SSD Characterization:
From Energy Consumption's Perspective

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Dankook University

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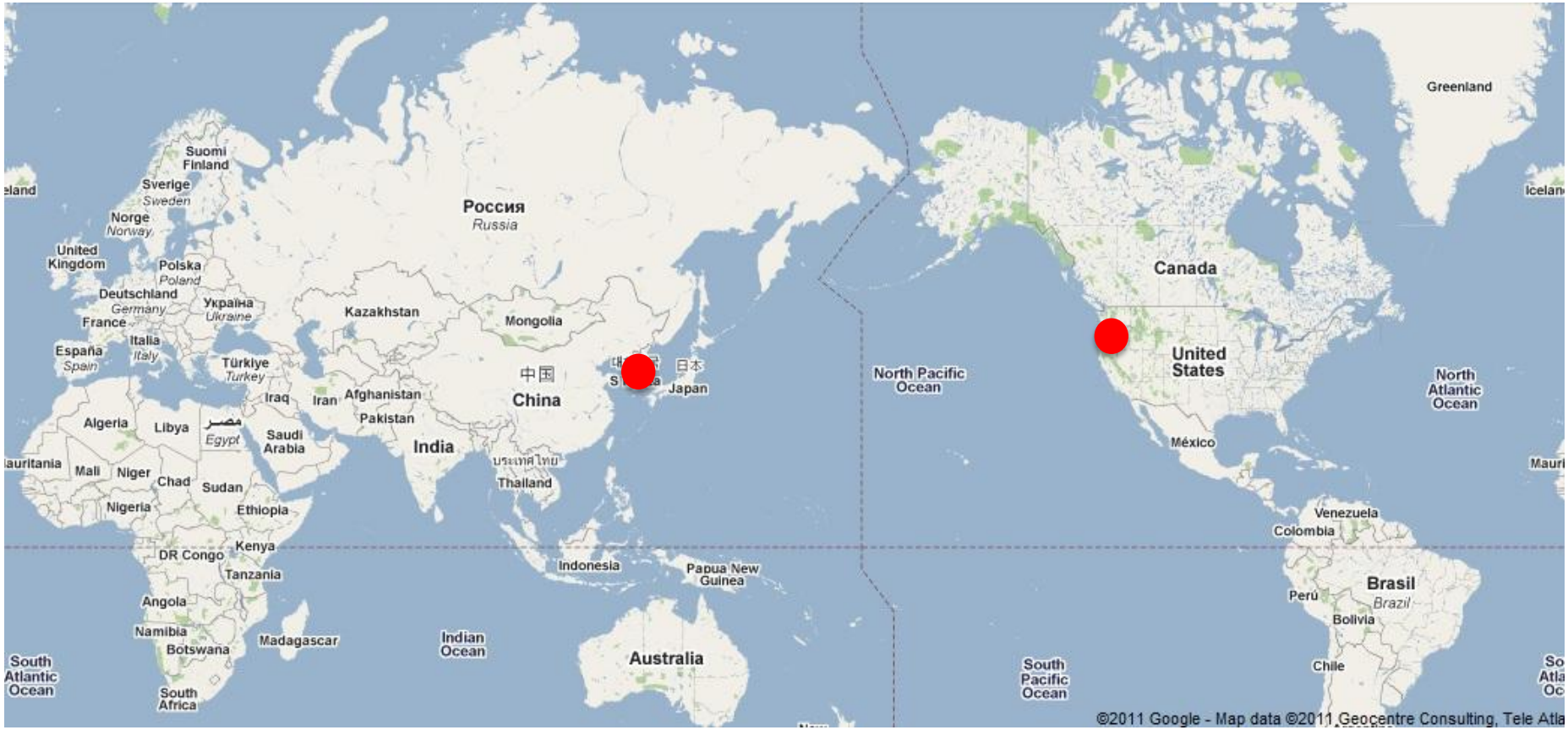
Korea University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Indonesia
Papua New
Guinea
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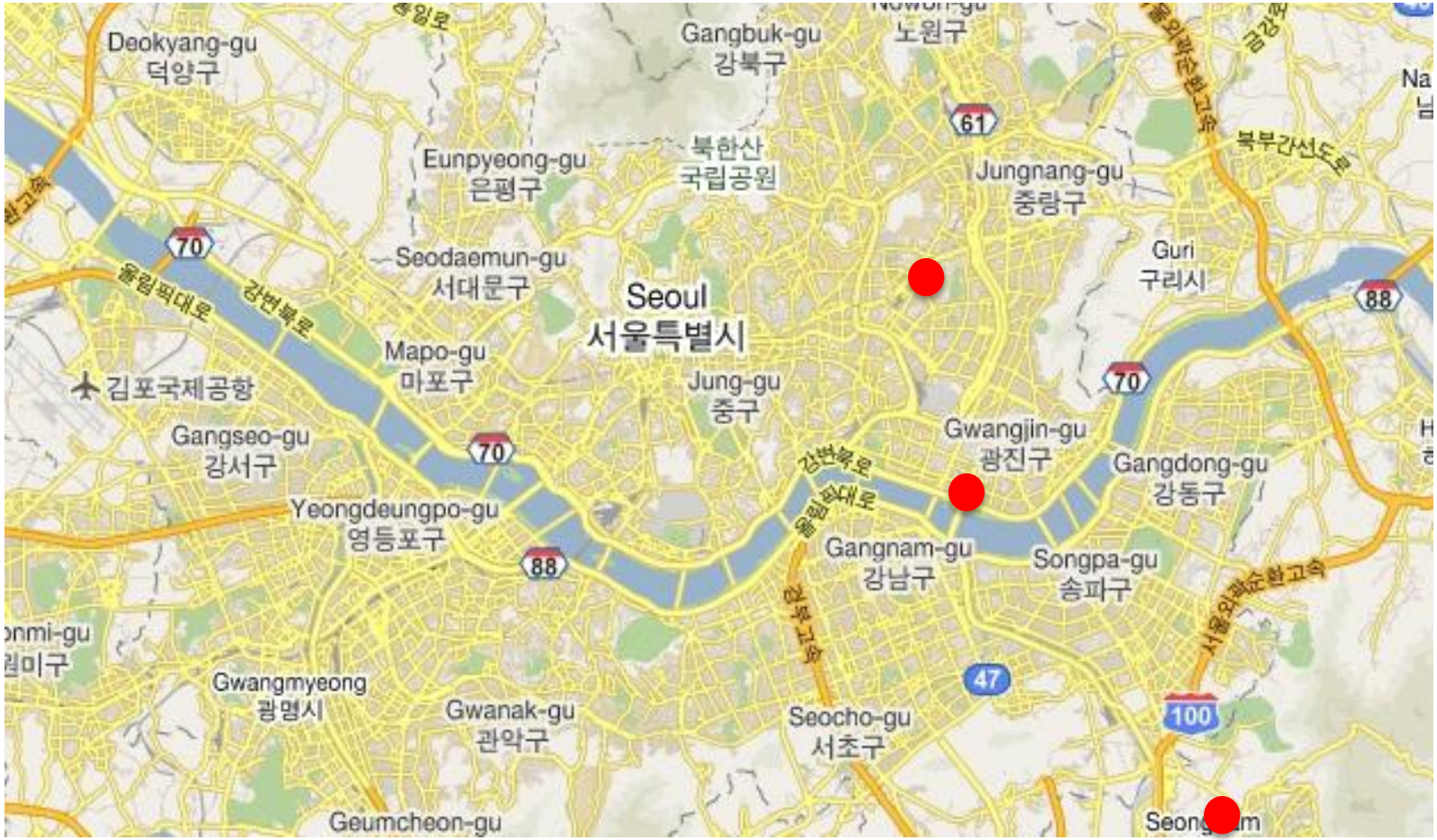
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61
70
88
47
100

Outline

- Motivation
- SSD Organization and Energy Consumption
- Channels, Ways and Clusters
- Case Study
- Power Budget
- Conclusion

Motivation

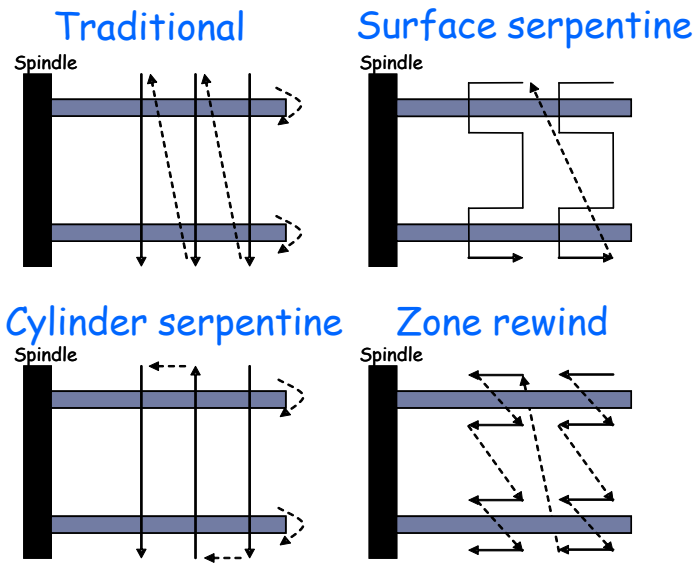
Motivation

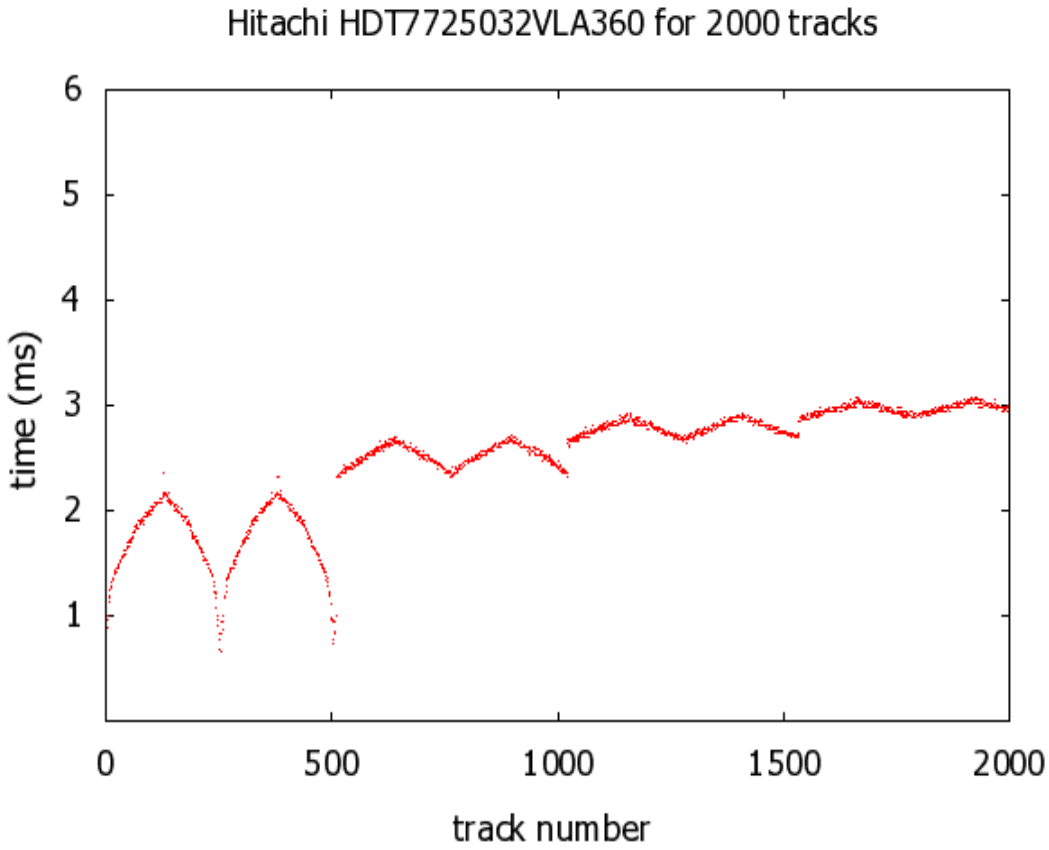
Understanding of Internal Mechanism of Storage Device is very important!

- Hard disk
  - Sector layout: cylinder serpentine vs. surface serpentine vs. hybrid serpentine
  - Number of zones
  - Degree of track skew
  - Disk scheduling algorithm

Characterizing HDD: Sector Layout

- Jongmin Gim et al, ACM ToS 6, 2 (July 2010)





Characterizing Storage Devices

HDD Characterization is via measuring Seek time and Rotational Latency.

