Hold (retention) stability
- Read stability
- Write stability (writability)
- Read access time

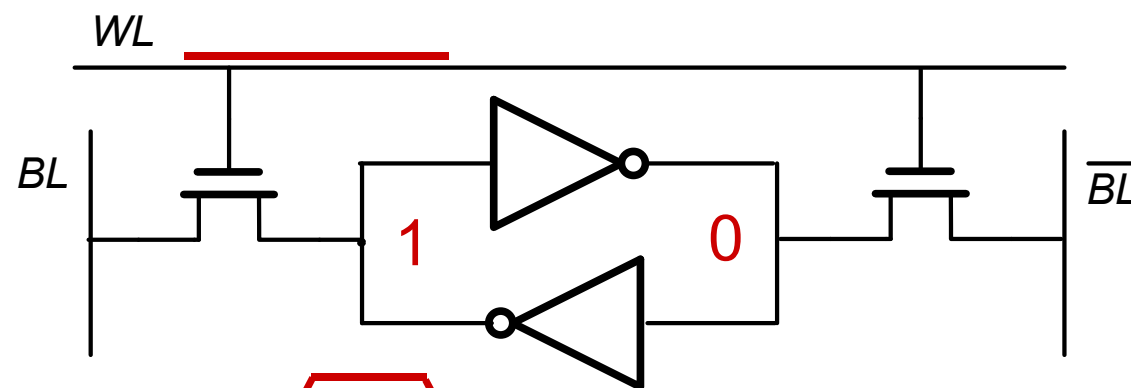


SRAM Operation

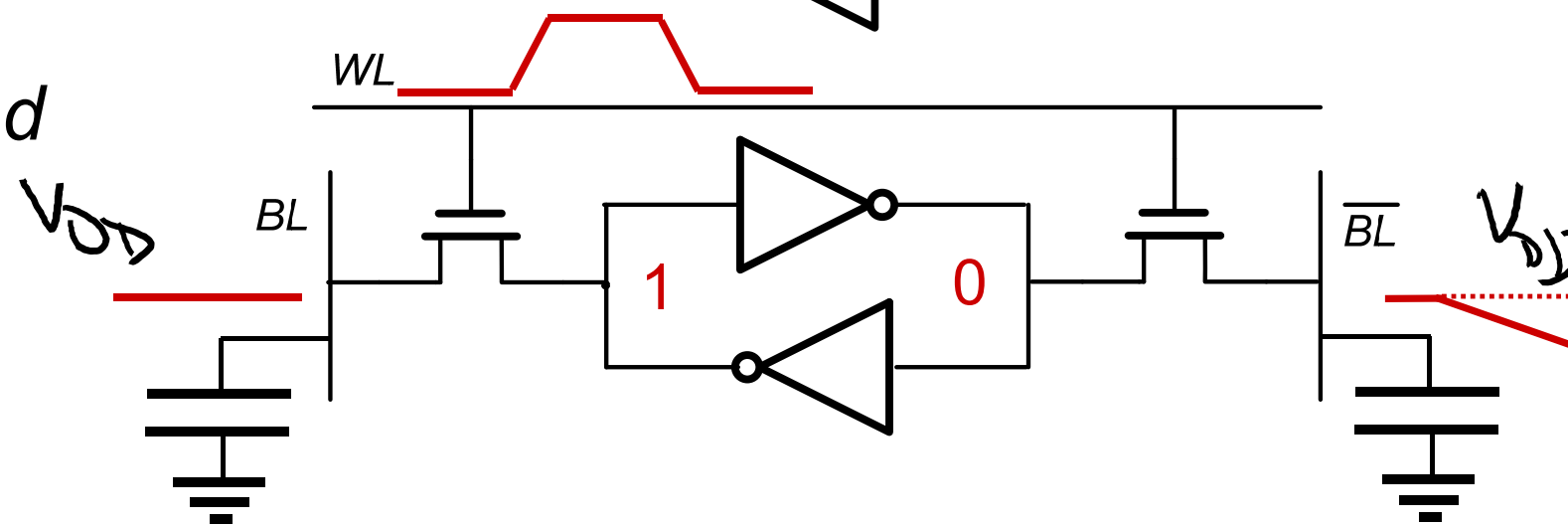
Write



