Analyzing Static and Dynamic Write Margin for Nanometer SRAMs

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- Motivation and Background.
- A Key Insight.
- Dynamic write-ability analysis.
- Static vs. Dynamic measures.
- Conclusions.

- $\uparrow$ varn. $\Rightarrow$ $\downarrow$ noise margins.
- Static metrics
  - Easy to measure
  - Ignore time
  - Pessimistic
  - Best metric?
- Better VCC_{min} estimation $\Rightarrow$ dynamic write-ability metric reqd.

Background: Static Approaches

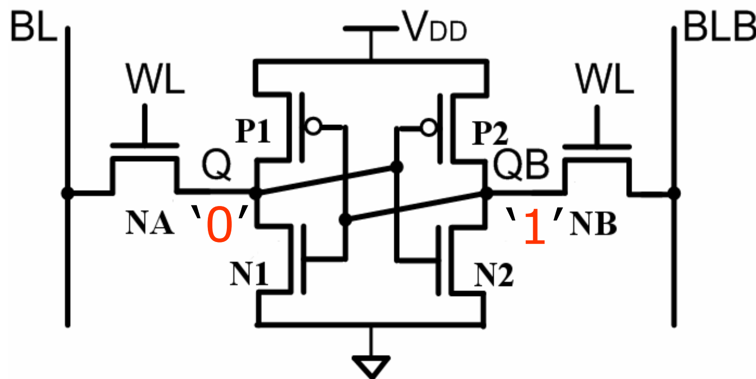
Least Squares (SNM)

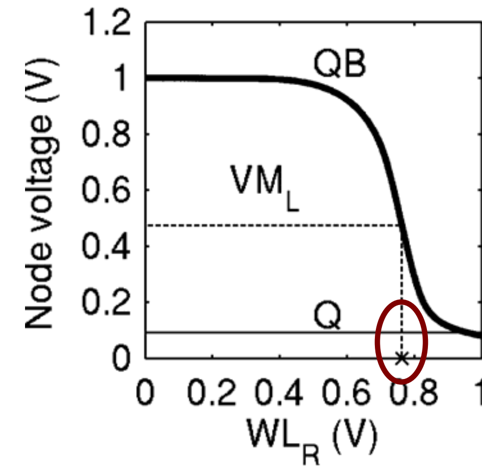
BL Sweep (VBL)

N-Curve (WTV,WTI)

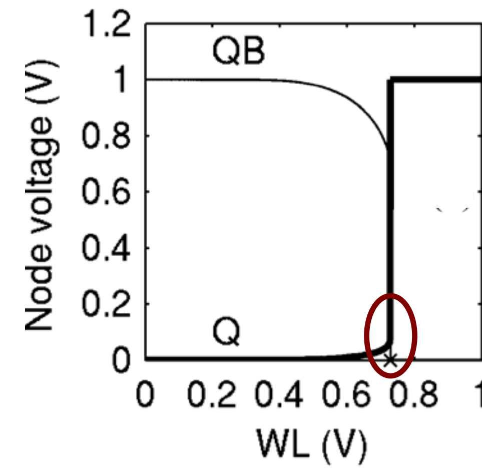
Background: Static Approaches

WL Sweep 1 (VWL_R)





WL Sweep 2 (VWL)