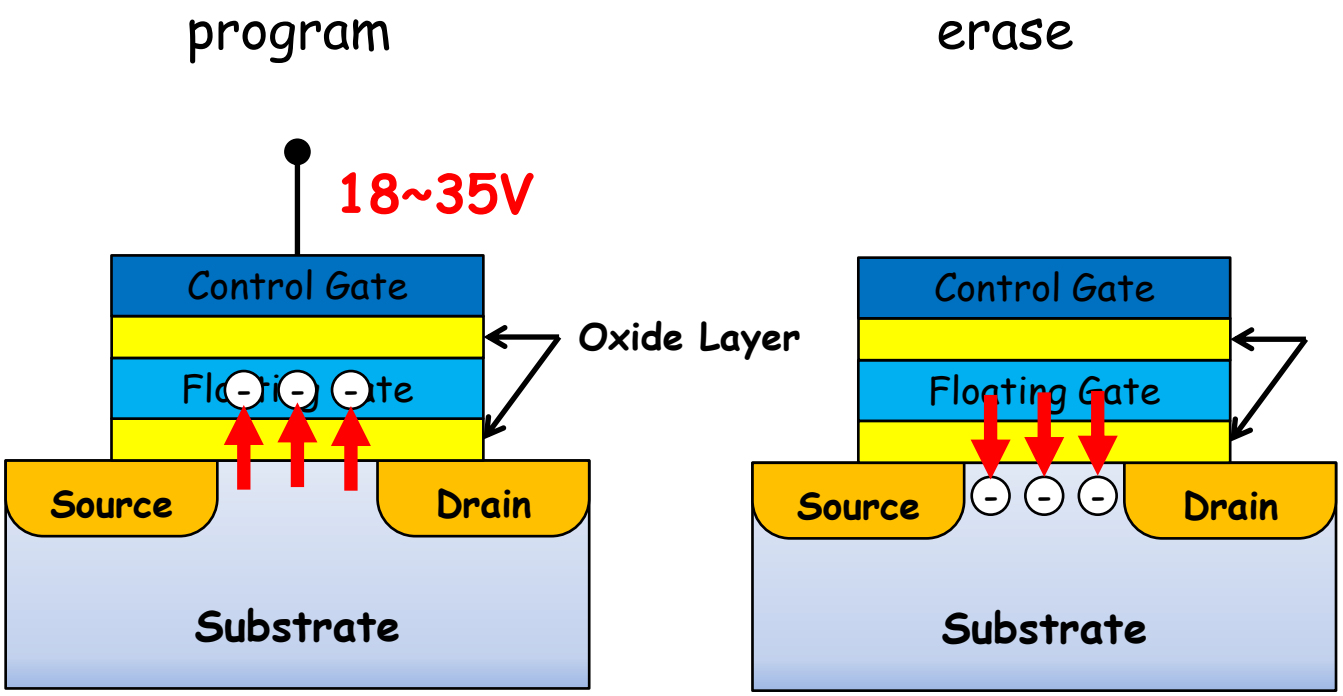
Characterizing SSD… what do we use?...

Motivation

How do we figure out the internals of SSD?

- What is available
  - the number of channels
  - the number of chips/packages per channels
- What is not available?
  - Sector placement , Garbage collection algorithm

Operations on NAND Flash Cell



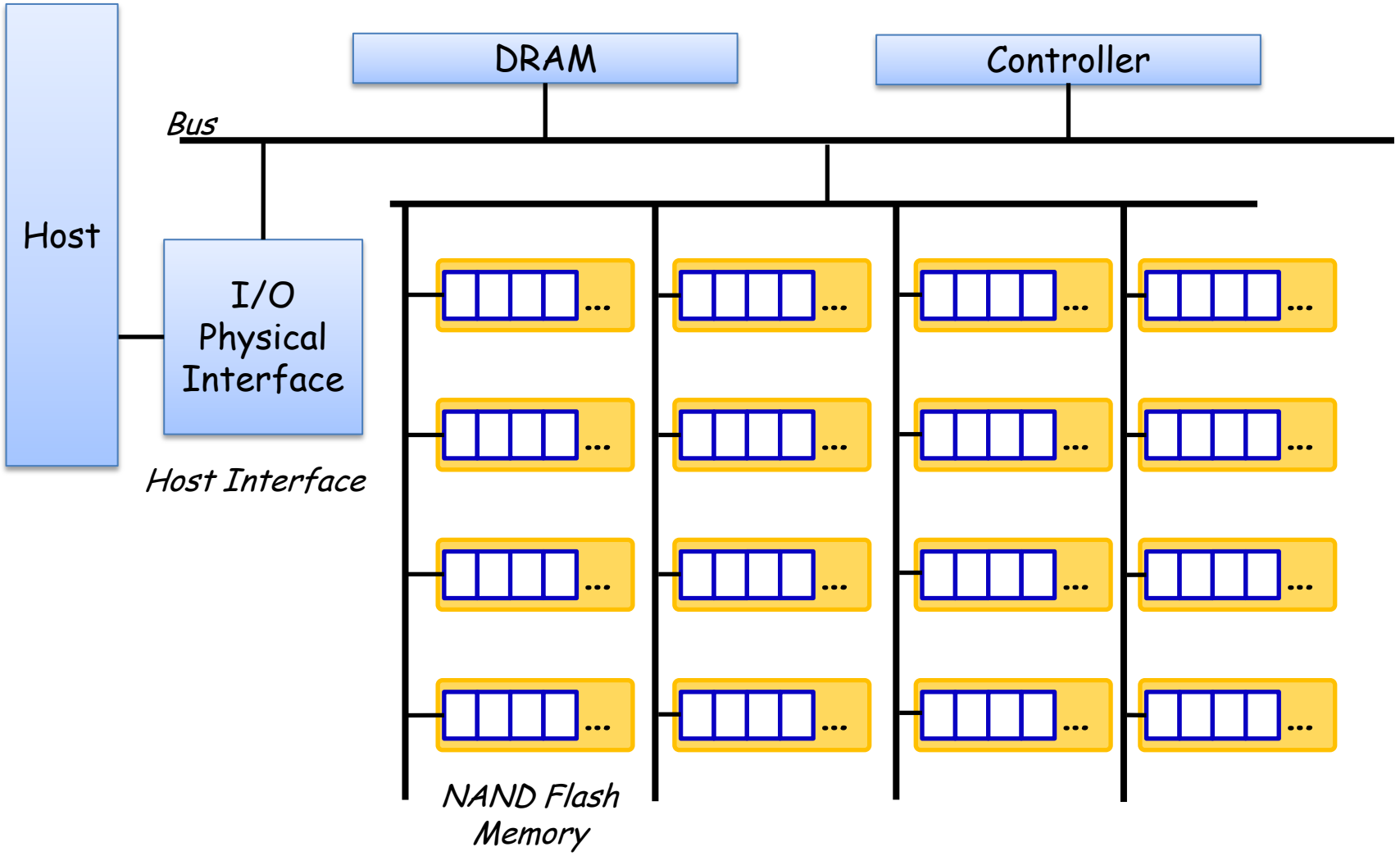
Operations on NAND Flash Cell

SSD Characterization

We will use "Energy Consumption"

SSD Organization and Energy Consumption

SSD Organization



Characteristics of SSD Behavior

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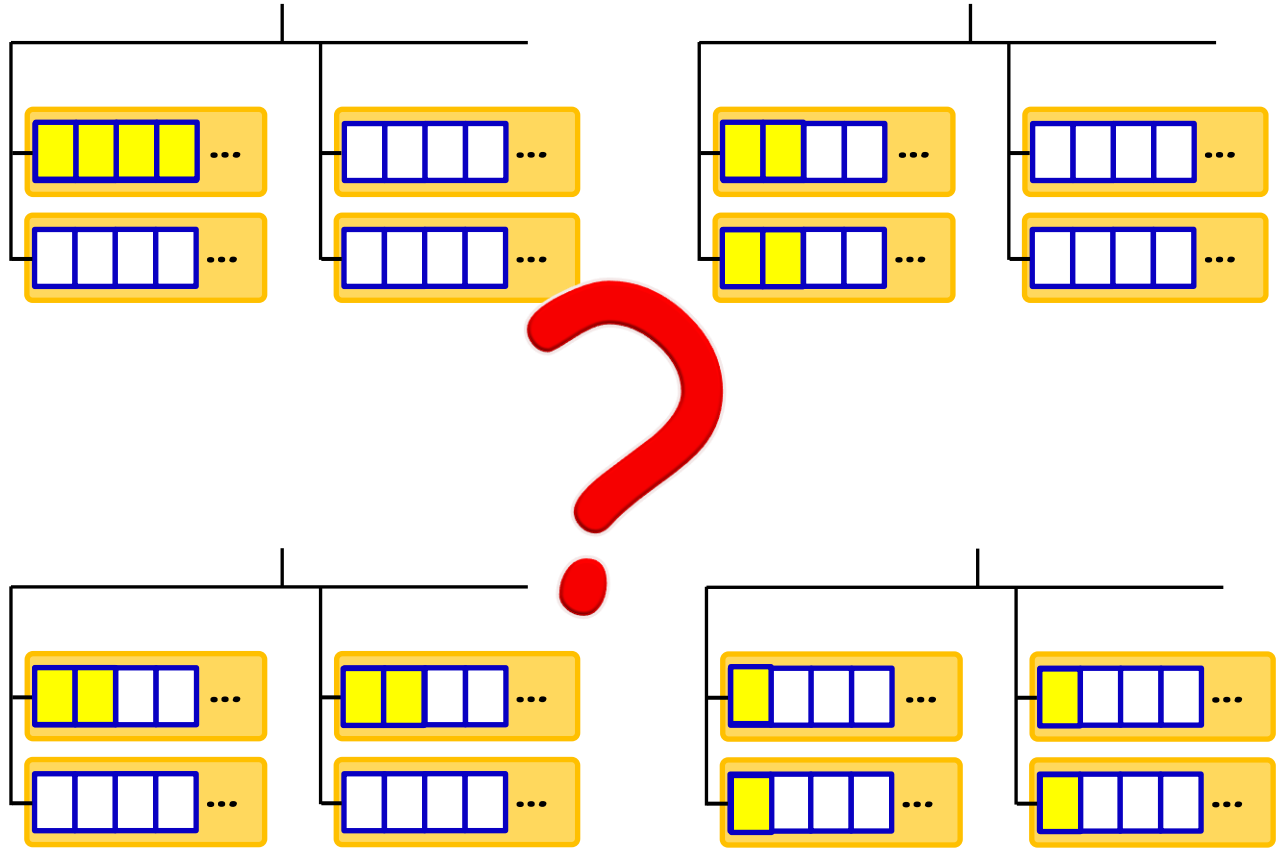
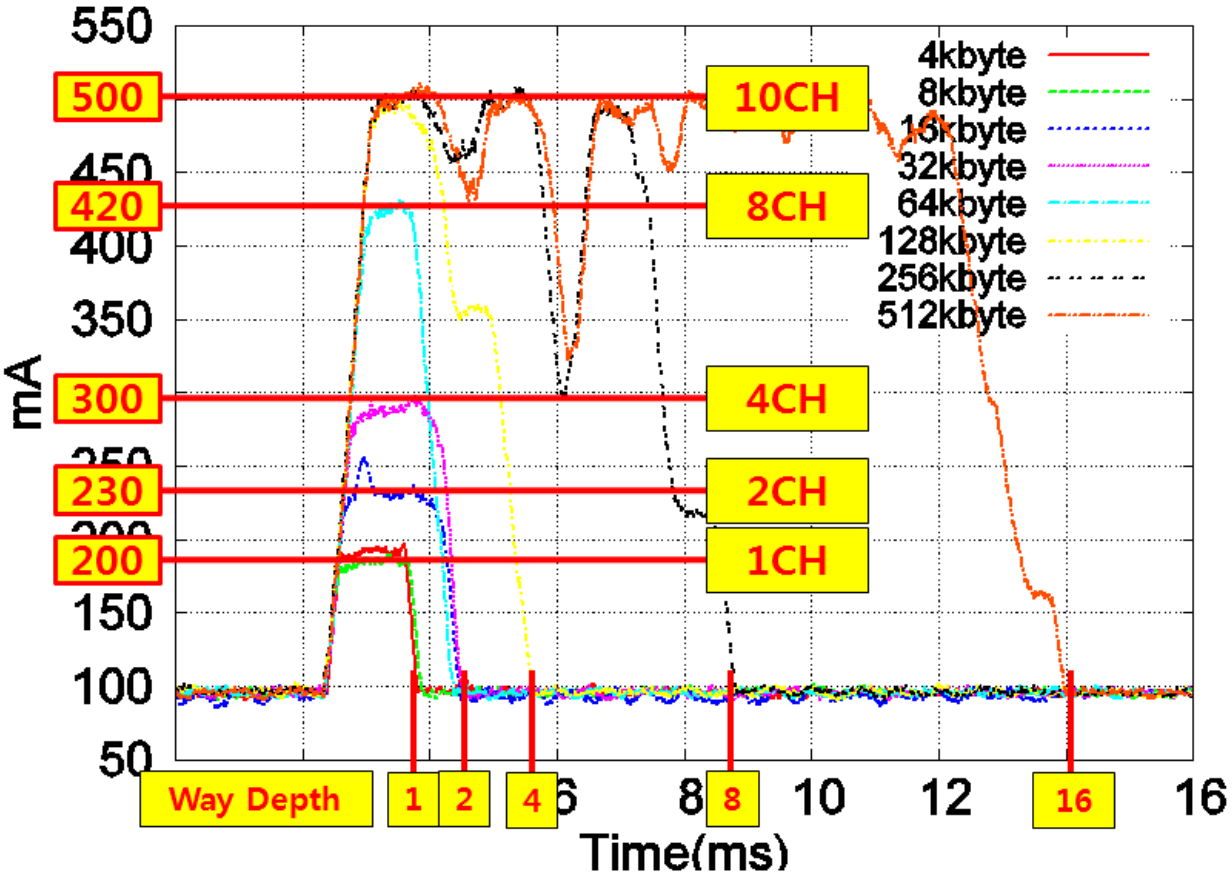
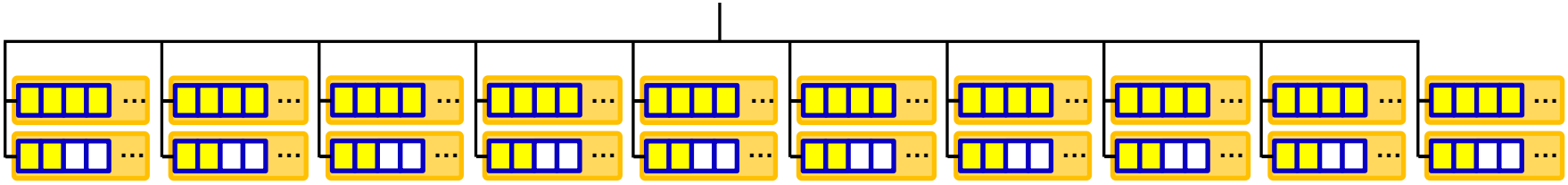