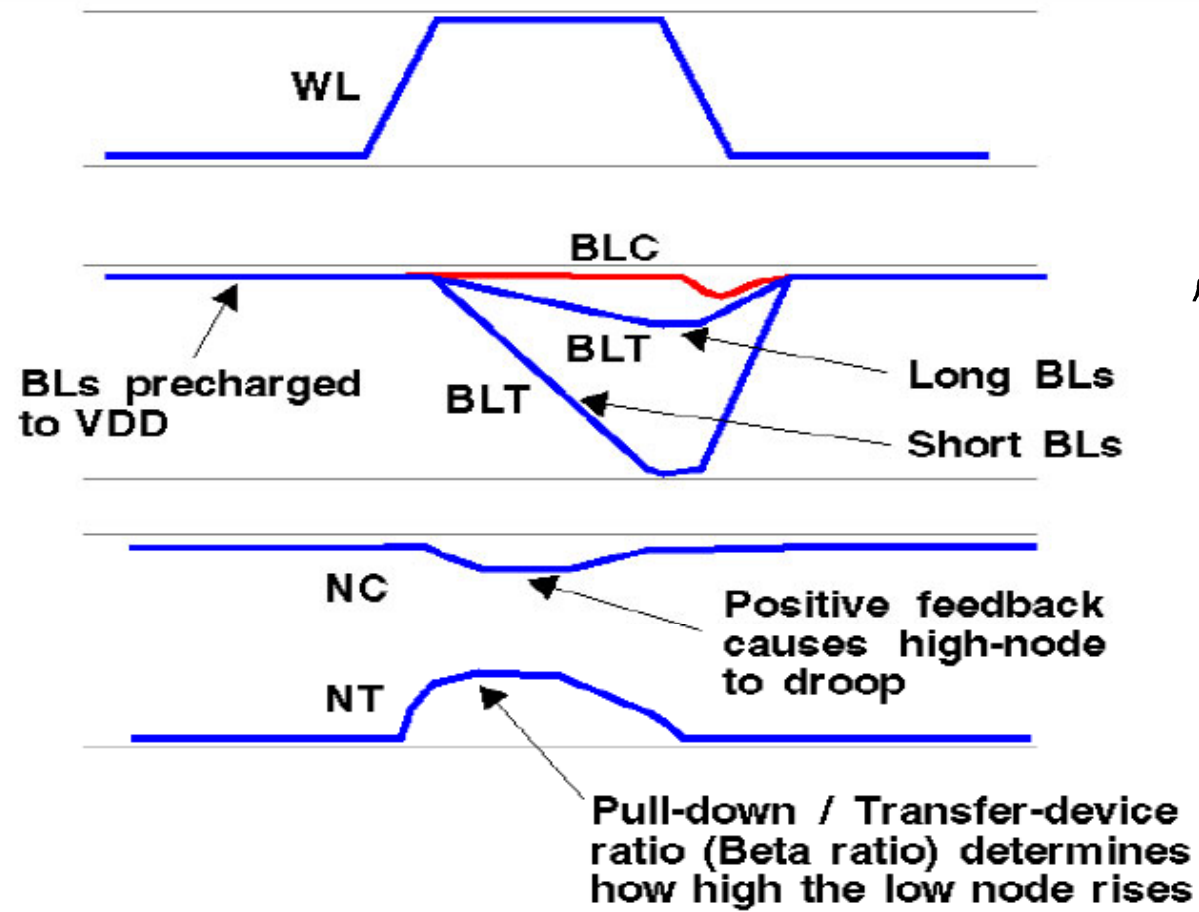
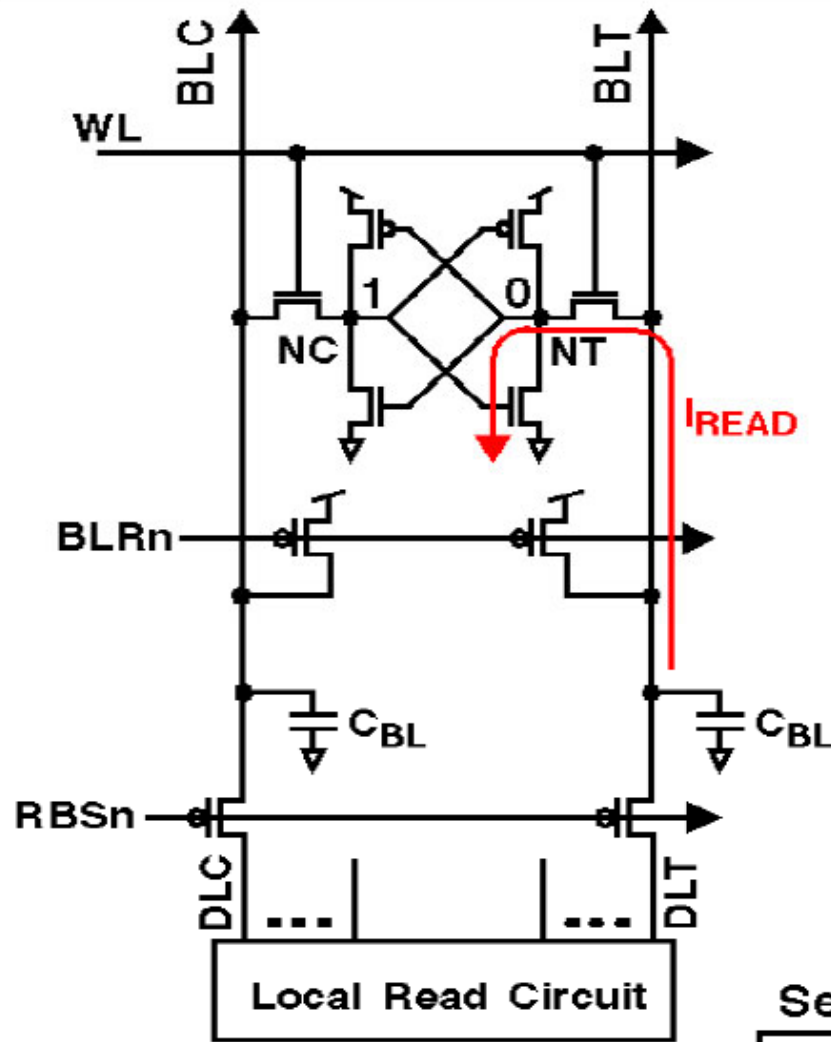
Retention



Read



6T-SRAM Array Basics – Read Operation

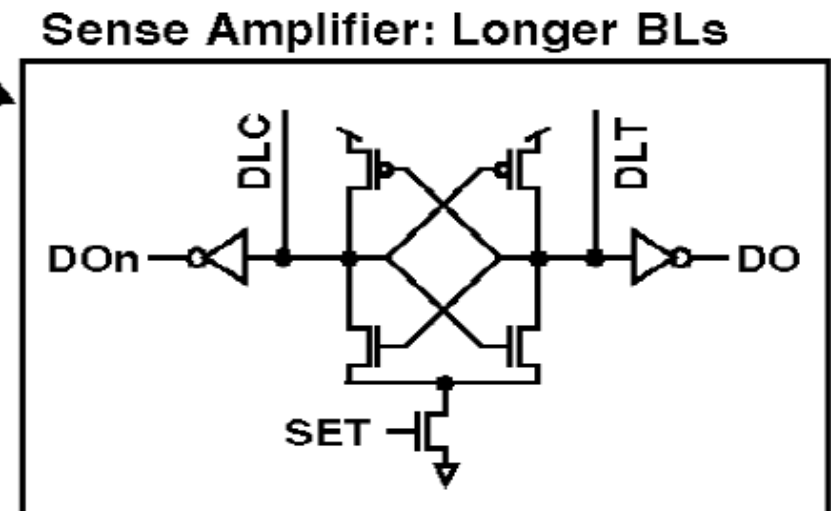
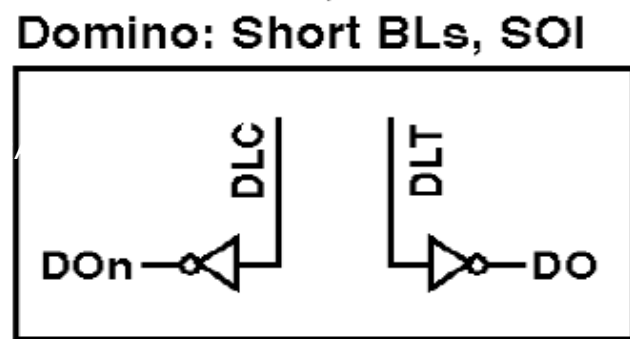