WM = VDD - WL

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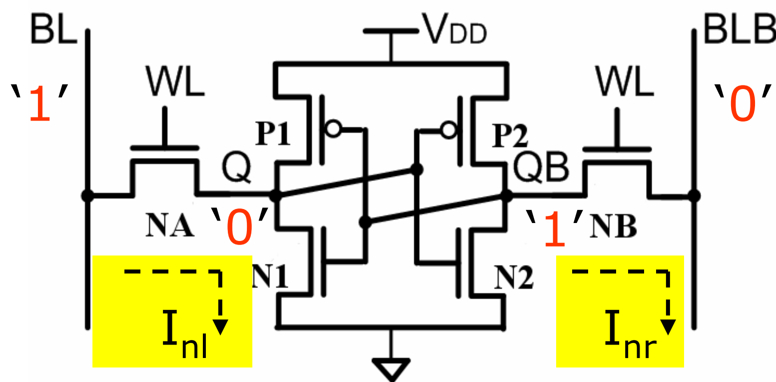
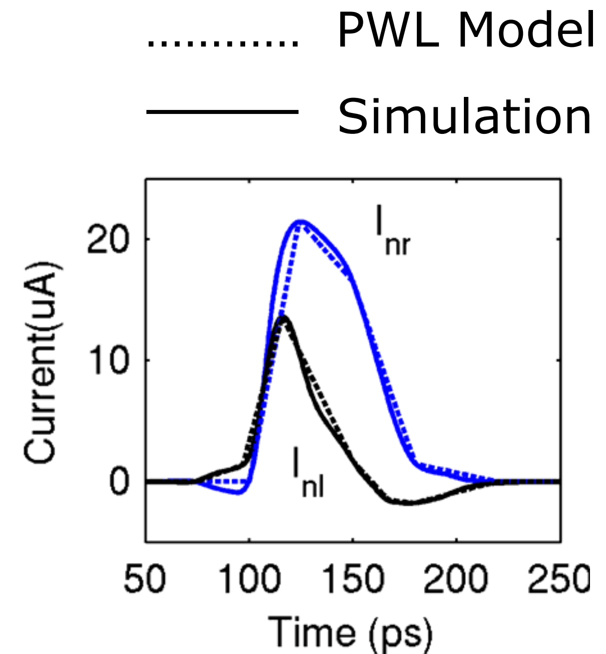
SRAM Write Operation

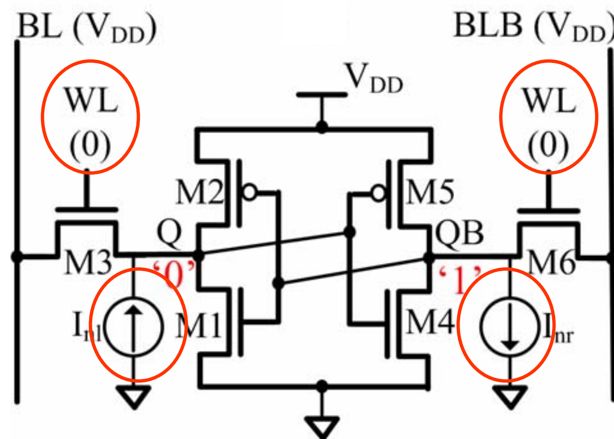
Currents look like noise pulses injected into the cell through access NFETs

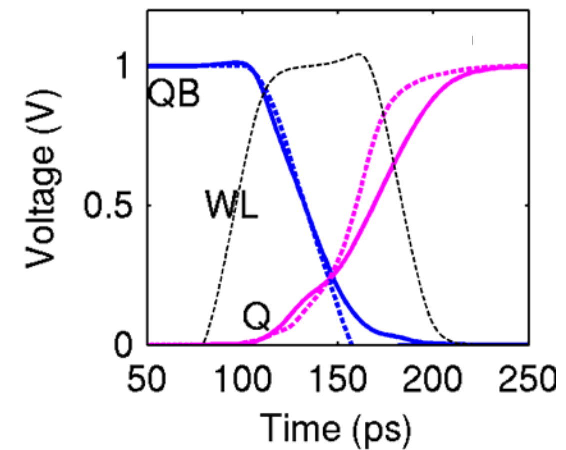




The current can be modeled by nearly triangular PWL pulse

SRAM Write Operation



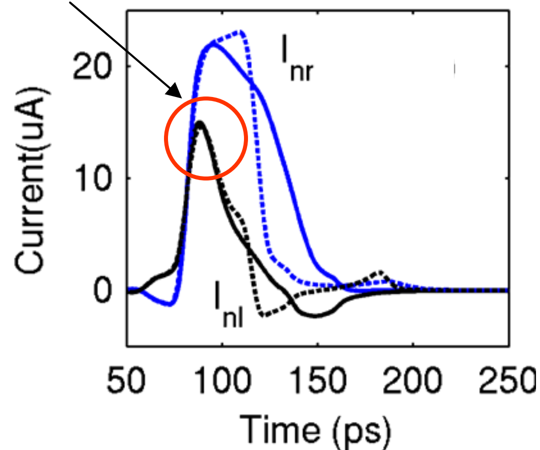


Key Insight: Current noise model of the write operation closely resembles actual write operation