IO Size vs. Energy Consumption





Channels, Ways, and Clusters

Writing 4 pages: 1 Channel X 1 Way

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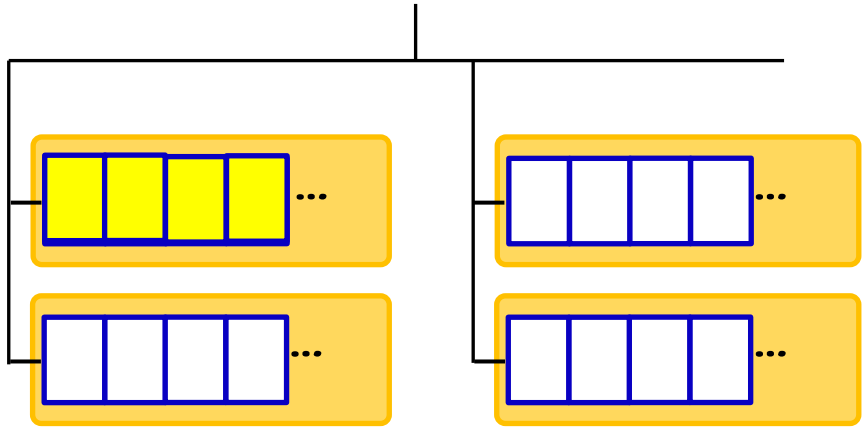
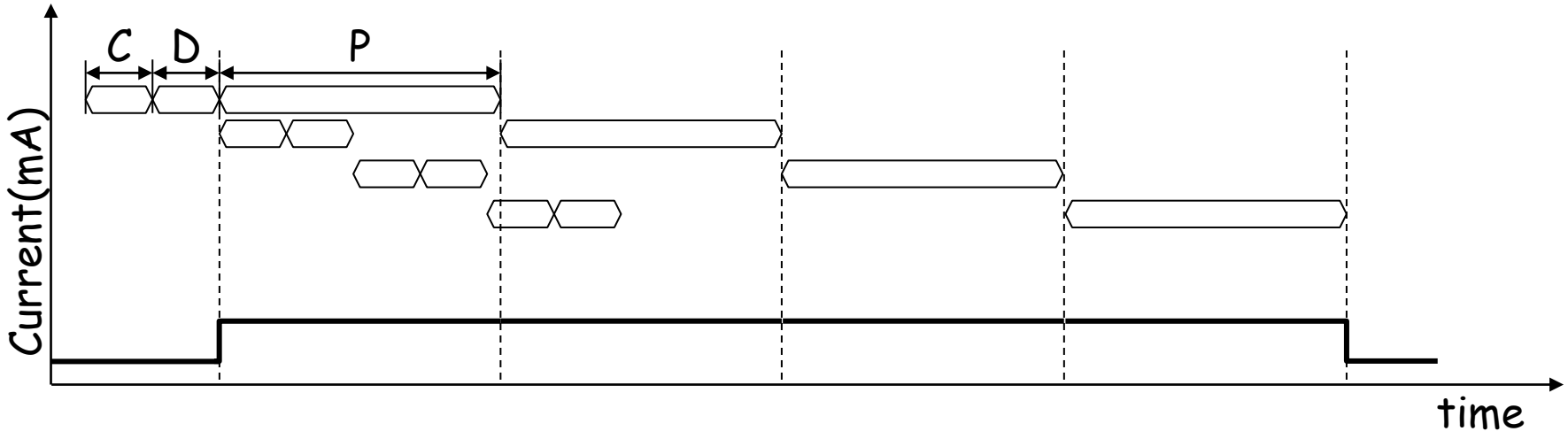
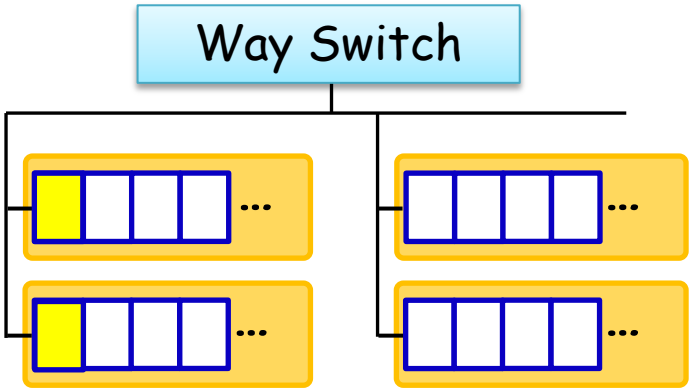
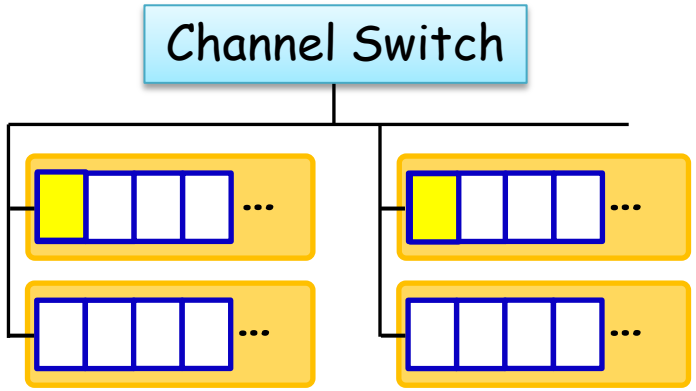
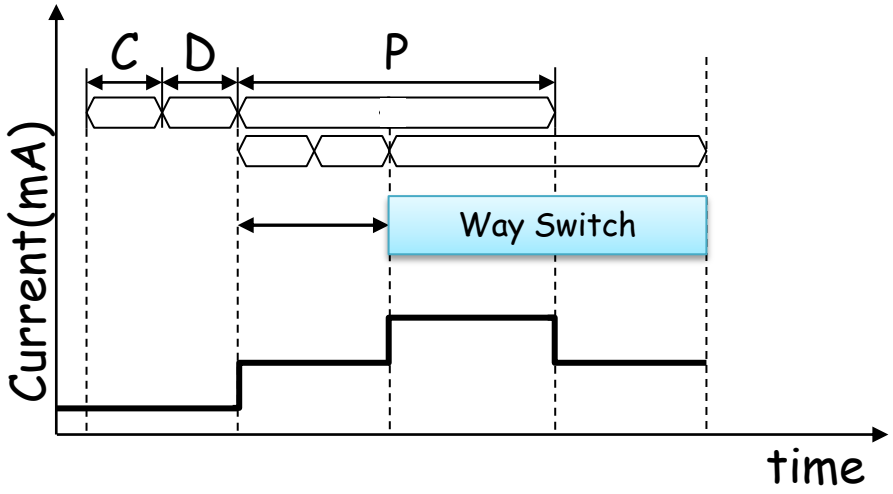


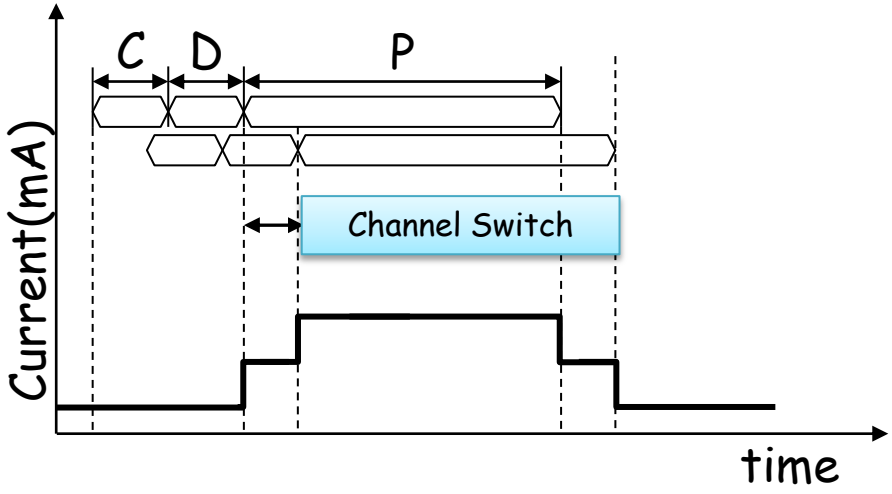


Way switch vs. Channel switch Delay









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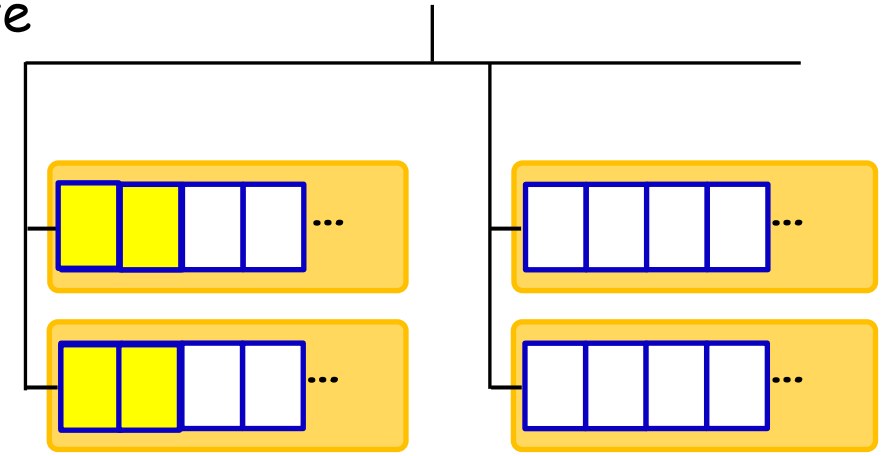

