

# 2.5X Endurance Extended by a 3-Dimensional DSP

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- What is Word-line Direction Data Pattern Effect?
  - WL Cell-to-cell Interference (WCI) During Program Operation
  - Charge Lateral Migration (CLM) During Retention
- Phison's New Finding: What is Bit-line Direction Data Pattern Effect (BLDPE)?
- A Novel 3-Dimensional Digital Signal Processing Algorithm
  - Combining the Word-line and Bit-line Direction Data Pattern Effect

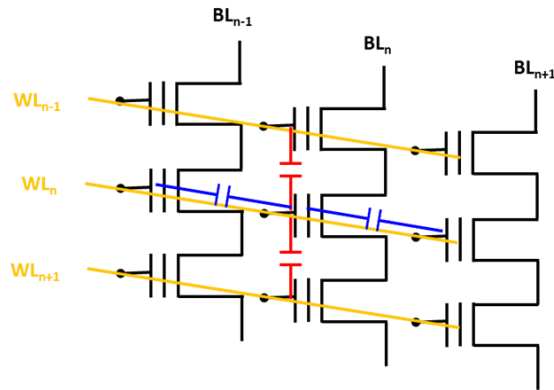
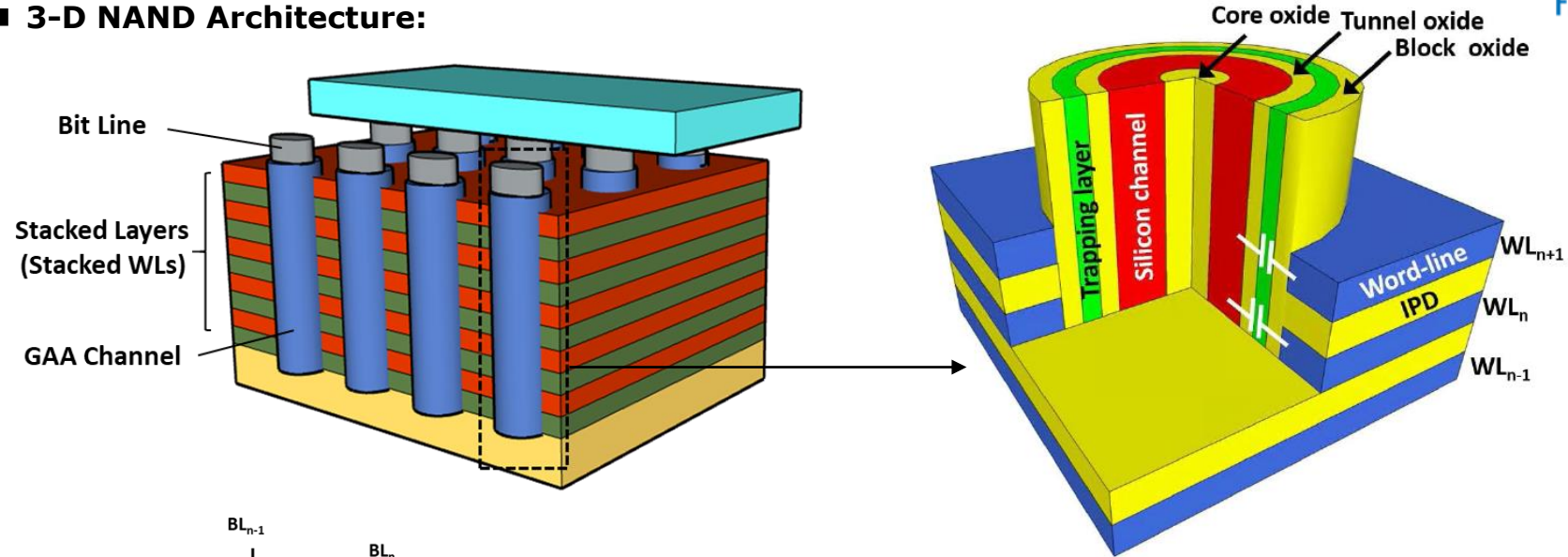


# Interference in 3-D NAND Flash



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## ■ 3-D NAND Architecture:



■ Stronger cell-to-cell interference, including WL and BL directions, is observed as devices are scaled.