$V_{C-100mV}$

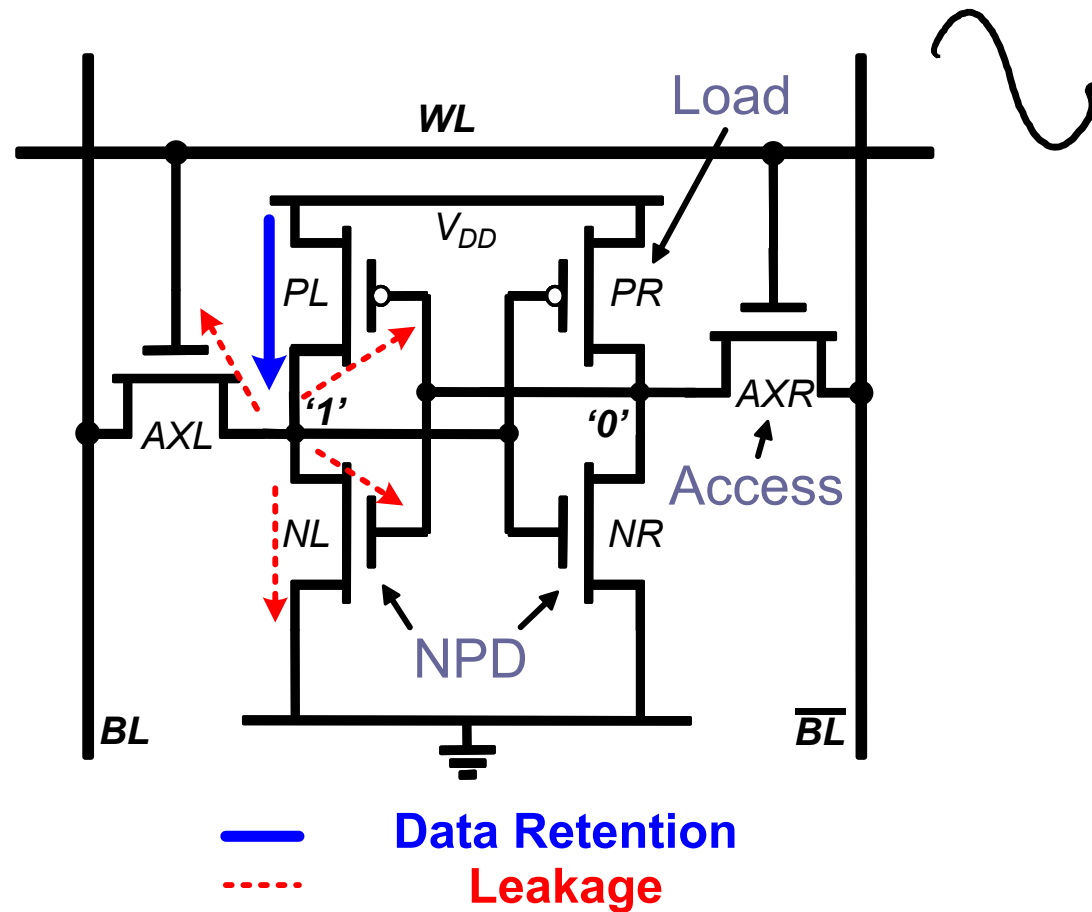
BLC ↓

BL ↑

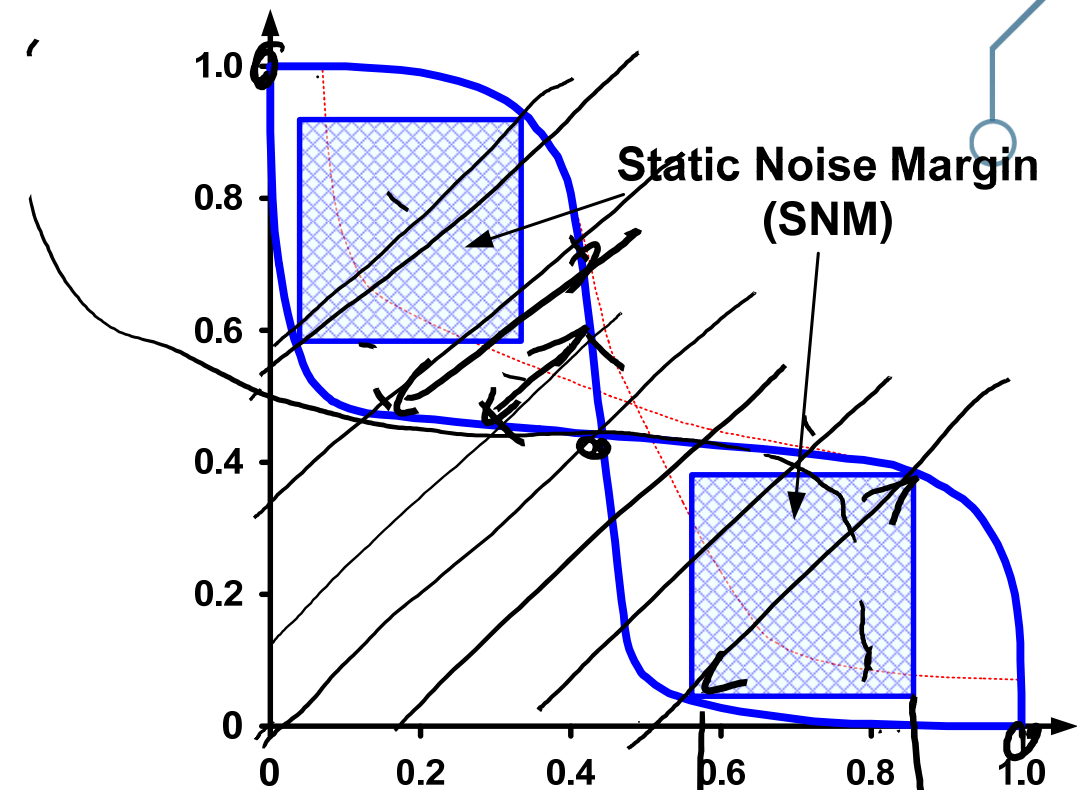
2x faster



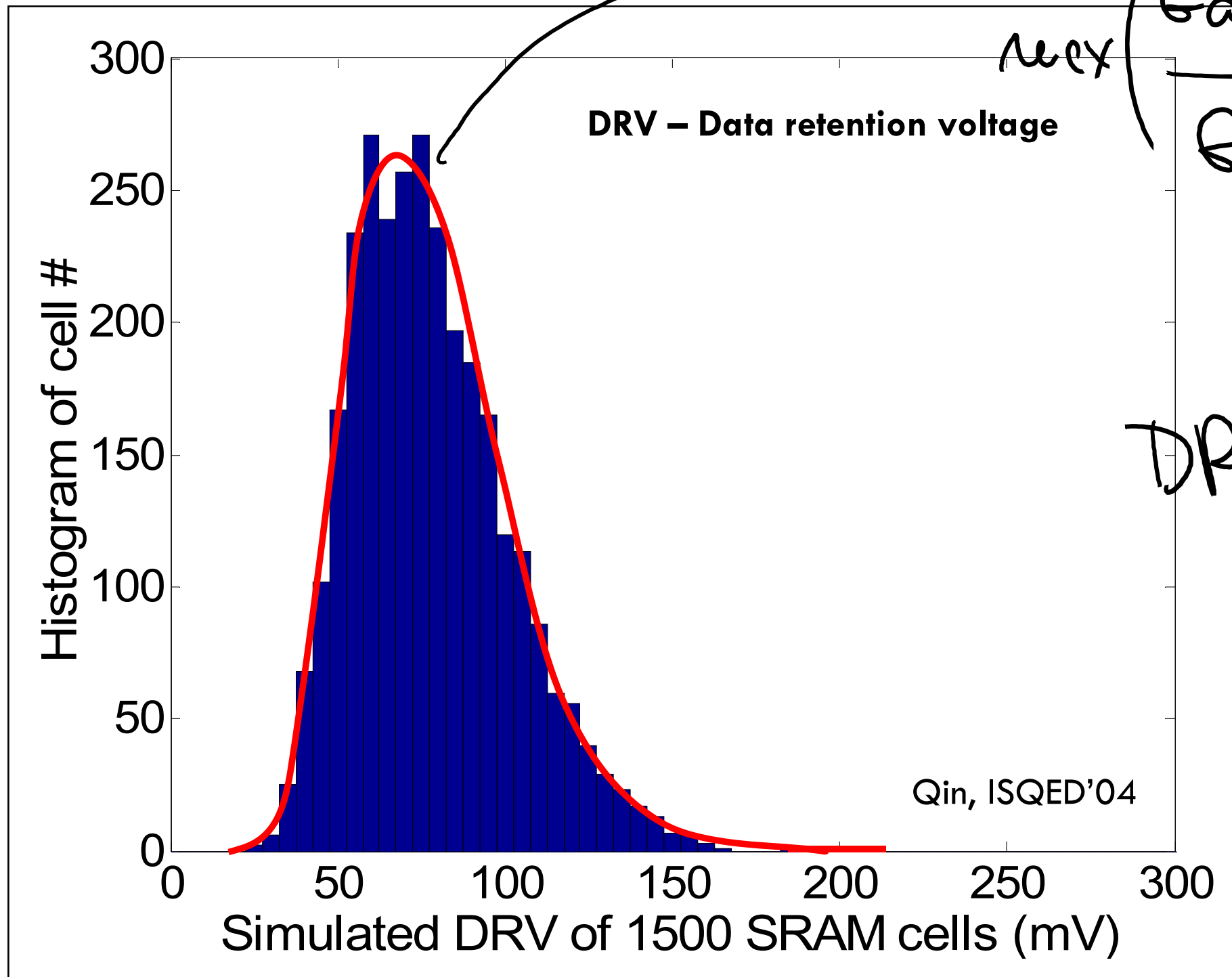
SRAM Design – Hold (Retention) Stability



- Scaling trend:
 - Increased gate leakage + degraded I_{ON}/I_{OFF} ratio
 - Lower V_{DD} during standby
- PMOS load devices must compensate for leakage