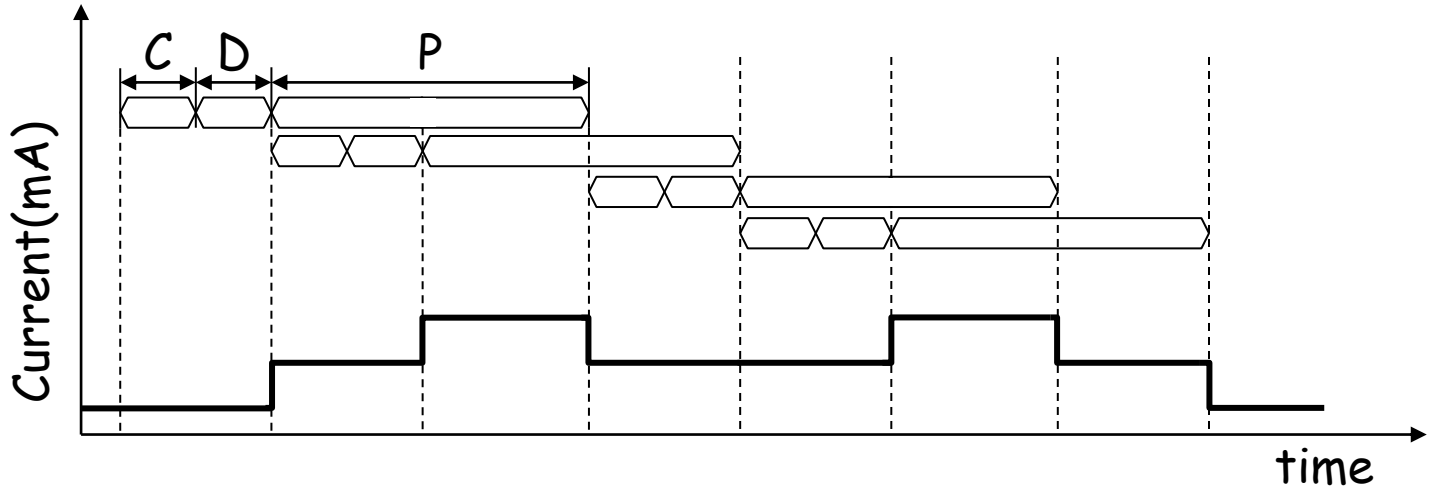

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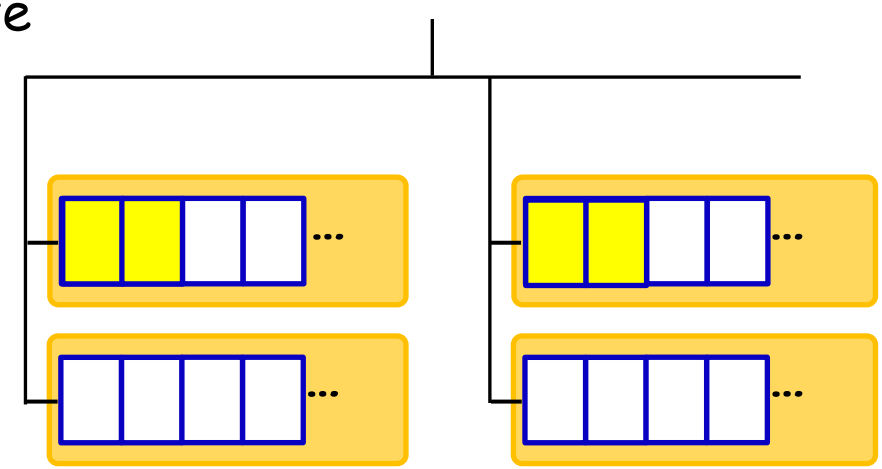

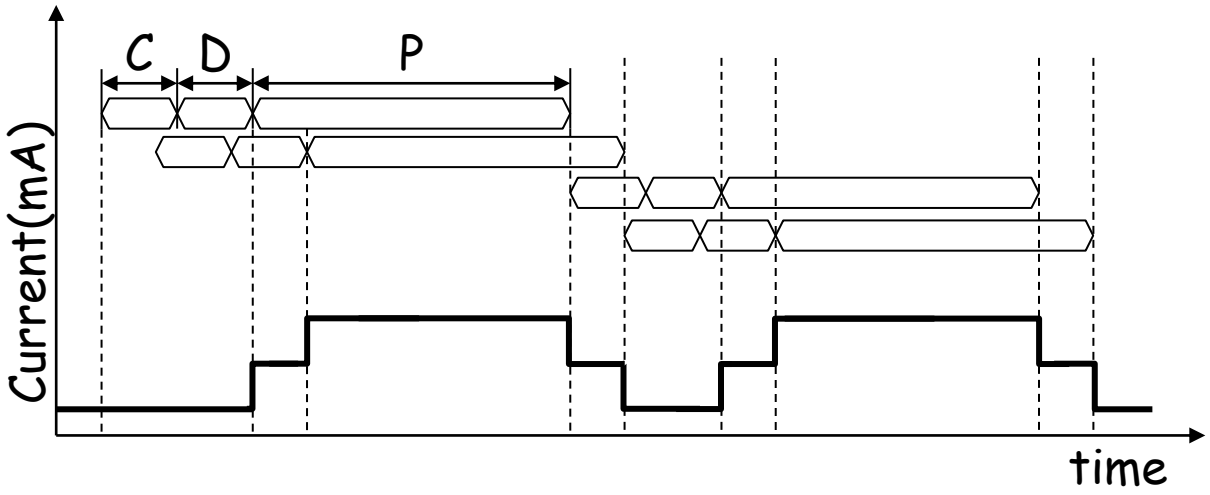

Writing 4 pages: 2 Channel X 2 Way

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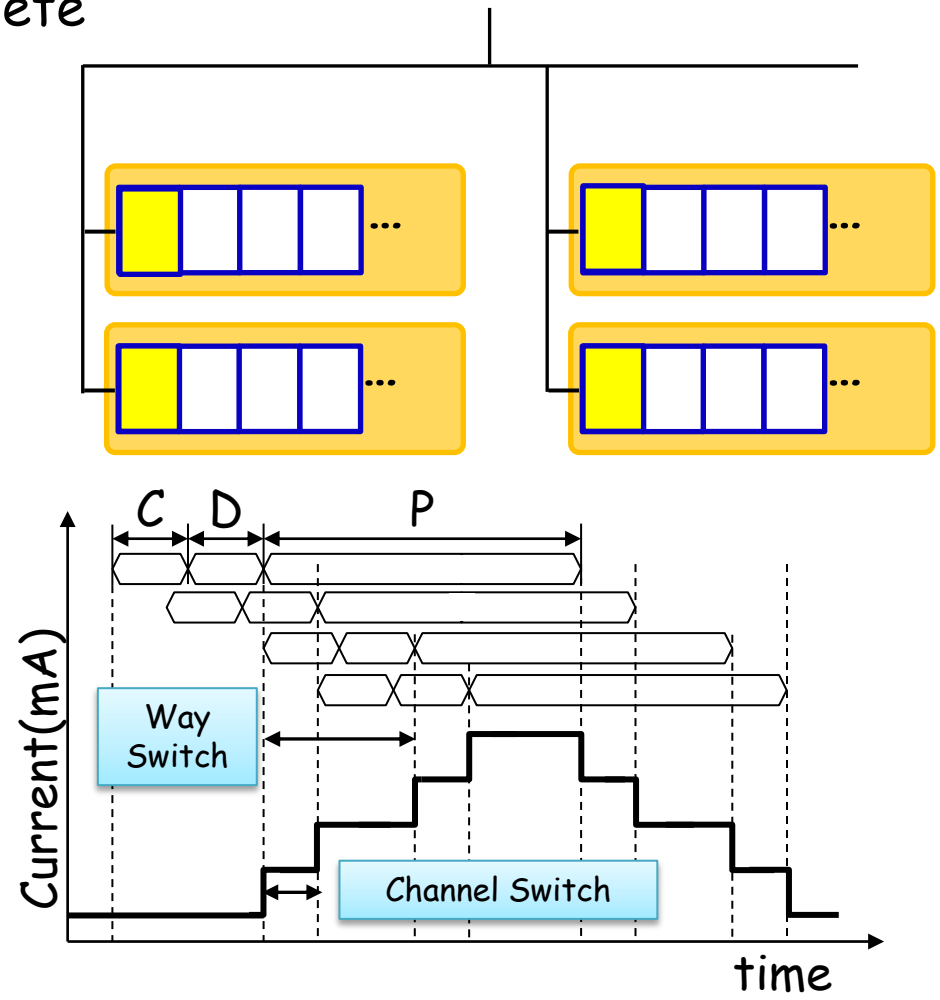
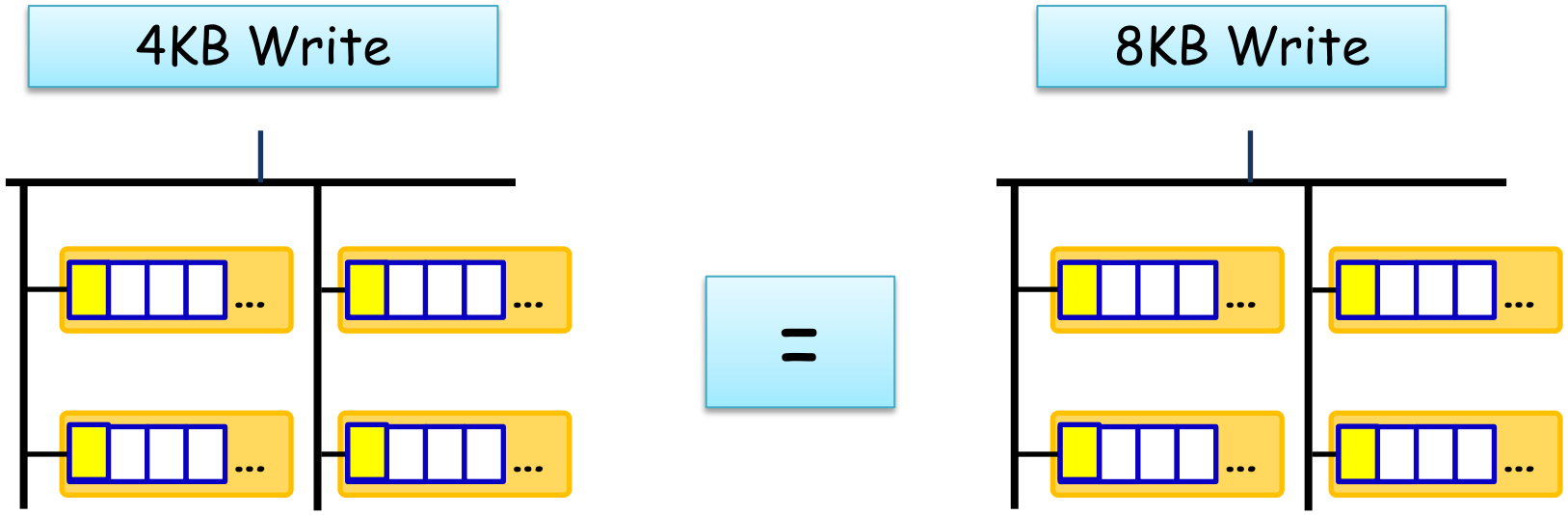


Cluster

- Cluster : Write Unit of SSD

=Page Write



Case Studies

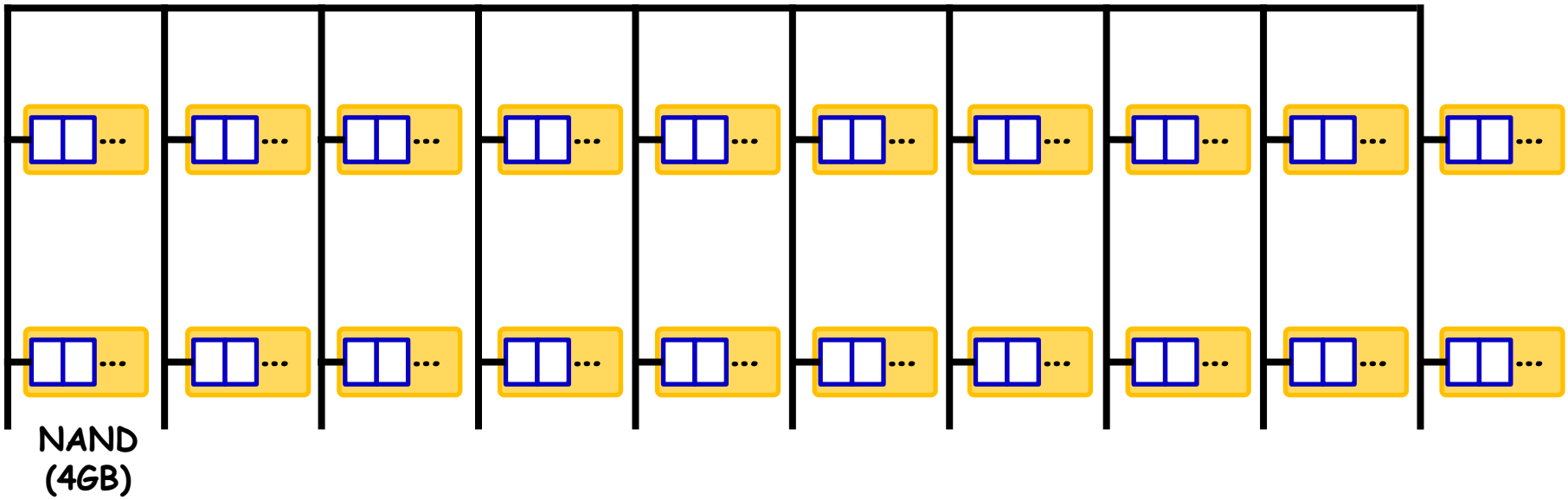
Measurement

Model	Vendor	Size	Channels	DRAM Size	Package	Type
X25M	Intel	80GB	10	16MB	20	MLC
MXP	SAMSUNG	128GB	8	128MB	16	MLC

- Oscilloscope (TDS3032)
- High resolution current probe(TCP202)
- Current probe to power line(V_{dd}) of the SSD
- Sampling interval(10samples MA): 10usec