—|—|— WL to WL interference  
—|—|— BL to BL interference

# Word-line Direction Data Pattern Effect

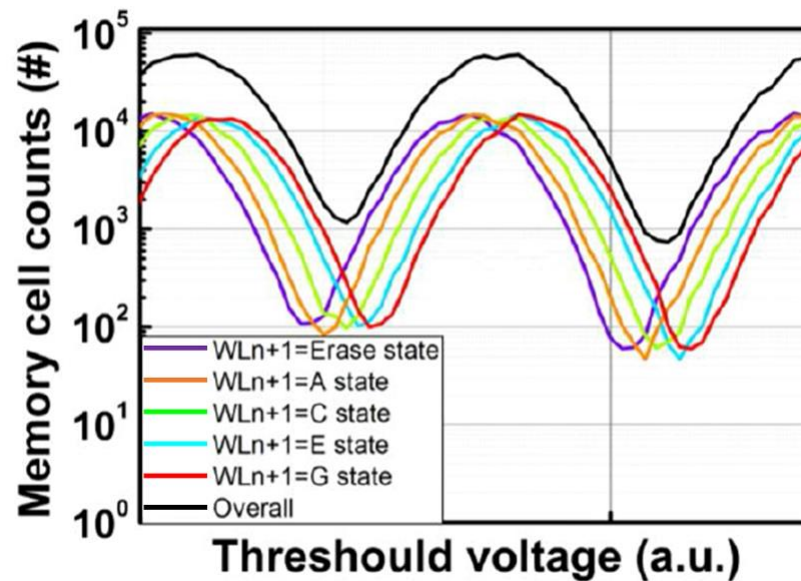
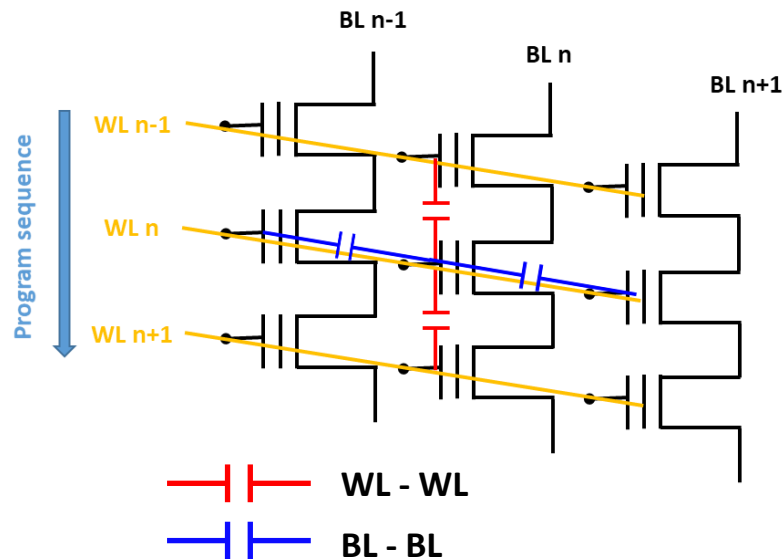


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Phison's Previous Work

(Ref. W. Lin et al., ITW, 2017)