Dependency on WL pulse width

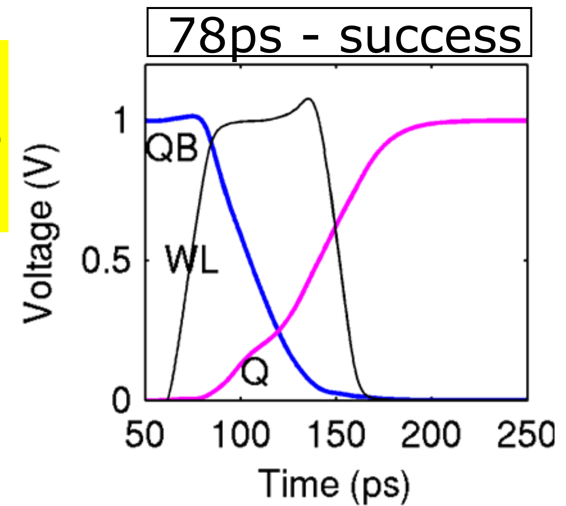
Longer WL duration
⇒ wider current pulse
⇒ write success

Same current amplitude

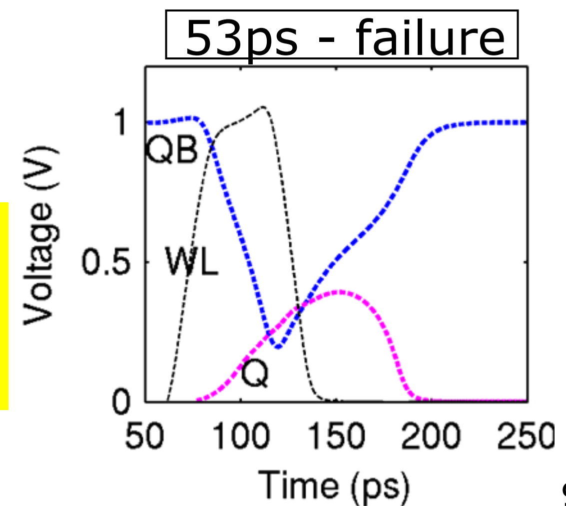


Insufficient WL duration
⇒ shorter current pulse
⇒ write failure

78ps - success



53ps - failure



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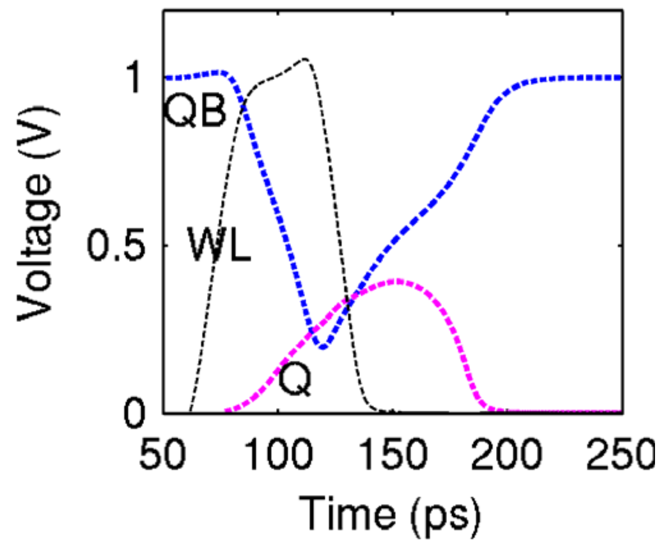
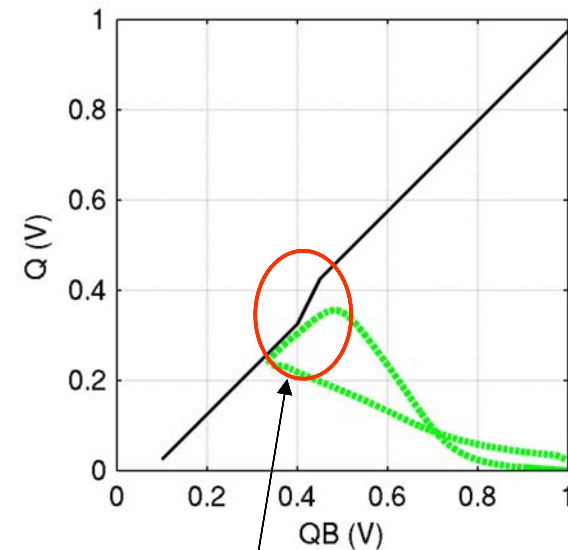
Dynamic write-ability analysis