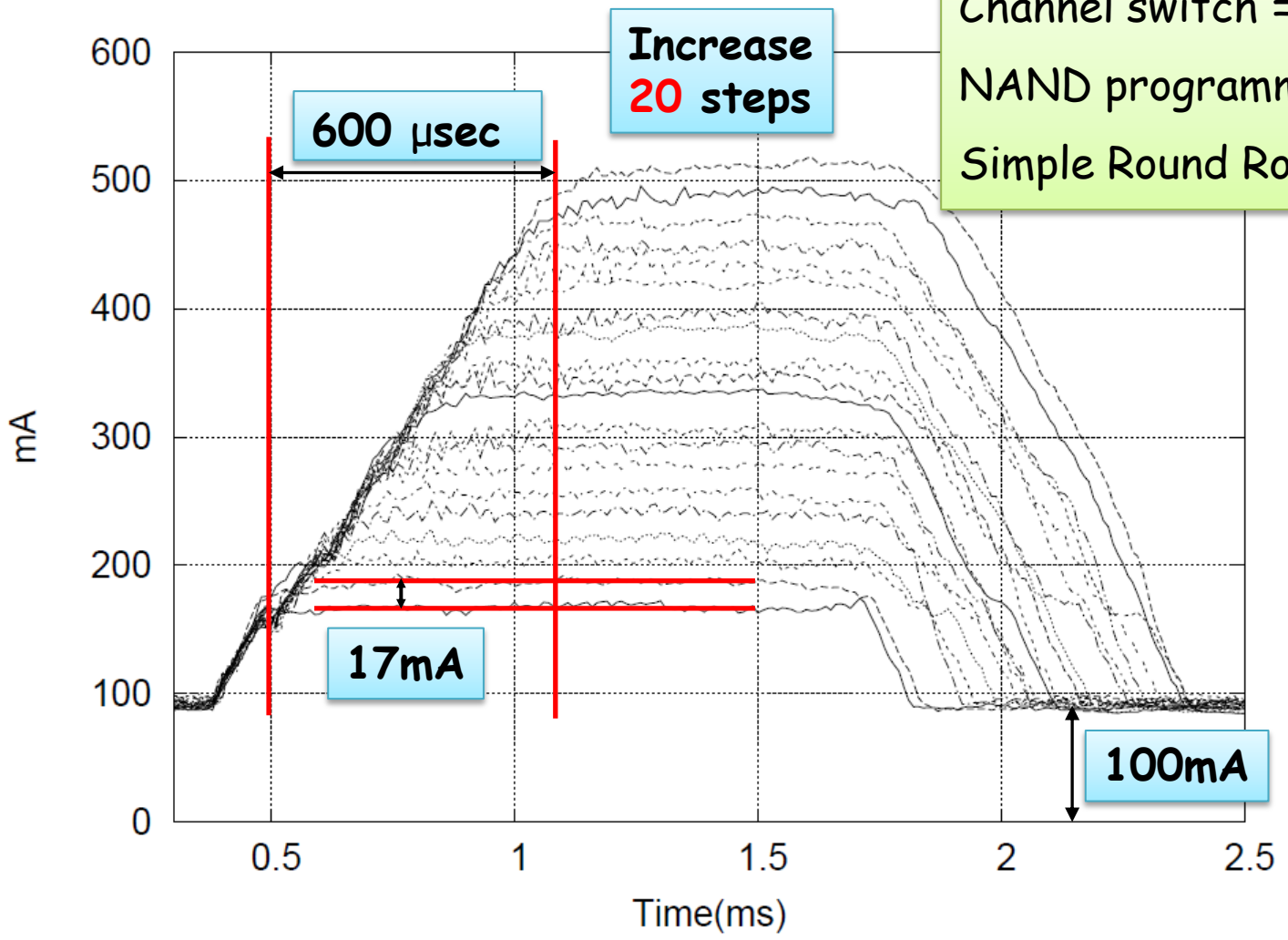
Case Study : Intel X25M

Capacity	80GB
No. of Channels	10
Packages/Channel	2
Package	4 GB



Case Study : Intel X25M

- IO Size: 4KB to 80KB

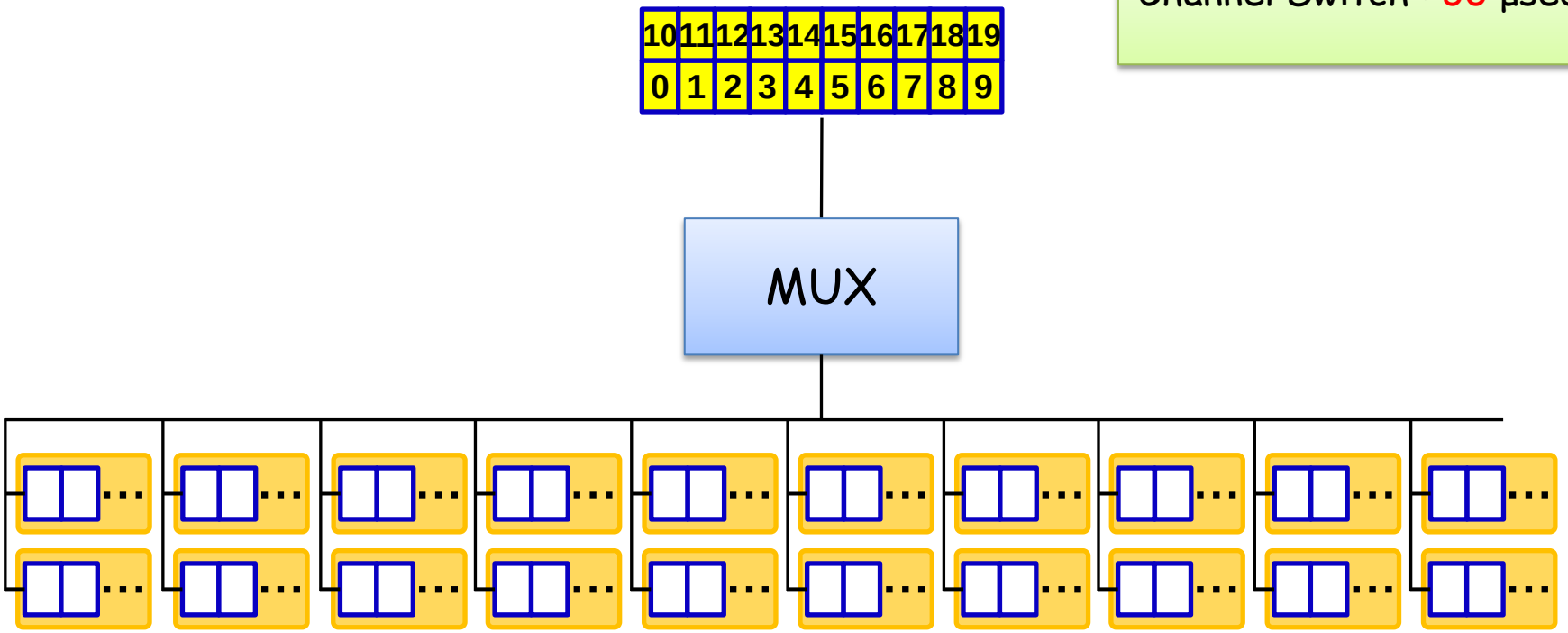


Case Study : Intel X25M

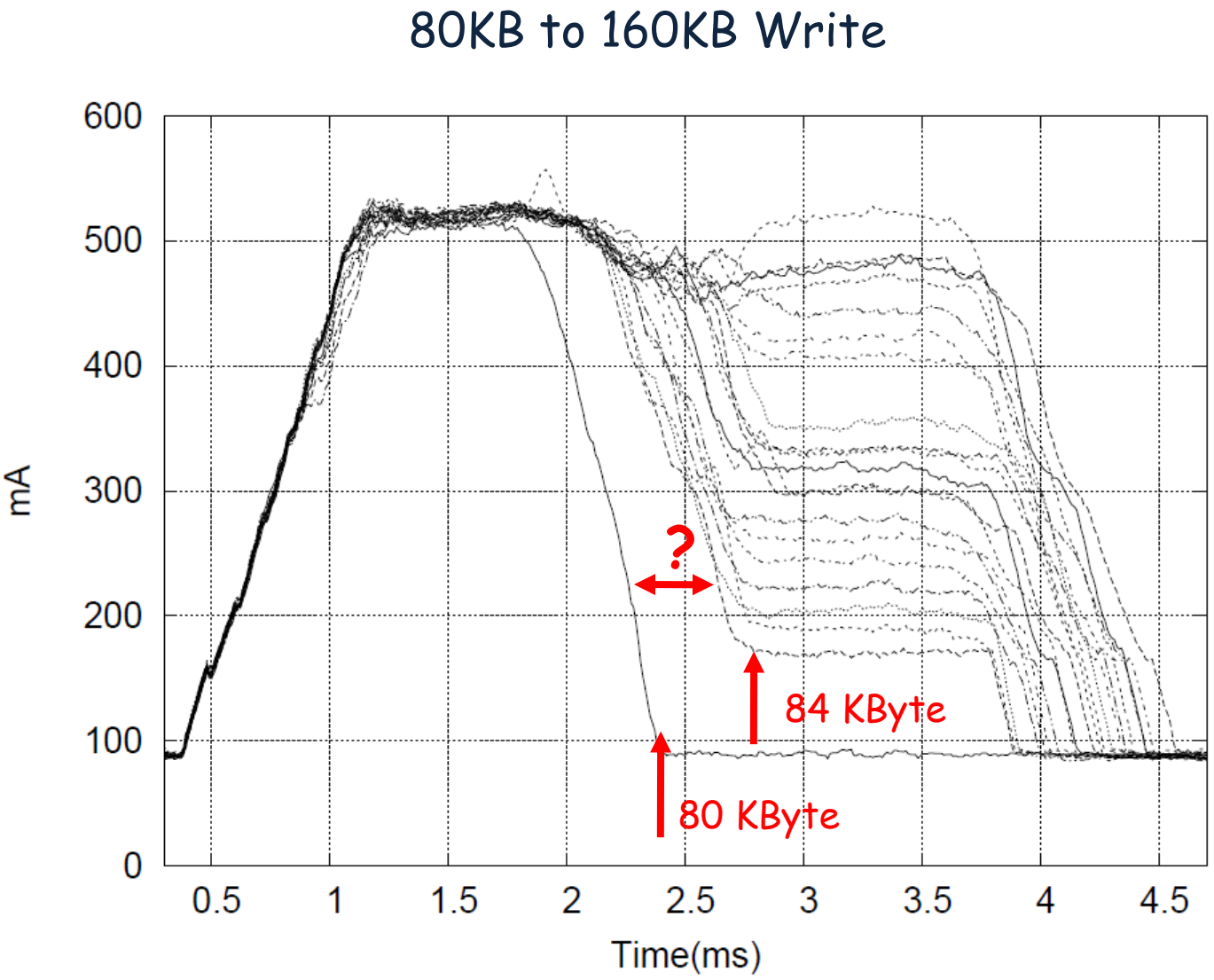
- 4KB to 80KB Sequential Write

= Page Write

Channel Switch =30 µsec



Case Study : Intel X25M



Case Study : Intel X25M

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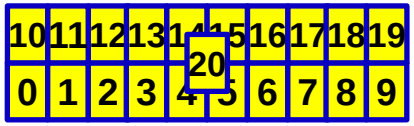
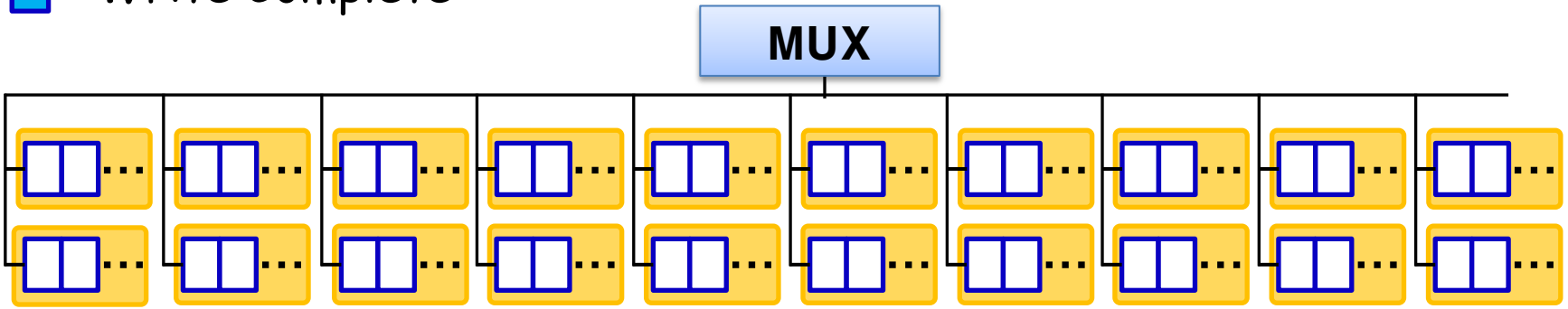
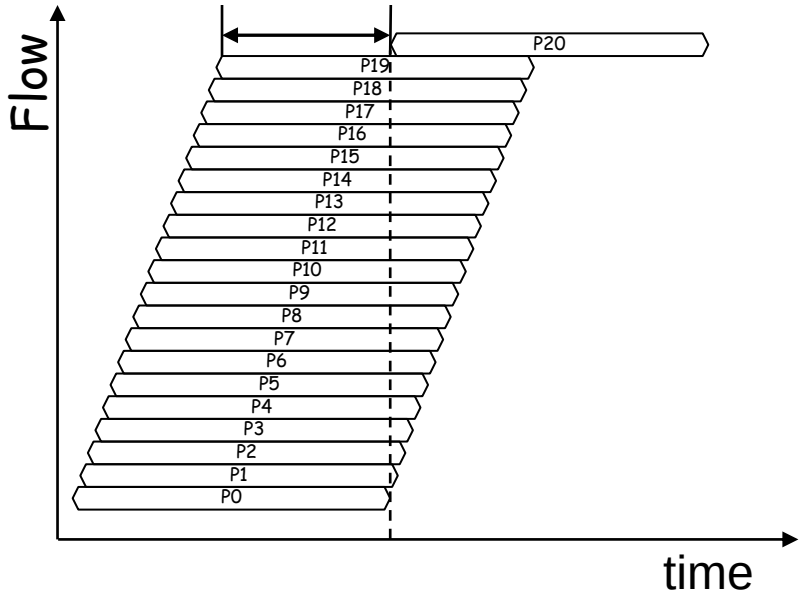
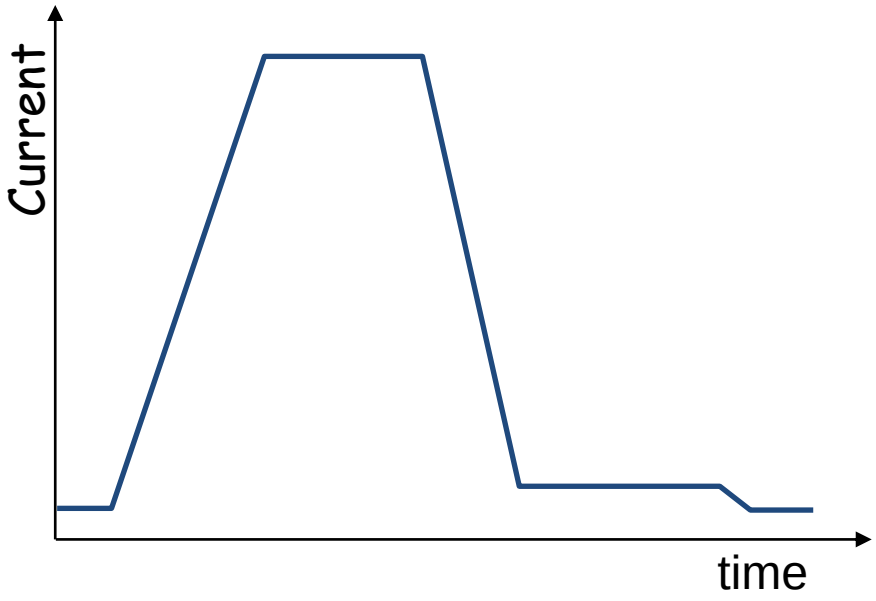


