CROW
A Low-Cost Substrate for Improving DRAM Performance, Energy Efficiency, and Reliability

Hasan Hassan
Minesh Patel      Jeremie S. Kim      A. Giray Yaglikci      Nandita Vijaykumar
Nika Mansouri Ghiasi      Saugata Ghose      Onur Mutlu

ETH Zürich
Carnegie Mellon University
Challenges of DRAM Scaling
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1. access latency
Challenges of DRAM Scaling

1. access latency
2. refresh overhead
Challenges of DRAM Scaling

1. access latency
2. refresh overhead
3. exposure to vulnerabilities
Conventional DRAM
Conventional DRAM

DRAM Subarray

row decoder

sense amplifier
Conventional DRAM

![Diagram of Conventional DRAM with DRAM Subarray and Sense Amplifier]
Copy Row DRAM (CROW)
Copy Row DRAM (CROW)

DRAM Subarray

regular rows

copy rows

sense amplifier

Row copy

SA
SA
SA
SA
SA
SA
SA

Copy Row DRAM (CROW)

Row copy
Multiple row activation
Use Cases of CROW
Use Cases of CROW

➢ CROW-cache
  ✓ reduces *access latency*
Use Cases of CROW

➢ CROW-cache
✓ reduces access latency
Use Cases of CROW

➢ CROW-cache
✓ reduces access latency
Use Cases of CROW

- **CROW-cache**
  - ✓ reduces *access latency*

- **CROW-ref**
  - ✓ reduces DRAM *refresh overhead*
Use Cases of CROW

➢ CROW-cache
  ✓ reduces access latency

➢ CROW-ref
  ✓ reduces DRAM refresh overhead
Use Cases of CROW

➢ CROW-cache
  ✓ reduces access latency

➢ CROW-ref
  ✓ reduces DRAM refresh overhead

➢ A mechanism for protecting against RowHammer
Key Results
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CROW-cache + CROW-ref

• 20% speedup
• 22% less DRAM energy
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CROW-cache + CROW-ref

- 20% speedup
- 22% less DRAM energy

Hardware Overhead

- 0.5% DRAM chip area
- 1.6% DRAM capacity
- 11.3 KiB memory controller storage
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