$T_{WL} = T_{CRIT} - 1ps$



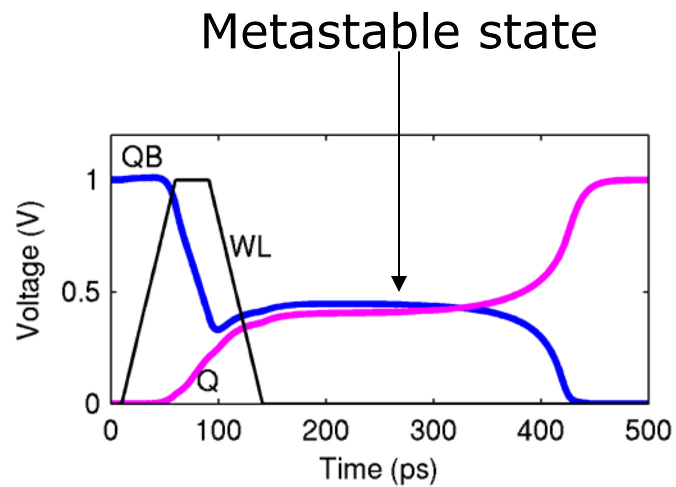
Separatrix = boundary between attraction regions

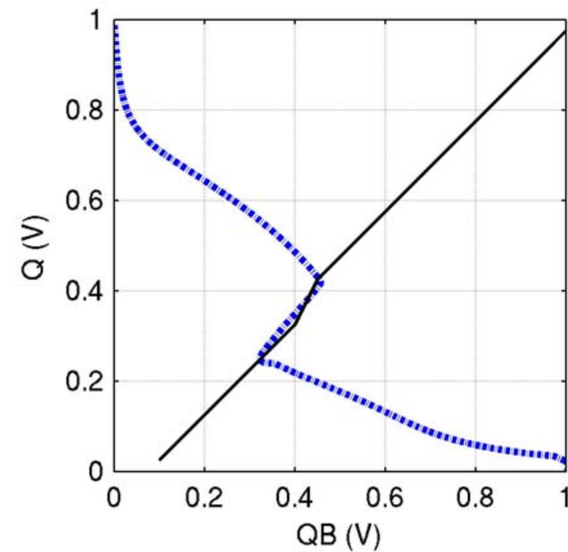


Variation skews separatrix

Dynamic write-ability analysis