Monte-Carlo Simulation of DRV Distribution



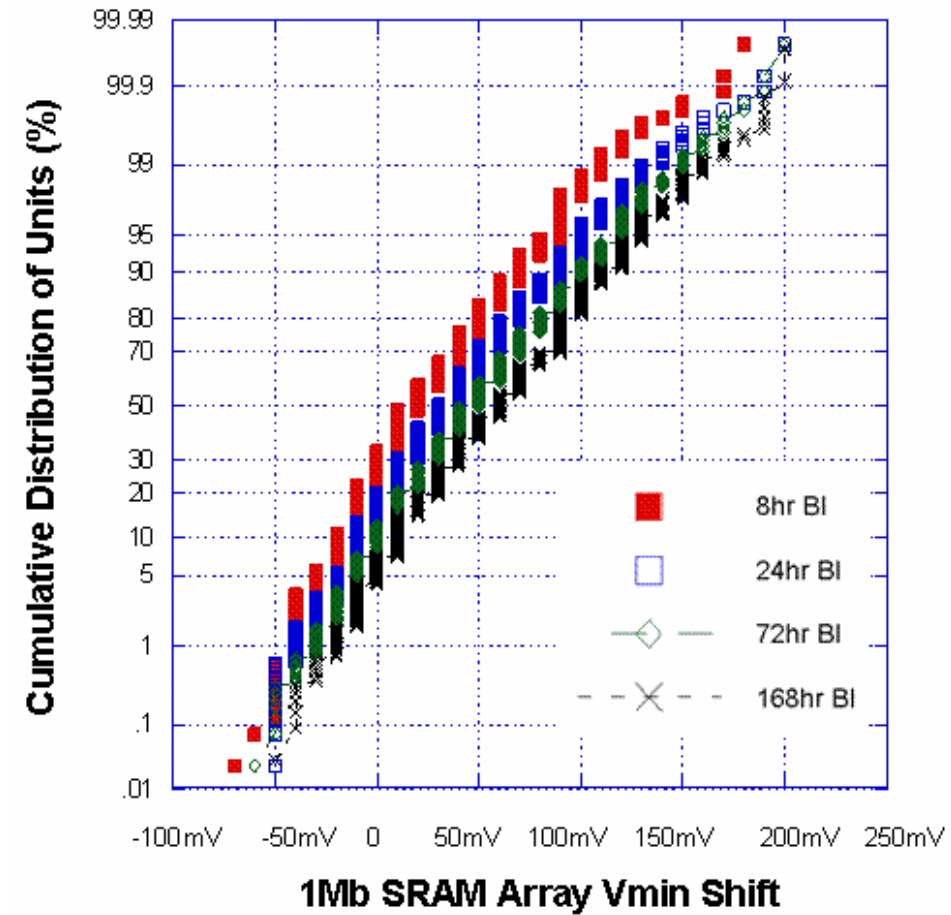
max (Gaussian 1)
Gaussian 2

DRV ~ 0.5V

Vmin Distribution

- Aggregate minimum operating voltage
- Digital test under supply sweep