## ■ Cell-to-cell Interference During Program Operation:



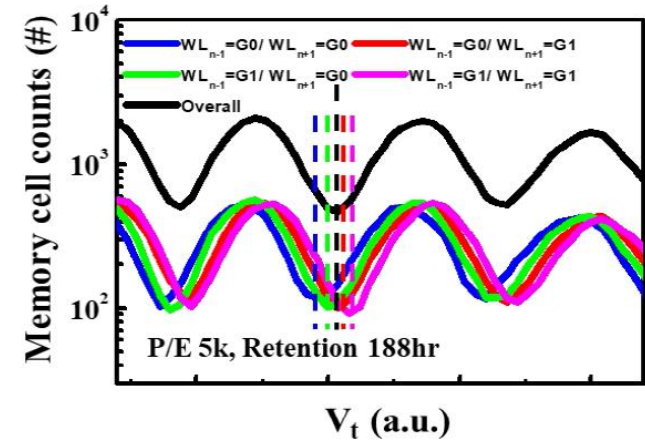
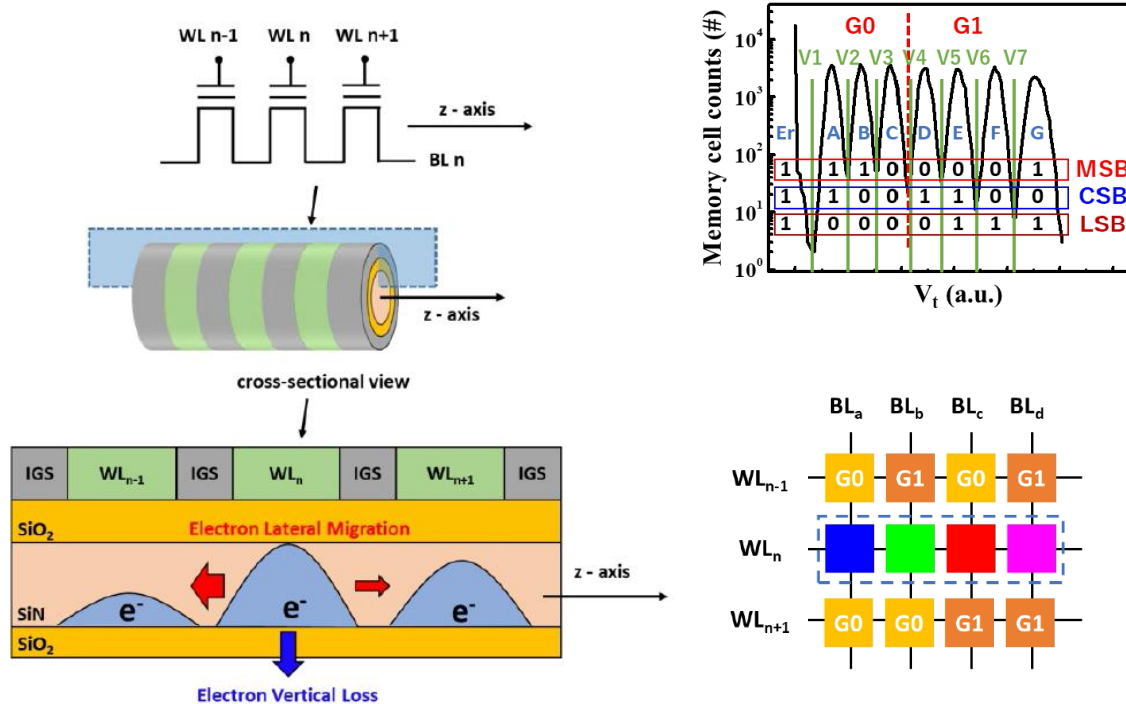
## ■ Threshold voltage ( $V_t$ ) of the word-line ( $WL_n$ ) is disturbed by the program operation on the next WL ( $WL_{n+1}$ ) due to cell-to-cell interference.

# Word-line Direction Data Pattern Effect



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## ■ Charge Lateral Migration During Retention:



- Also,  $V_t$  retention loss on  $WL_n$  induced by silicon nitride trapped charge lateral migration is affected by the amount of stored charges in both  $WL_{n+1}$  and  $WL_{n-1}$ .