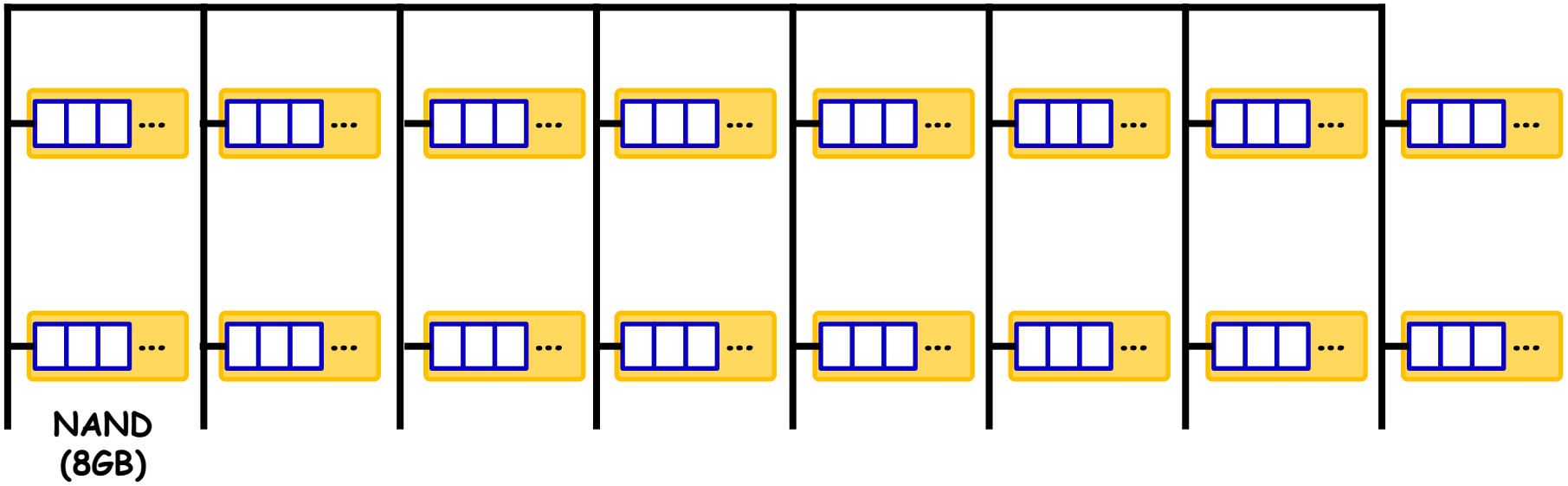




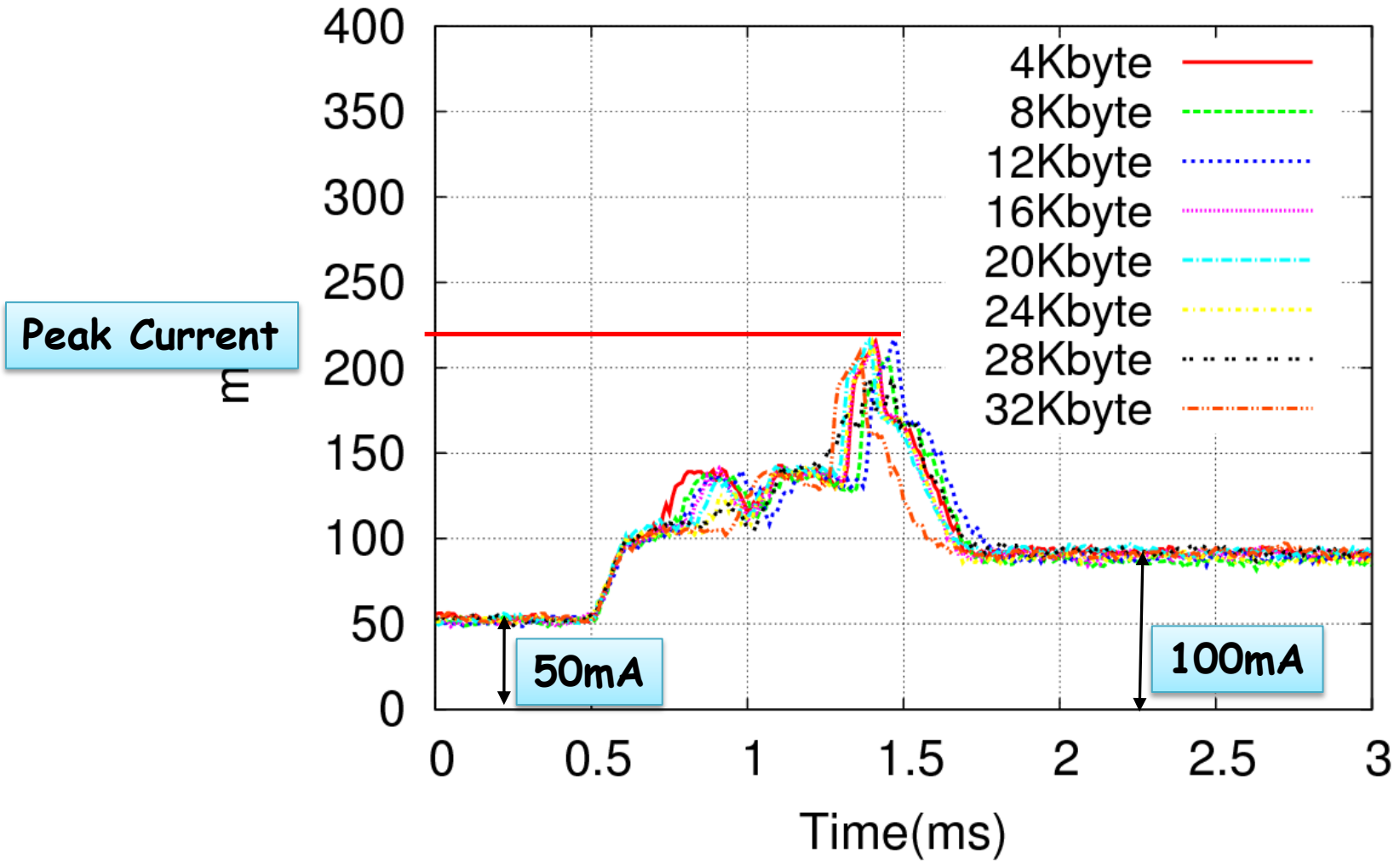


Case Study : SAMSUNG MXP

Capacity	128GB
No. of Channels	8
Packages/Channel	2
Package	8 GB

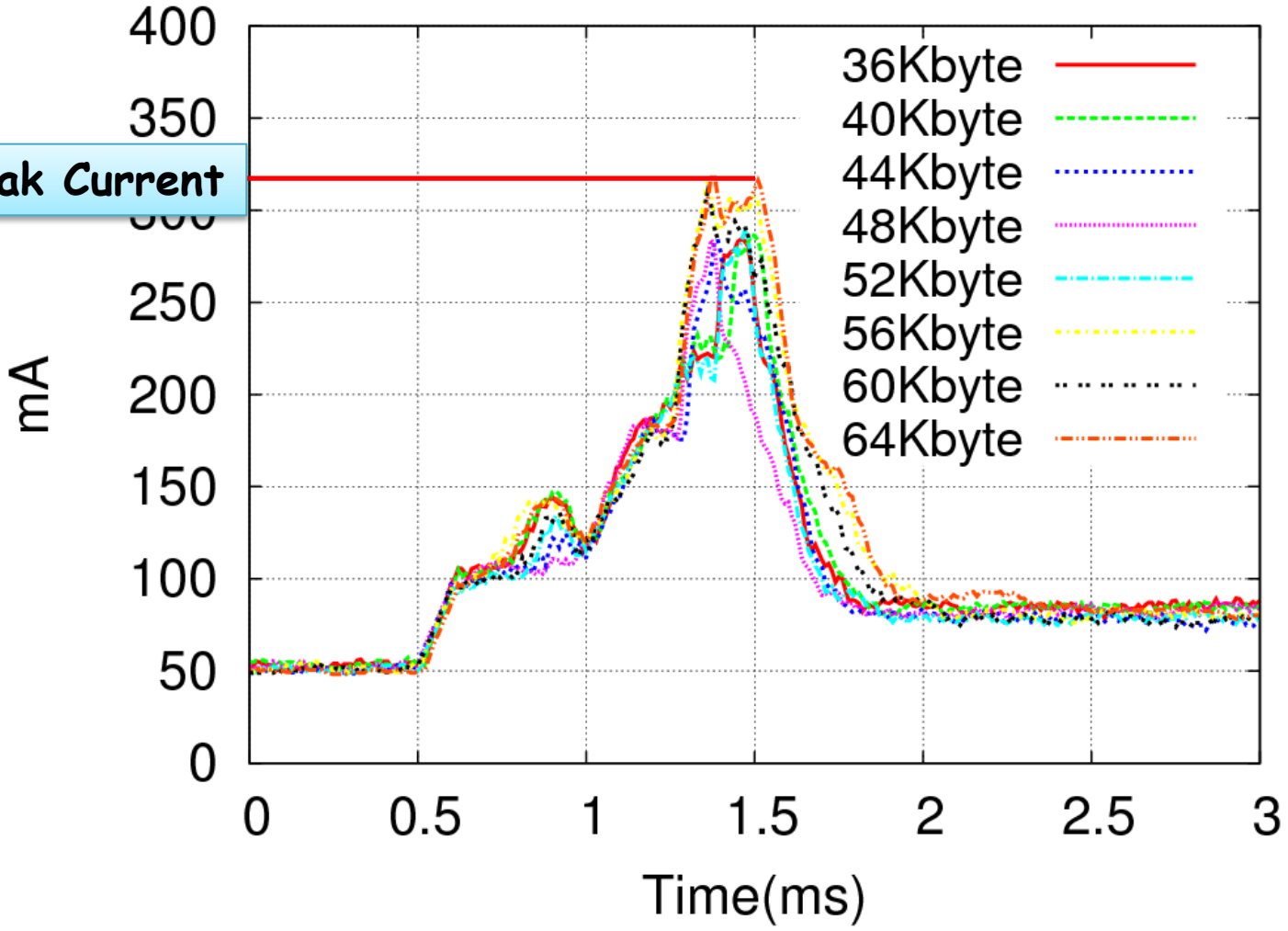


Case Study : SAMSUNG MXP



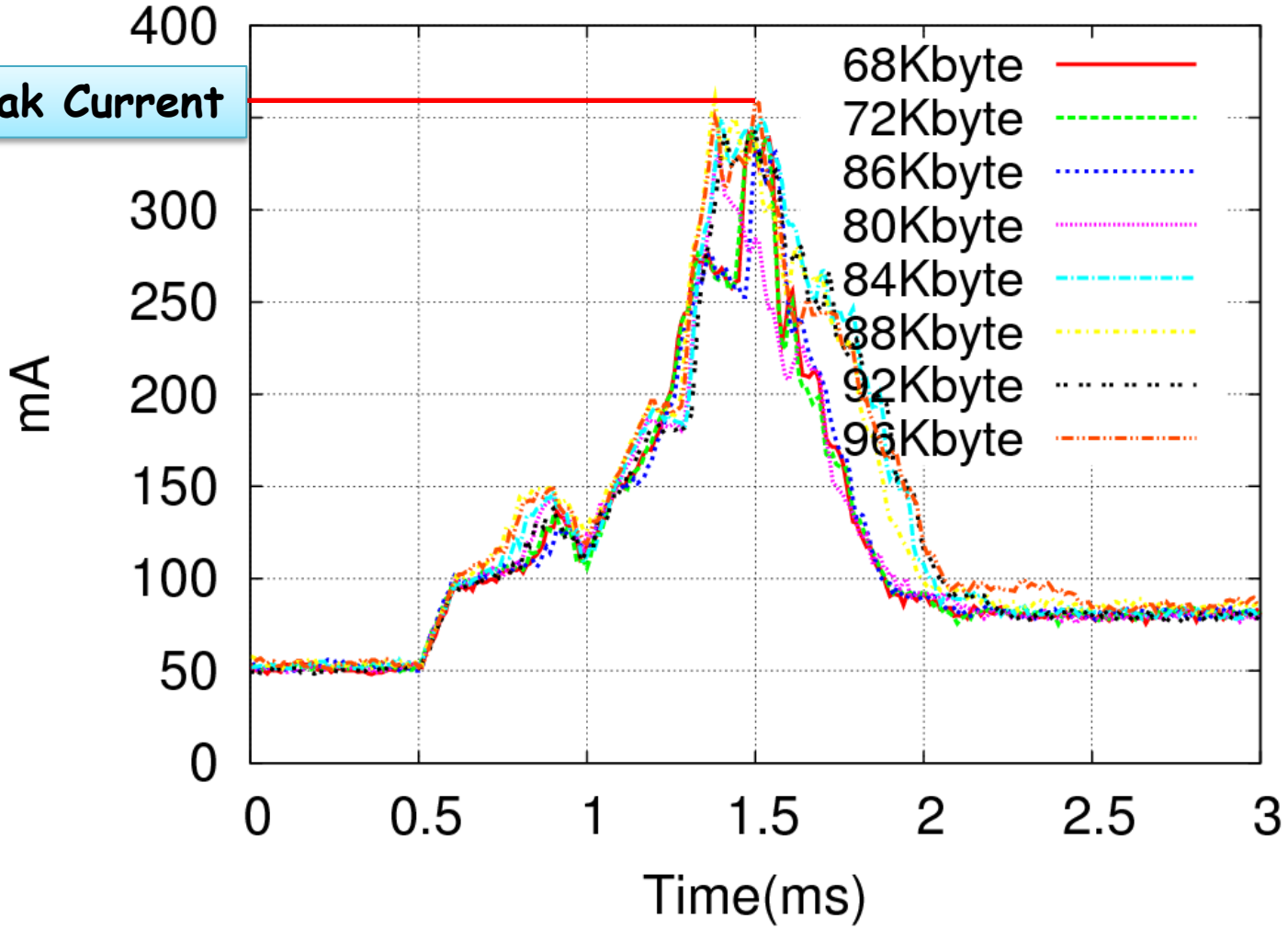
Case Study : SAMSUNG MXP

Same Peak Current

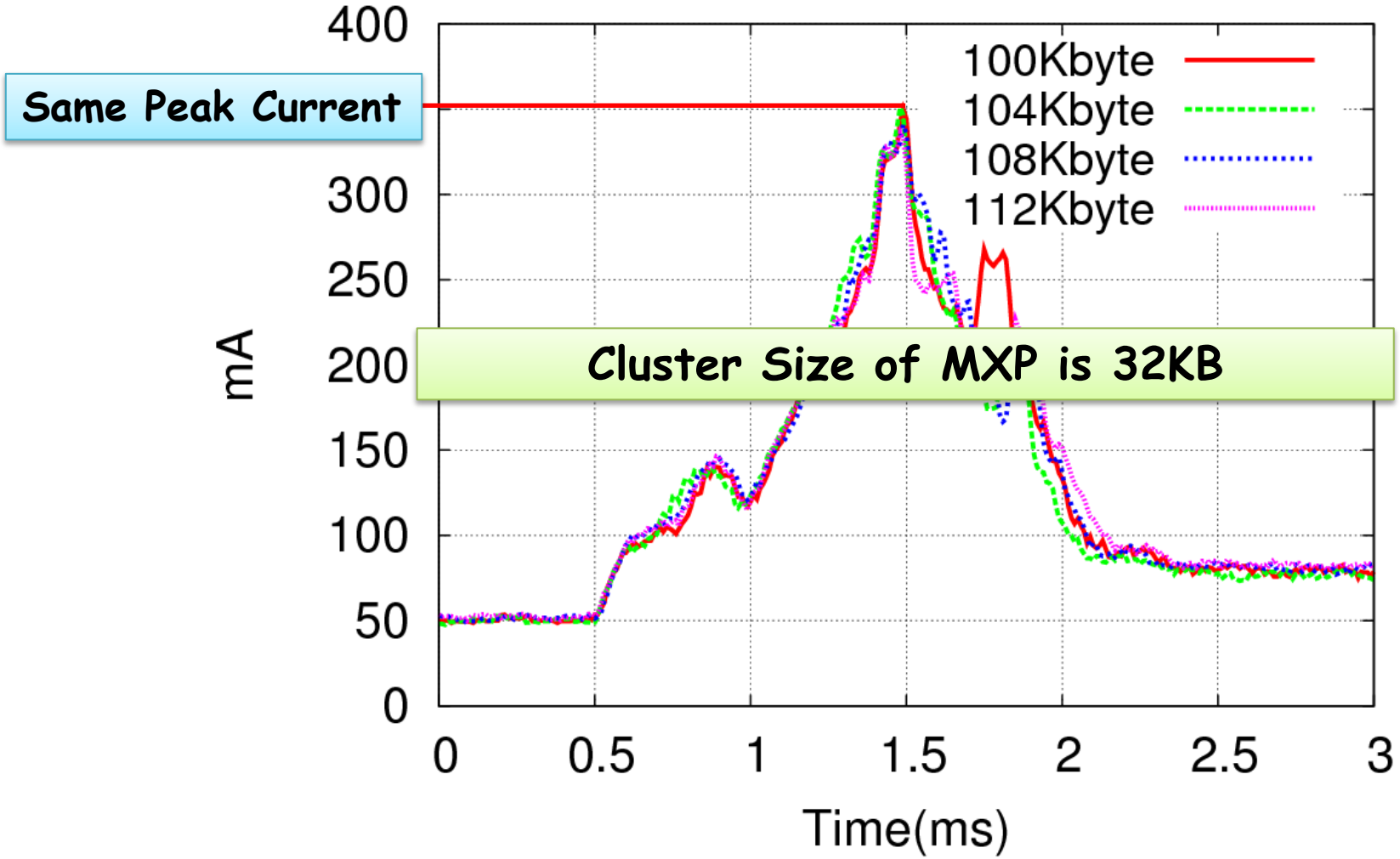


Case Study : SAMSUNG MXP

Same Peak Current



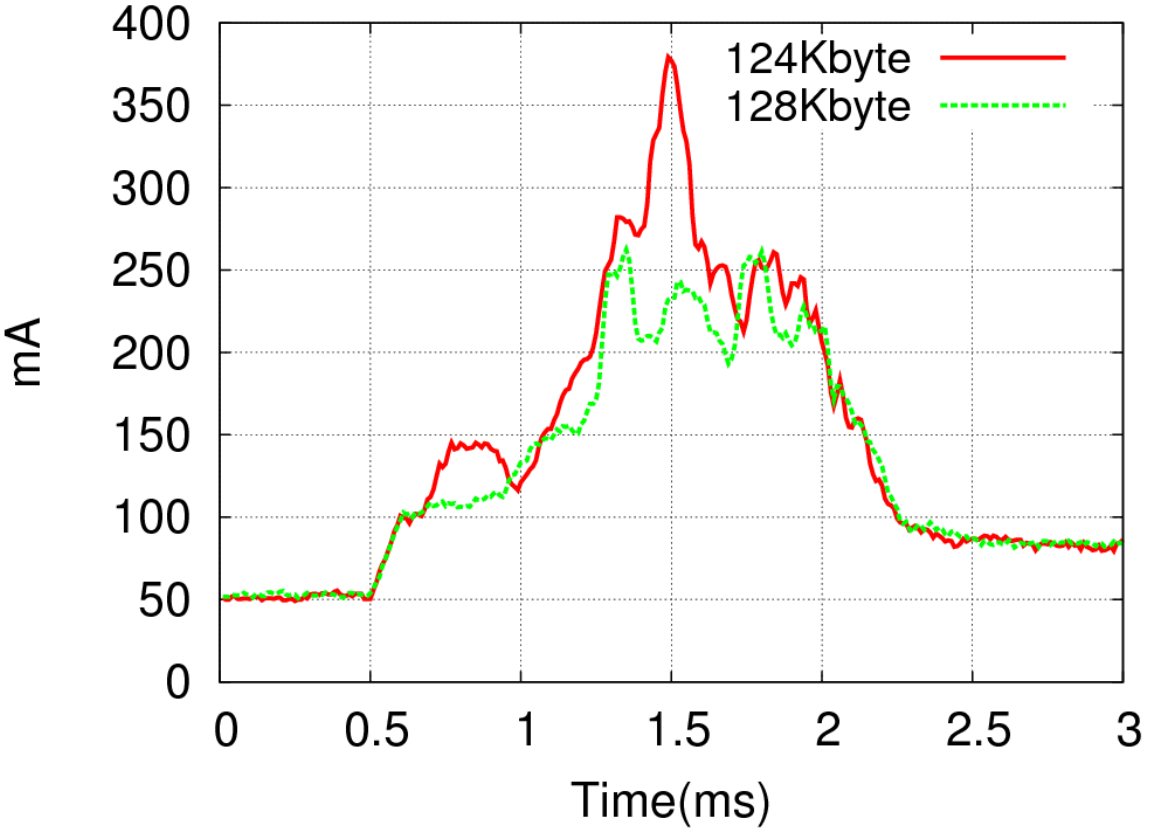
Case Study : SAMSUNG MXP



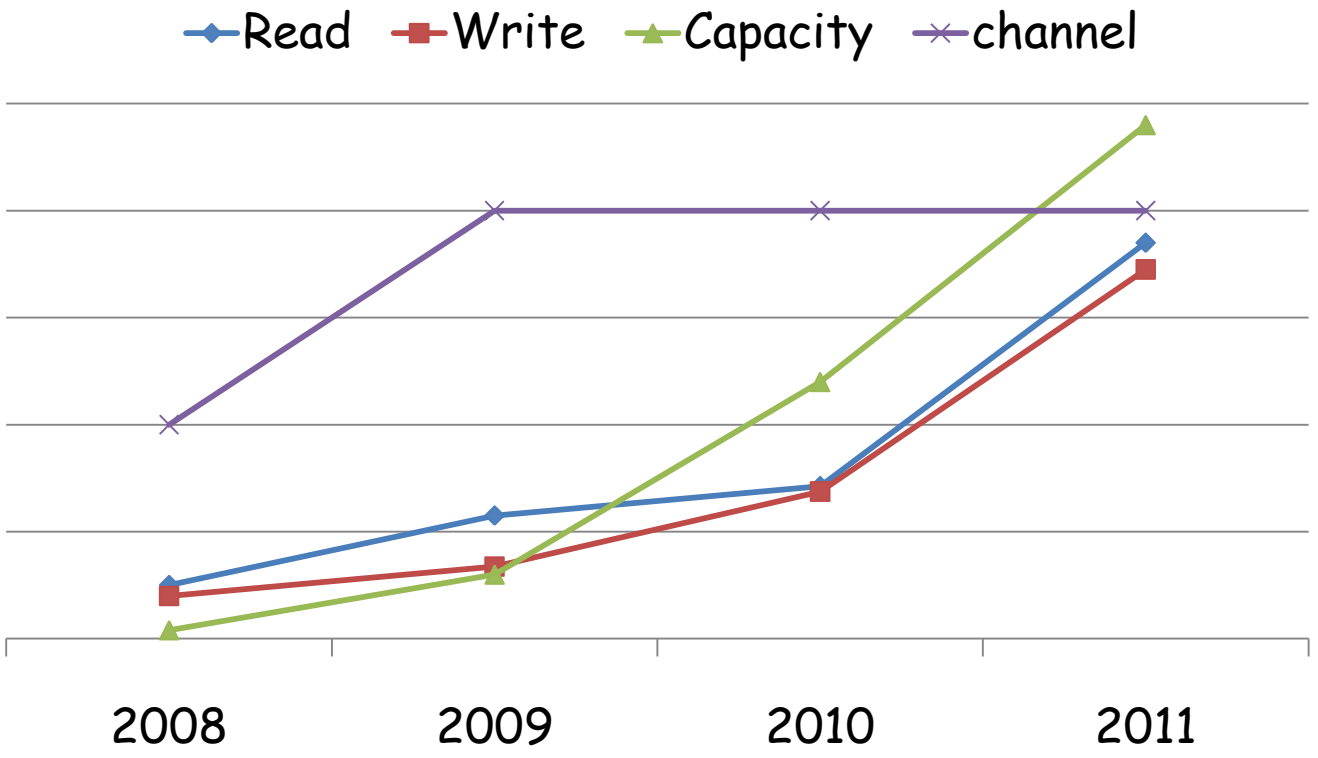
Case Study : SAMSUNG MXP

What we still do not know of

Peak of 128 Kbyte < Peak Current of 124 KByte



Forth Coming Problem in Multi-channel SSD



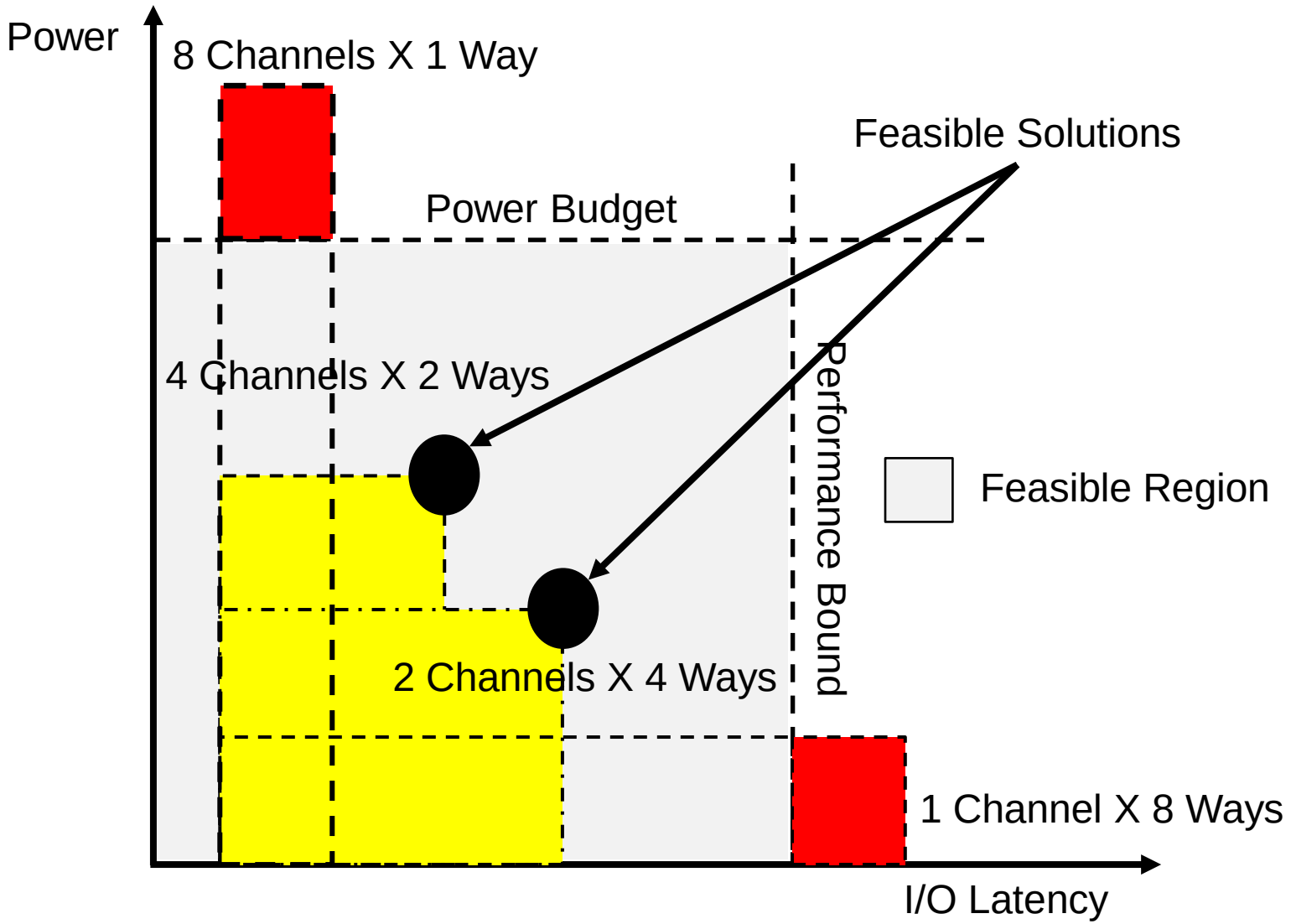
Model Name	Release
SATA3035 (Mtron)	2008.01