1Mb SRAM Array Vmin Shift w/ Burn-In

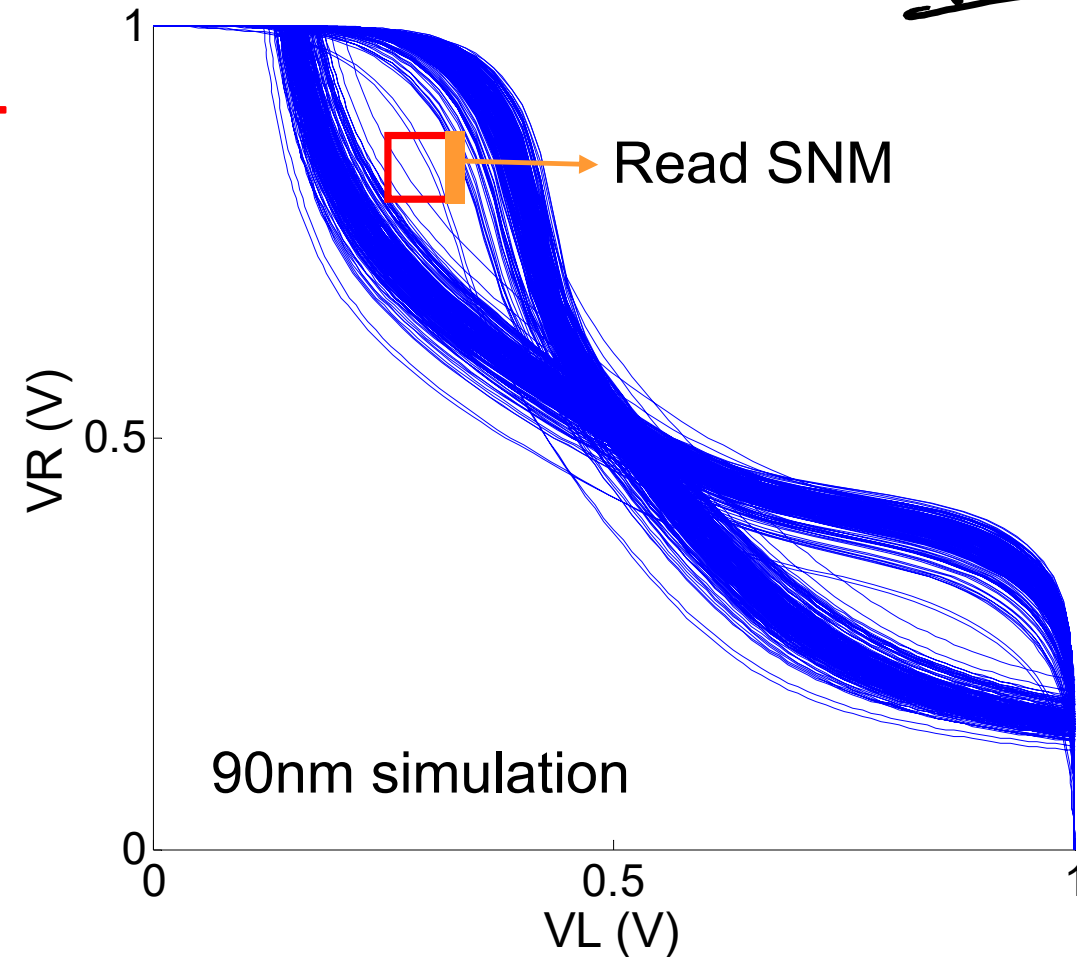
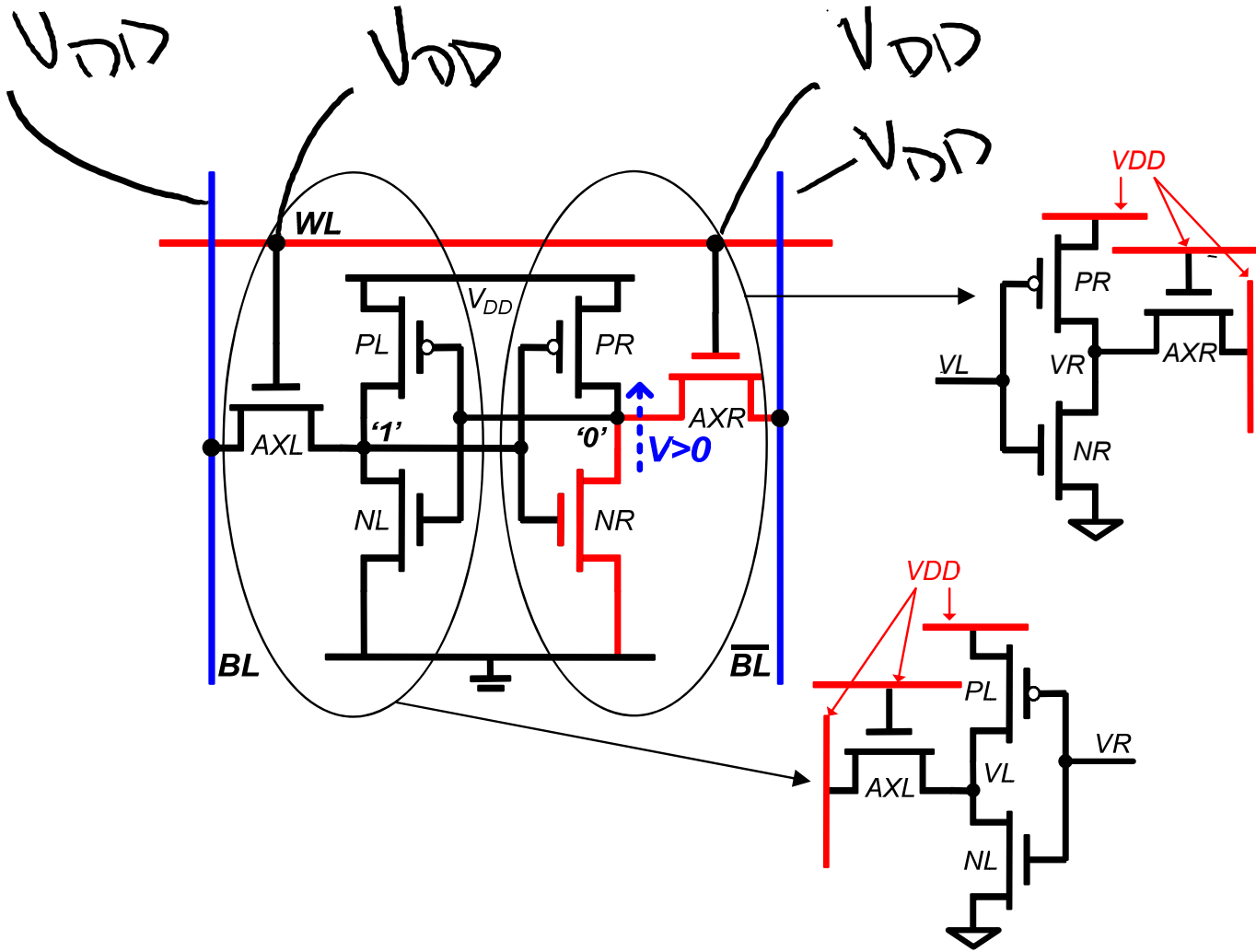


M Ball, IEDM'06



4.C Static Read/Write Margins

Read Stability – Static Noise Margin (SNM)