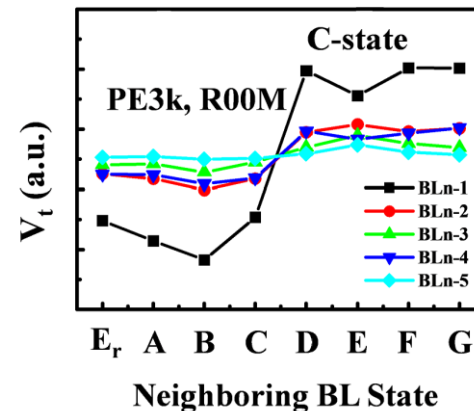
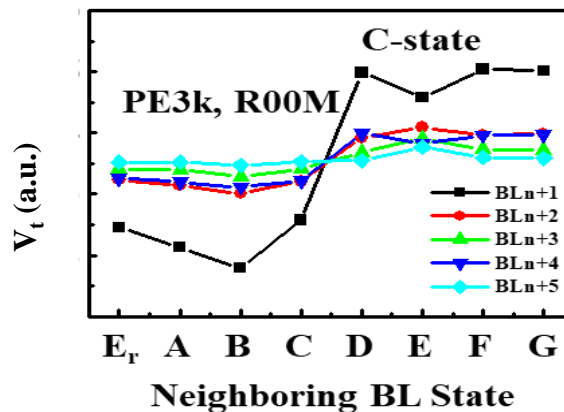
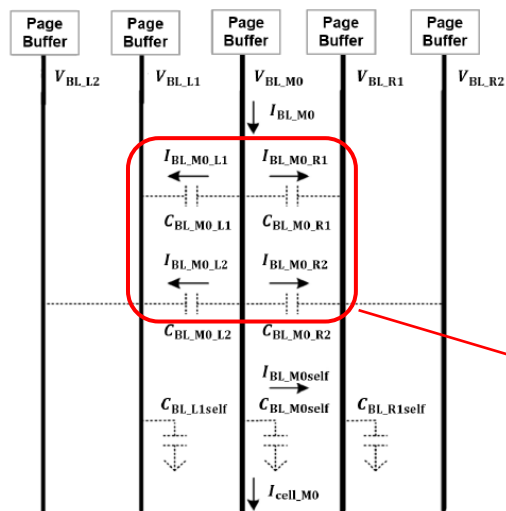
# Bit-line Direction Data Pattern Effect



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## Phison's New Finding!

### ■ Bit-line Configuration



#### Adjacent BL at lower $V_t$ state

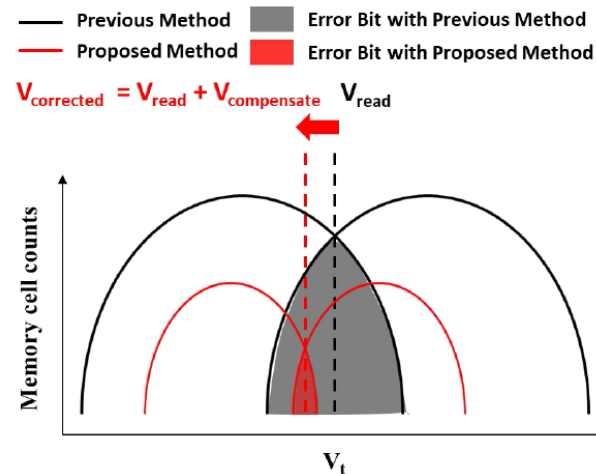
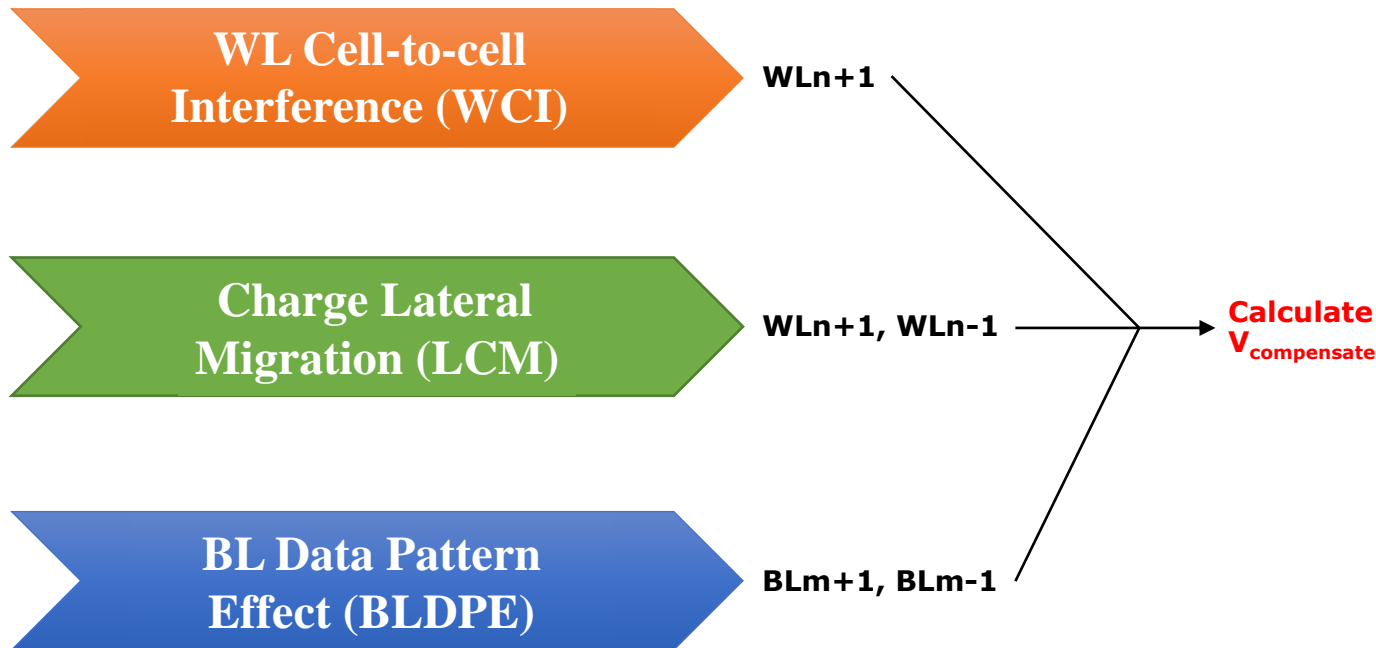
-> Target BL discharges faster ->  $V_t$  of target cell is lower