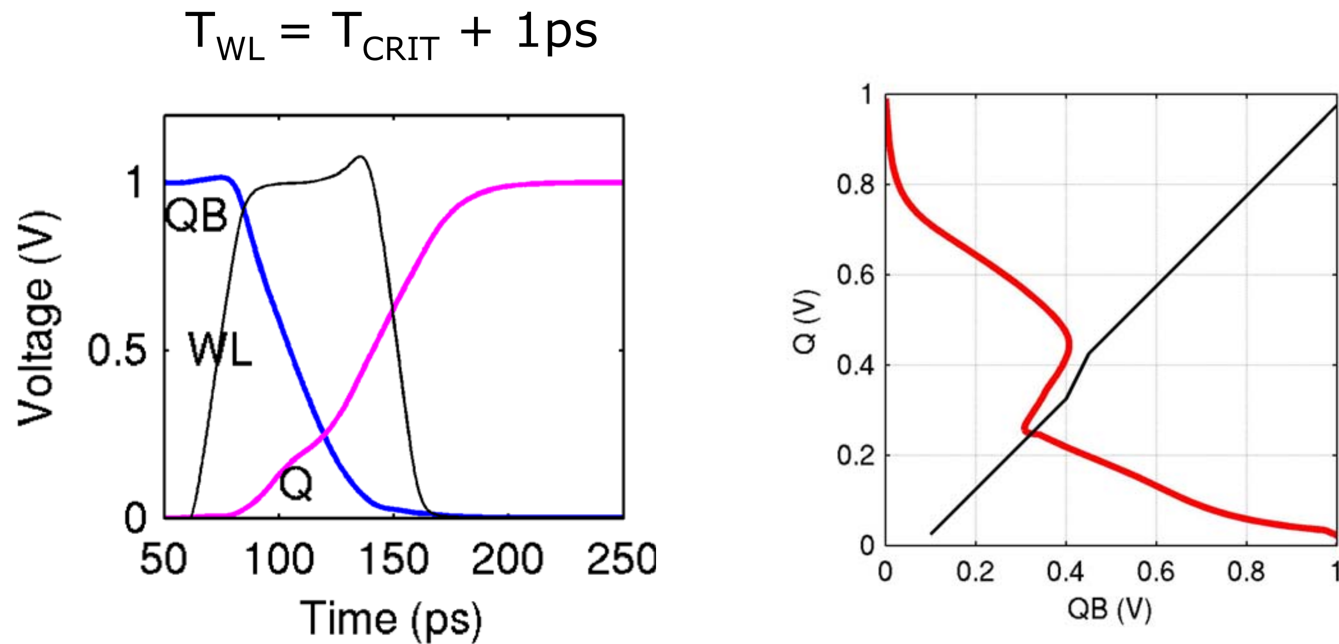
Metastable state





$T_{WL} = T_{CRIT}$

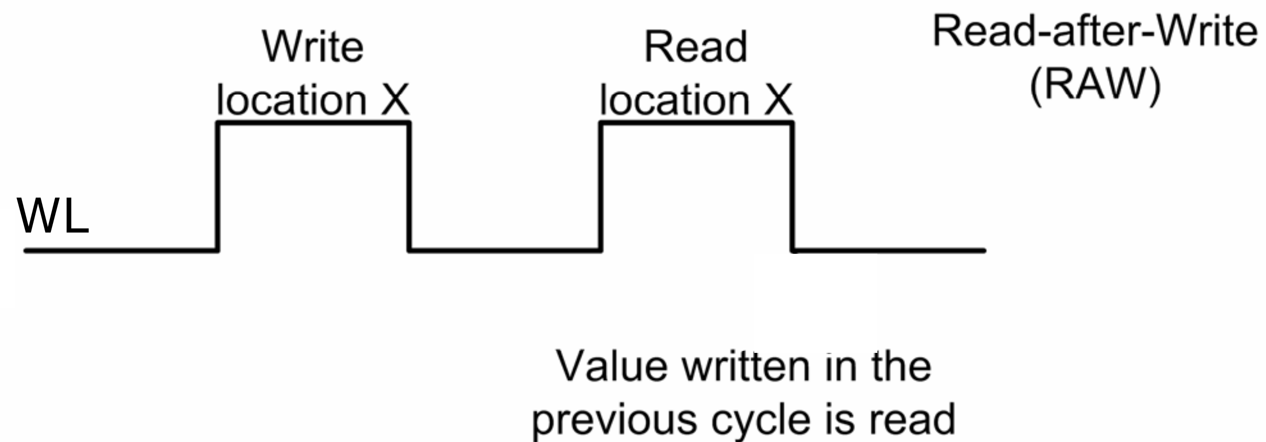
Dynamic write-ability analysis



T_{CRIT} = WL pulse width when the cell just flips