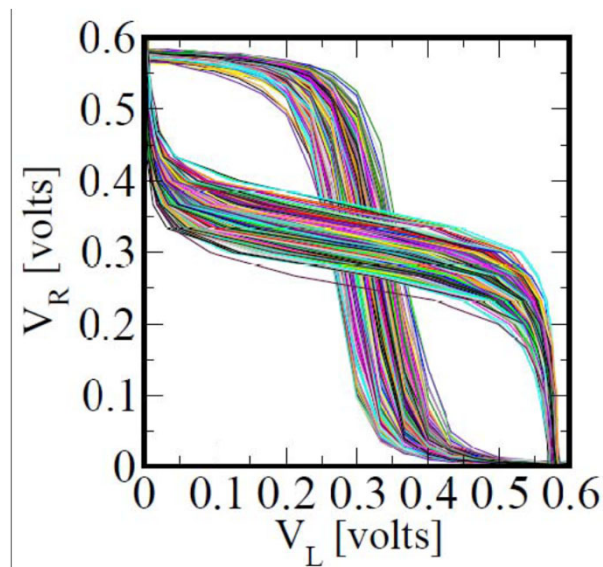
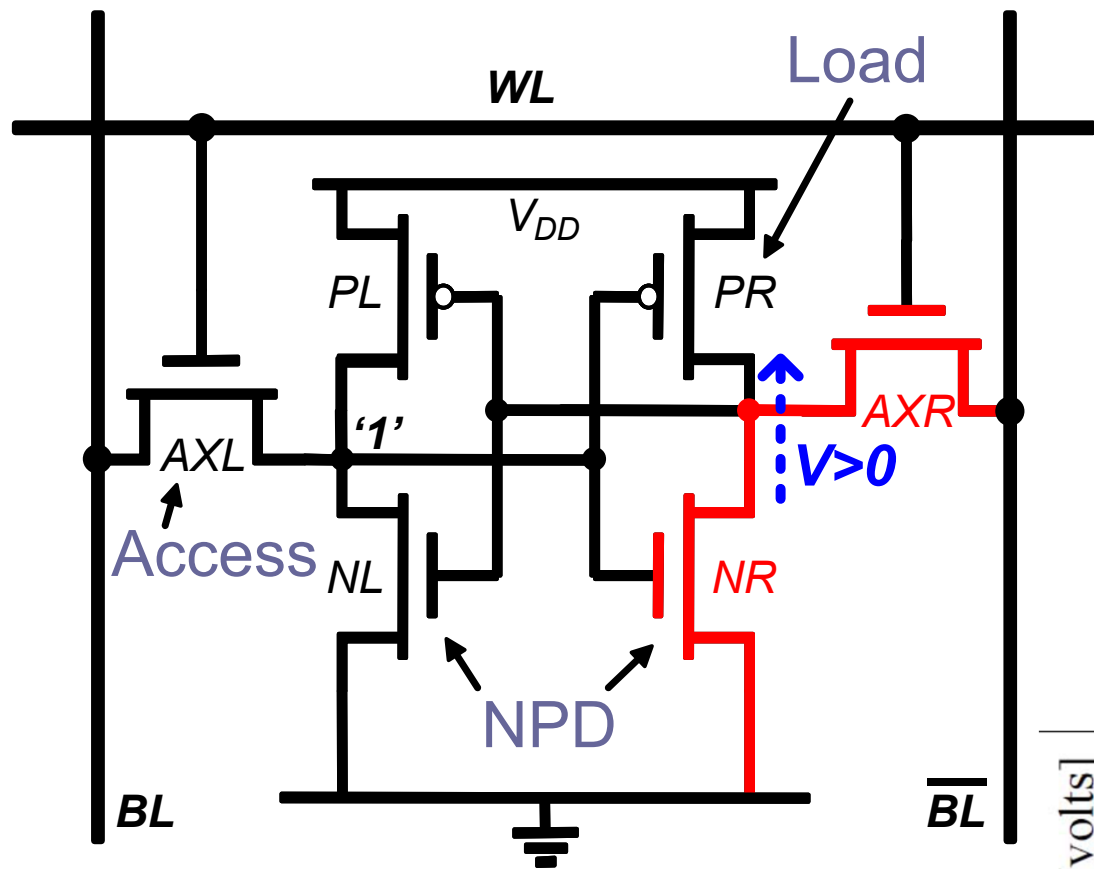
- Read SNM is the contention between the two sides of the cell under read stress.

$$\Delta V_{Th} \propto \frac{1}{C_{ox} \sqrt{WL}}$$

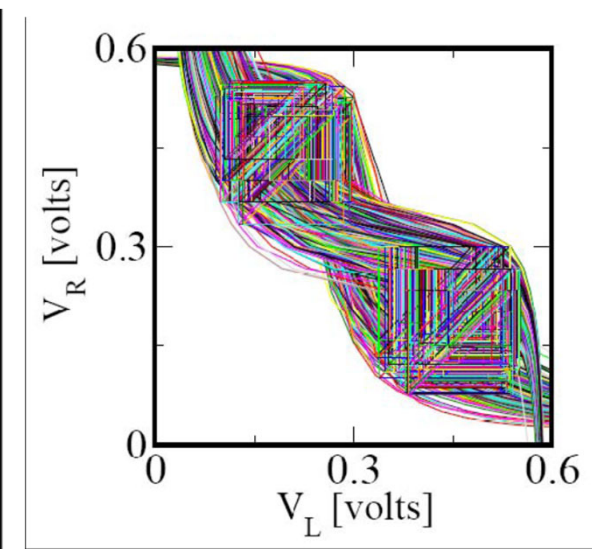
Due to RDF

E. Seevinck, JSSC 1987

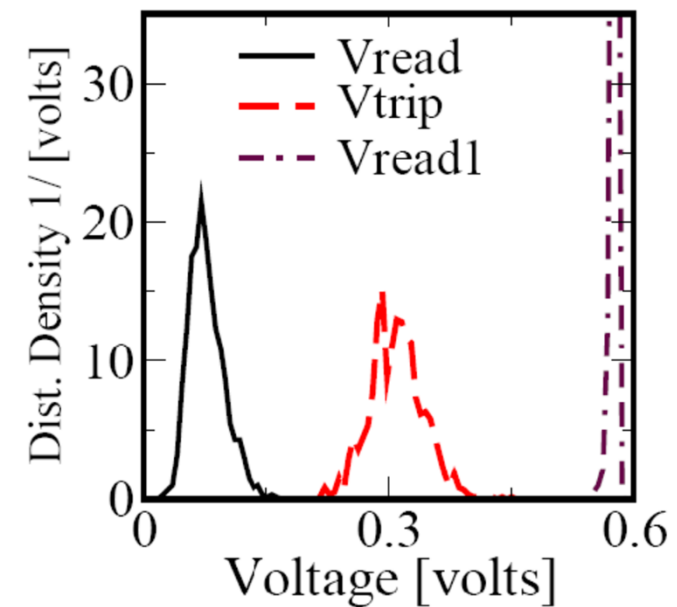
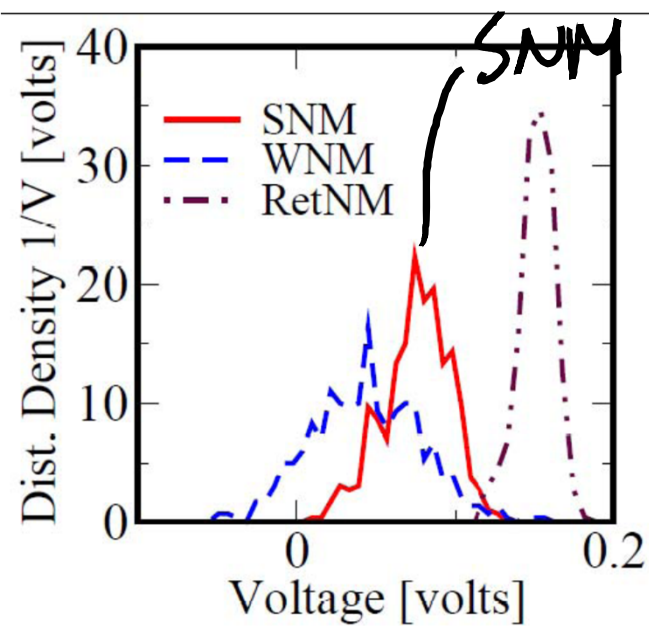
Read SNM - Measurements