#### Adjacent BL at higher $V_t$ state

-> Target BL discharges slower ->  $V_t$  of target cell is higher

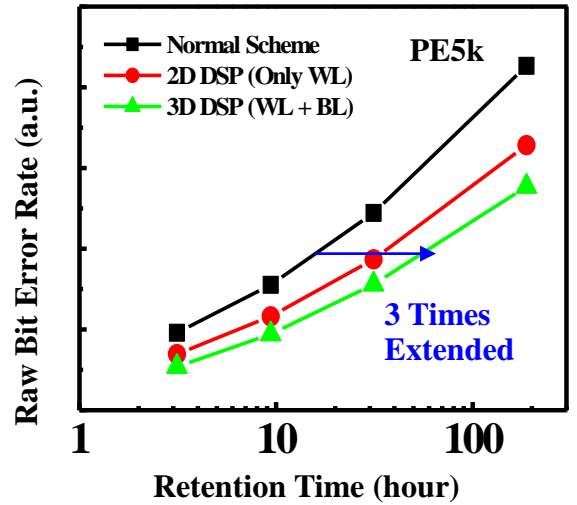
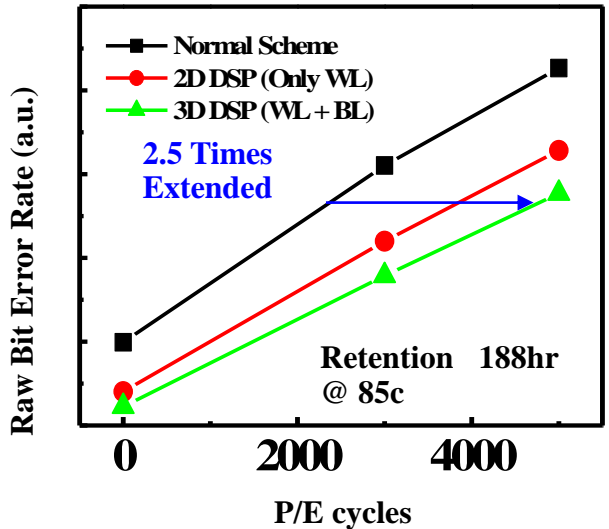
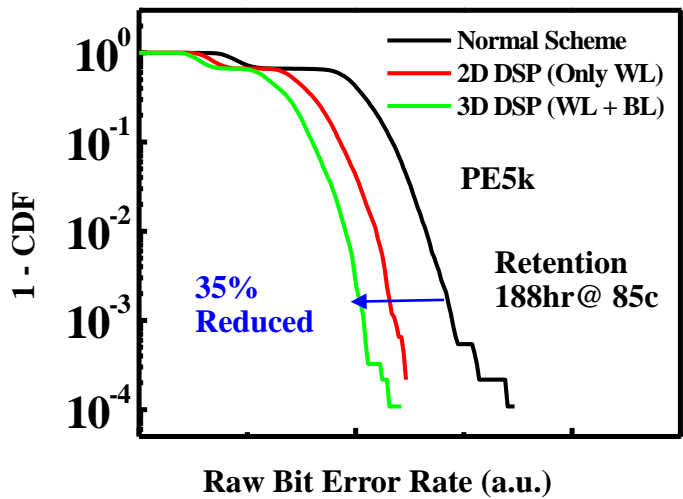
# A Novel 3-D Digital Signal Processing Algorithm