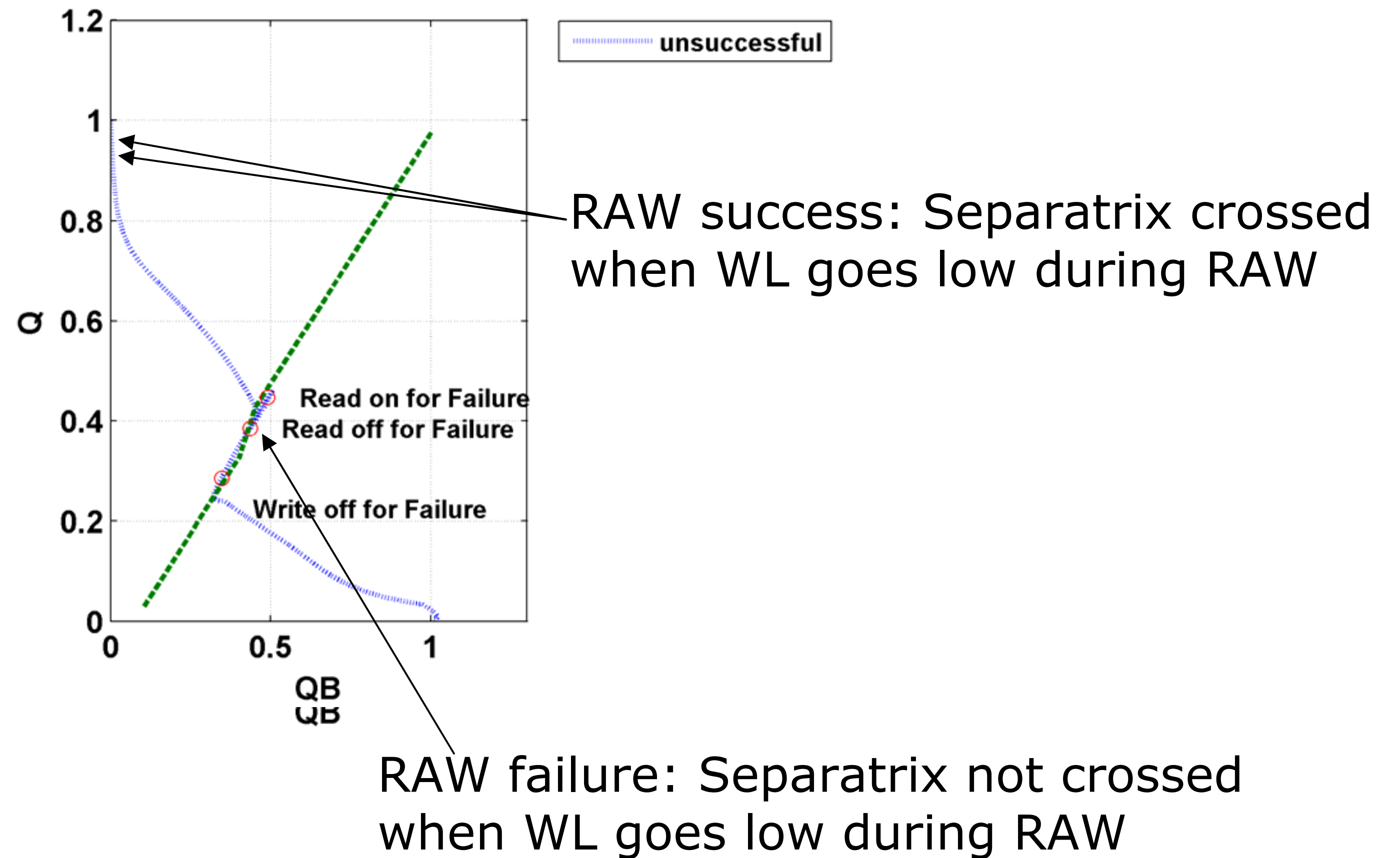
Write Failure definition

- Cell eventually flips
- Correct Read-after-write (RAW)

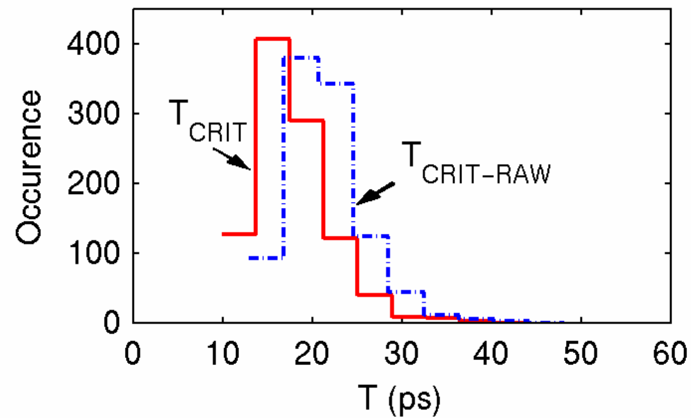


$T_{CRIT\text{-}RAW}$ = min. T_{WL} needed for successful RAW.