Retention fluctuations



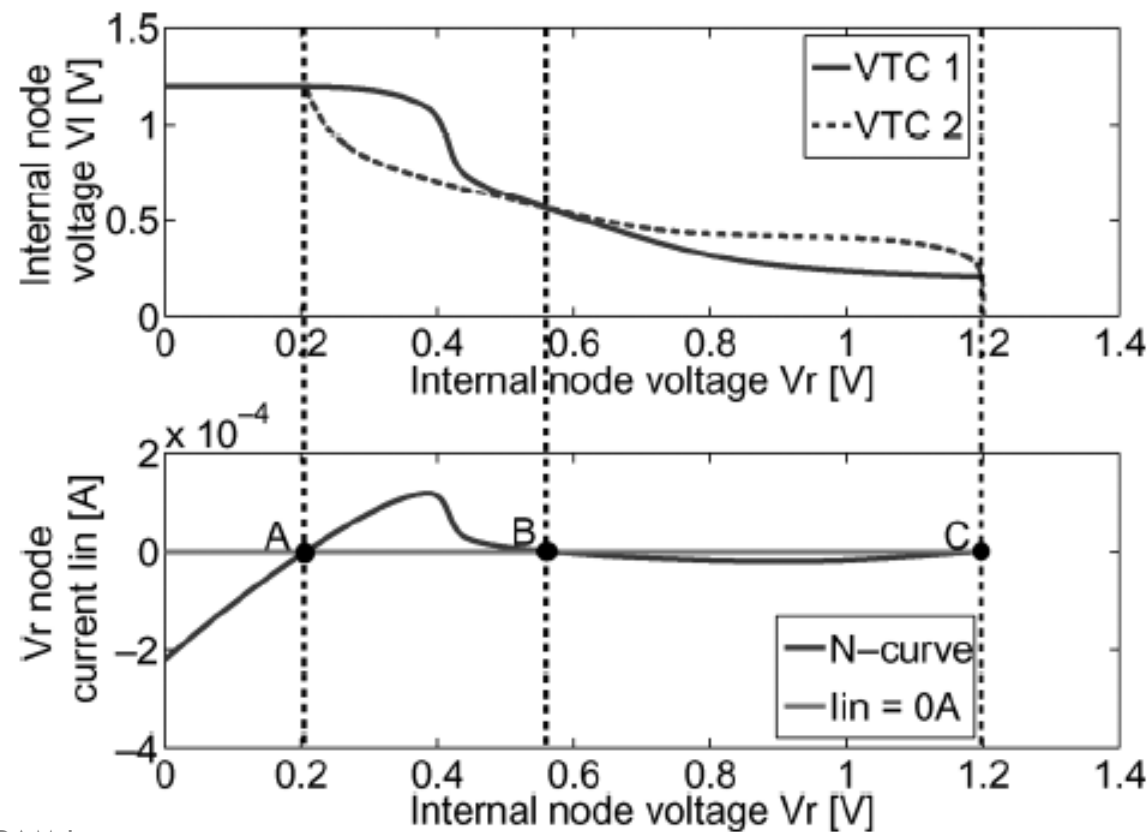
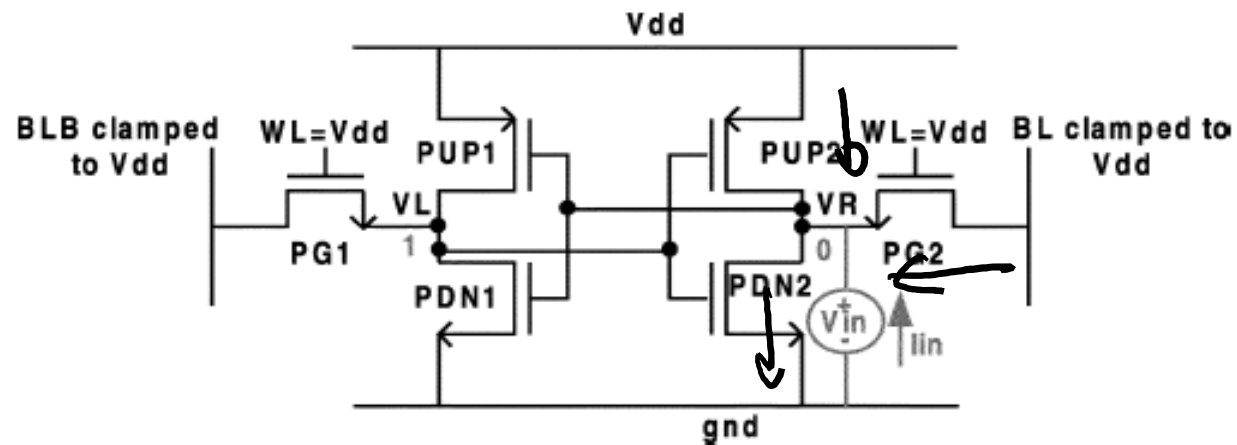
Read Fluctuations