## ■ 3-Dimensional (WCI, LCM, BLDPE) digital signal processing algorithm:



- With the proposed signal processing algorithm, extra read operations are conducted to detect the program states of neighboring WLs/BLs. By measuring the states of adjacent cells, a tight  $V_t$  distribution on the target cell is obtained accordingly.

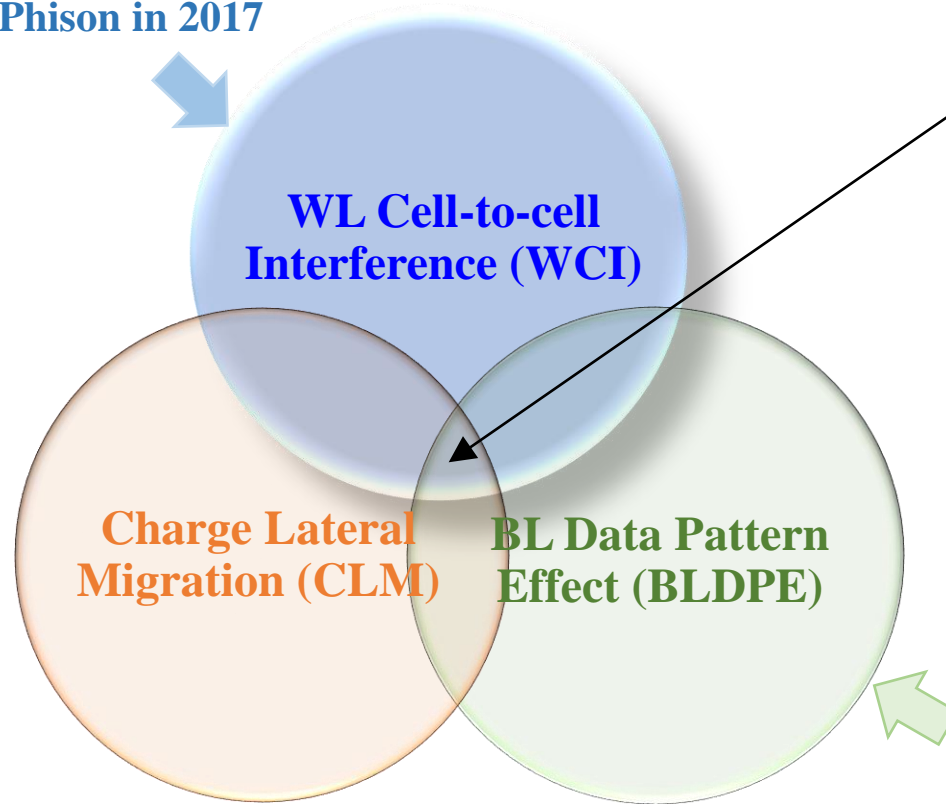
# A Novel 3-D Digital Signal Processing Algorithm





# Conclusion

The original DSP algorithm  
based on WCI was proposed  
by Phison in 2017



**3D DSP Algorithm:**



**Error Bit: 35% Reduced**

**Endurance: 2.5 Times Extended**

**Retention: 3 Times Extended**

**Phison's New Finding in 2023**



**THANK YOU!**