Dynamic write-ability analysis: RAW



T_{CRIT} vs. $T_{CRIT-RAW}$



- Similar distributions.
- T_{CRIT} simulation easier.
- High-speed SRAM $\Rightarrow$ $T_{CRIT-RAW}$
- Slower SRAMs $\Rightarrow$ T_{CRIT}

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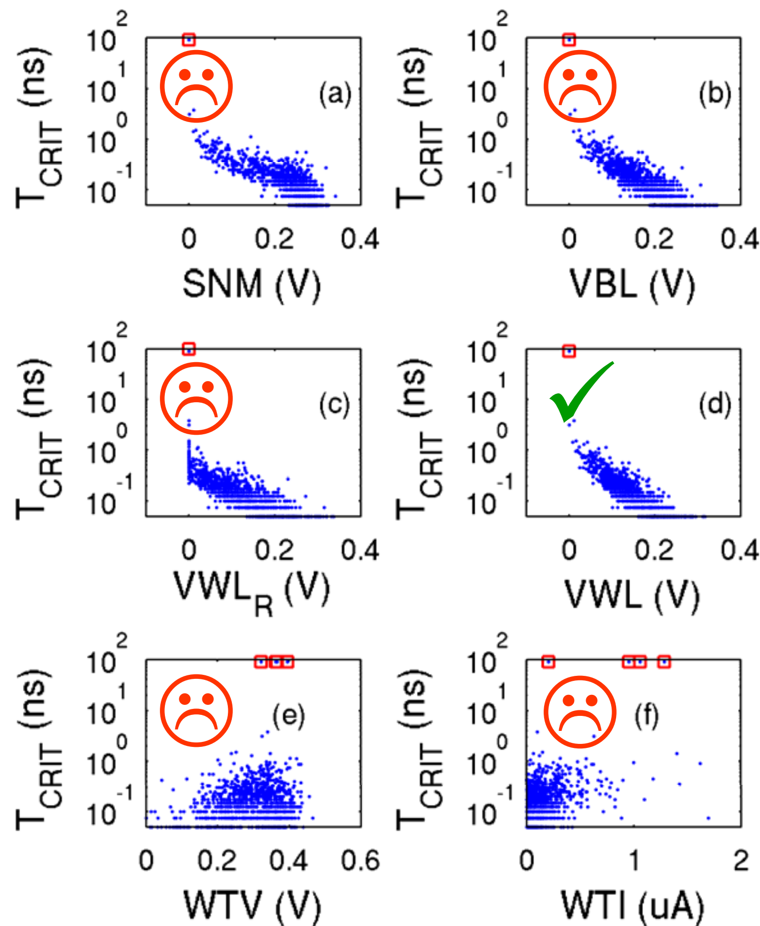
Correlation with Access transistor

	T_{CRIT}	Least Sqs.	BL sweep	WL sweep 1	WL sweep 2	N-curve	
Corr. Coeff.	0.6	-0.54	-0.61	-0.60	-0.65	-0.15	-0.03

N-curve metrics poorly correlated with ΔV_T of Access FET

Correlation with static metrics



Correlations at VDD = 0.6 V

Can use static metric to prescreen and follow up with dynamic metric

Best correlated static metric: WL sweep 2

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- Modeled write operation as current noise pulse.
- Used Separatrix and T_{CRIT} for dynamic write-ability.
- Studied correlation between static and dynamic metrics.
- Found most correlated static metric.

- Thank you for your attention.
- This work was supported by the MARCO/DARPA Focus Research Center for Circuit and Systems Solutions(C2S2) and by the SRC.
- Any Questions?