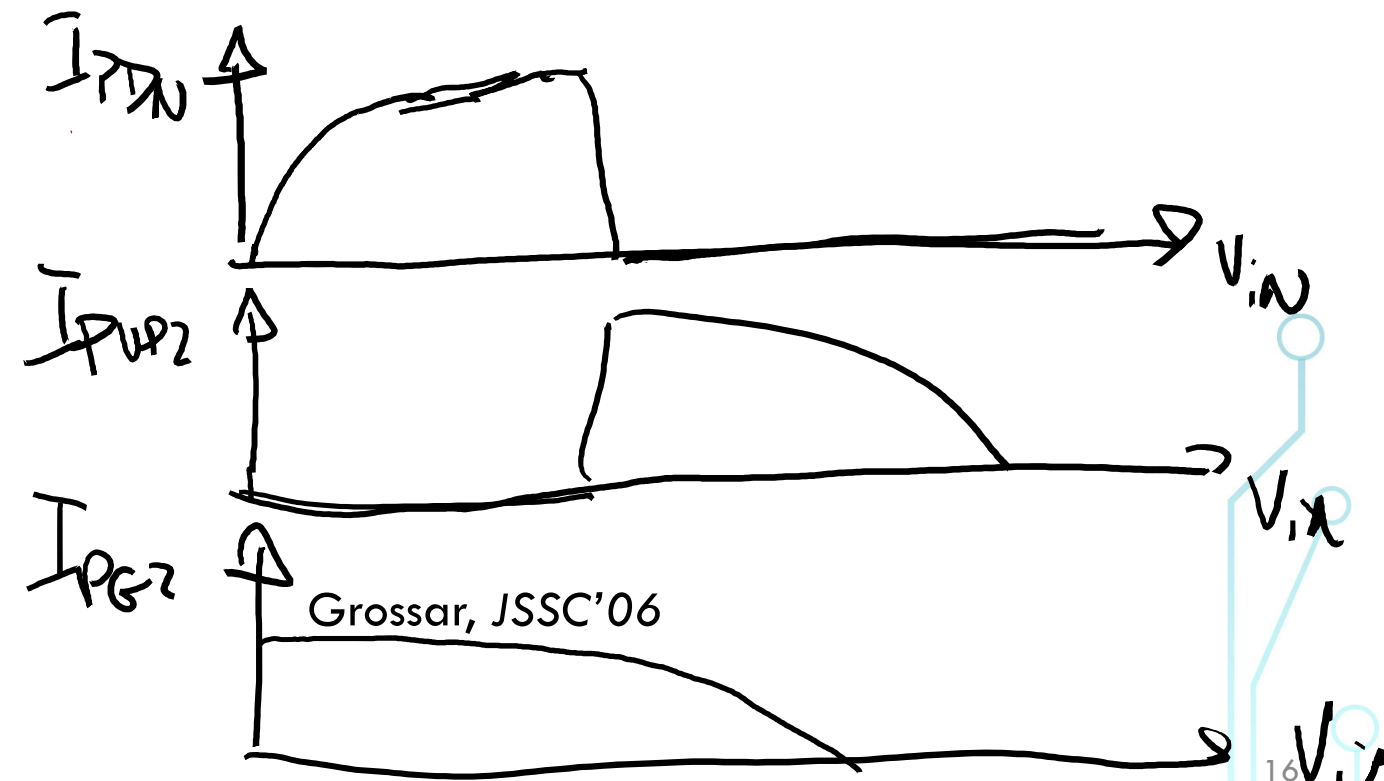
➤ Read margin vs. retention margin

Bhavnagarwala, IEDM'05

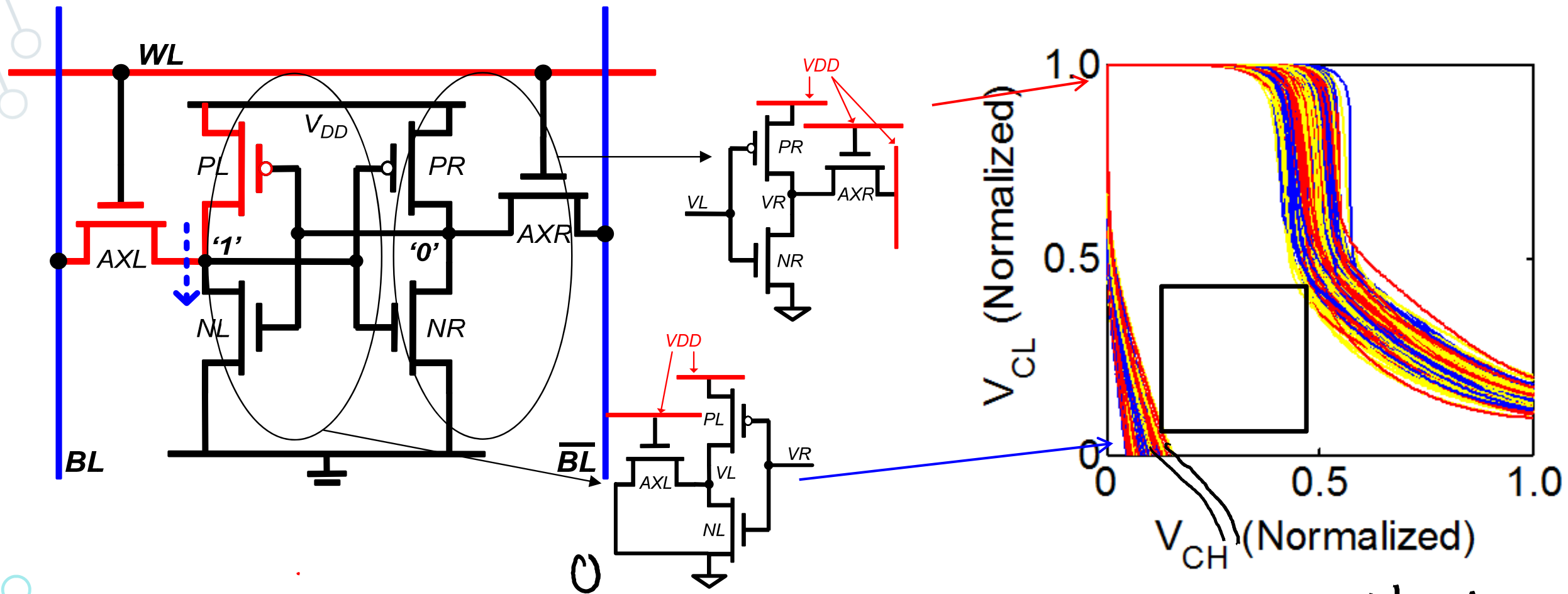
Read Stability – N-Curve



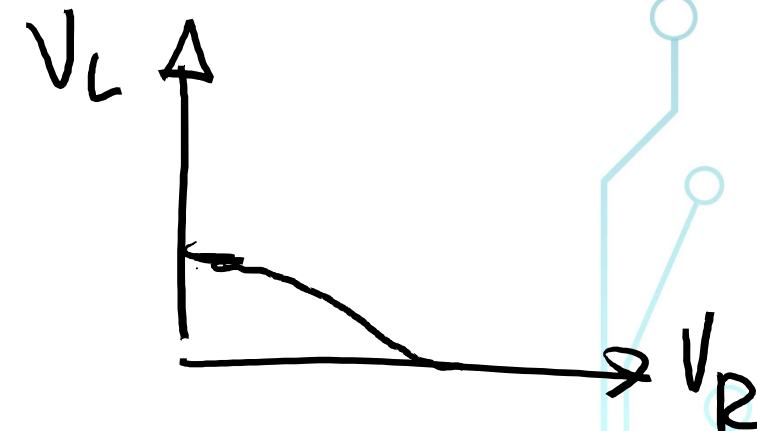
- A, B, and C correspond to the two stable points A and C and the meta-stable point B of the SNM curve
- When points A and B coincide, the cell is at the edge of stability and a destructive read can occur



Write Stability – Write Noise Margin (WNM)



- Writeability is becoming harder with scaling
- Optimizing read stability and writeability at the same time is difficult



A. Bhavnagarwala, IEDM 2005