Vertex (OCZ)	2009.03
Vertex2 (OCZ)	2010.07
REVO Drive X2 (OCZ)	2011.01

Forth Coming Problem in Multi-channel SSD

- 10 channel: peak 500 mA
- 16 Channel: peak 800 – 900 mA → SSD is no long Green.
- Further, excessive peak current can cause…

  ✓supply voltage drop
  ✓ground bounce
  ✓signal noise
  ✓black-out
  ✓Etc…

Power Budget



Summary

	X25M	MXP
✓ Cluster Size :	4KB	32KB
✓ programming:	17 mA	35mA
✓ Peak Current :	500mA	350mA
✓ Channel switch:	30 µsec	
✓ Energy		
✓ Performance		
✓ Small Write		
✓ Large write		
✓ Standby current		

Summary

- Energy Consumption is very good tool to characterizeSSD.
- For larger number of channels, peak current will soon be a significant issue.
- We introduce the notion of Power Budge to resolve this issue.


Q&A

Related Works

- Dongkun Shin et al, NVRAMOS 2010 Spring

Applied different workloads(random, sequential, etc) to SSDs and Measured the power consumption

- Laura M. Grupp et al, MICRO 2009

Custom Board + Flash Memory

Read

Program

Erase

Basic Operation

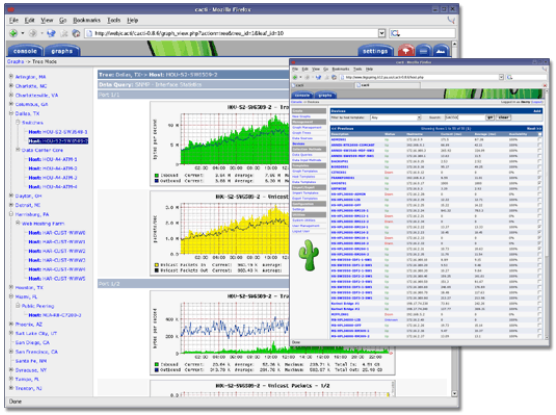
Power Consumption of Flash Memory Basic Operations

Related Works

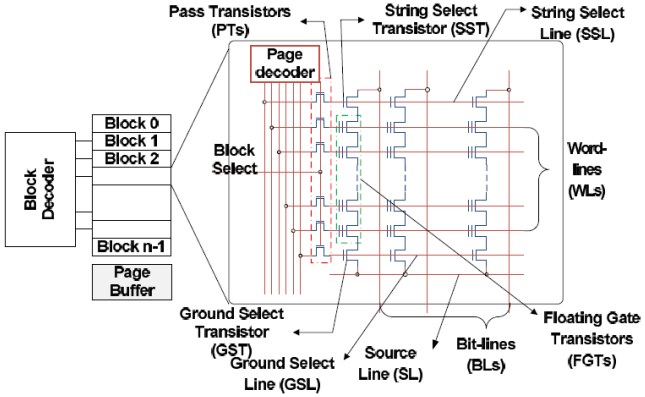
- Euiseong Seo et al, HotPower'08

Applied different workloads(random, sequential, etc) to SSDs
with different request sizes (varied the file systems)
Measured the Power Consumption

- Vidyabhushan Mohan et al, Date '10



CACTI 5.3

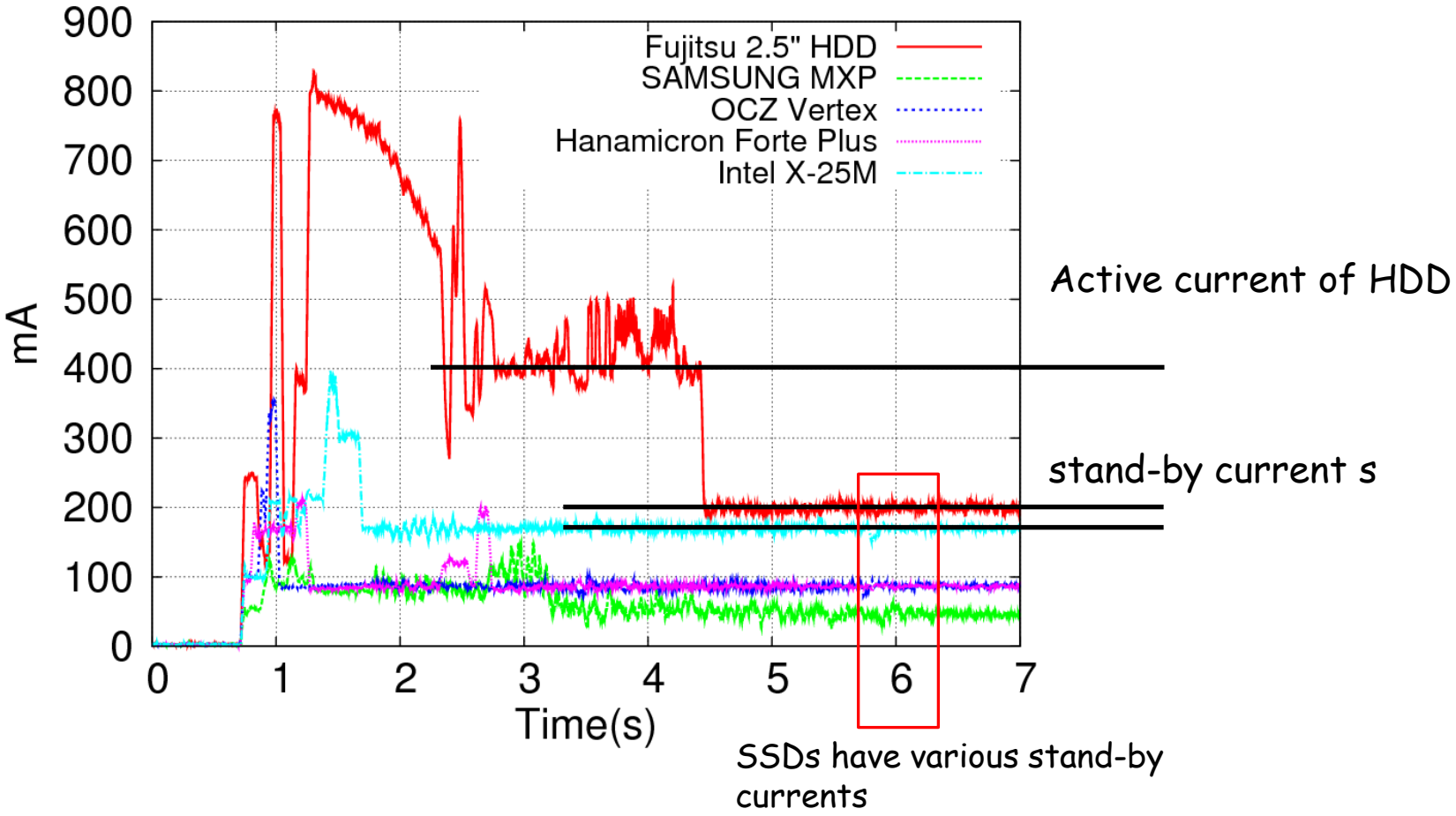


developed a detailed power model
for the NAND flash chip itself with CACTI 5.3

Operations on NAND Flash Cell

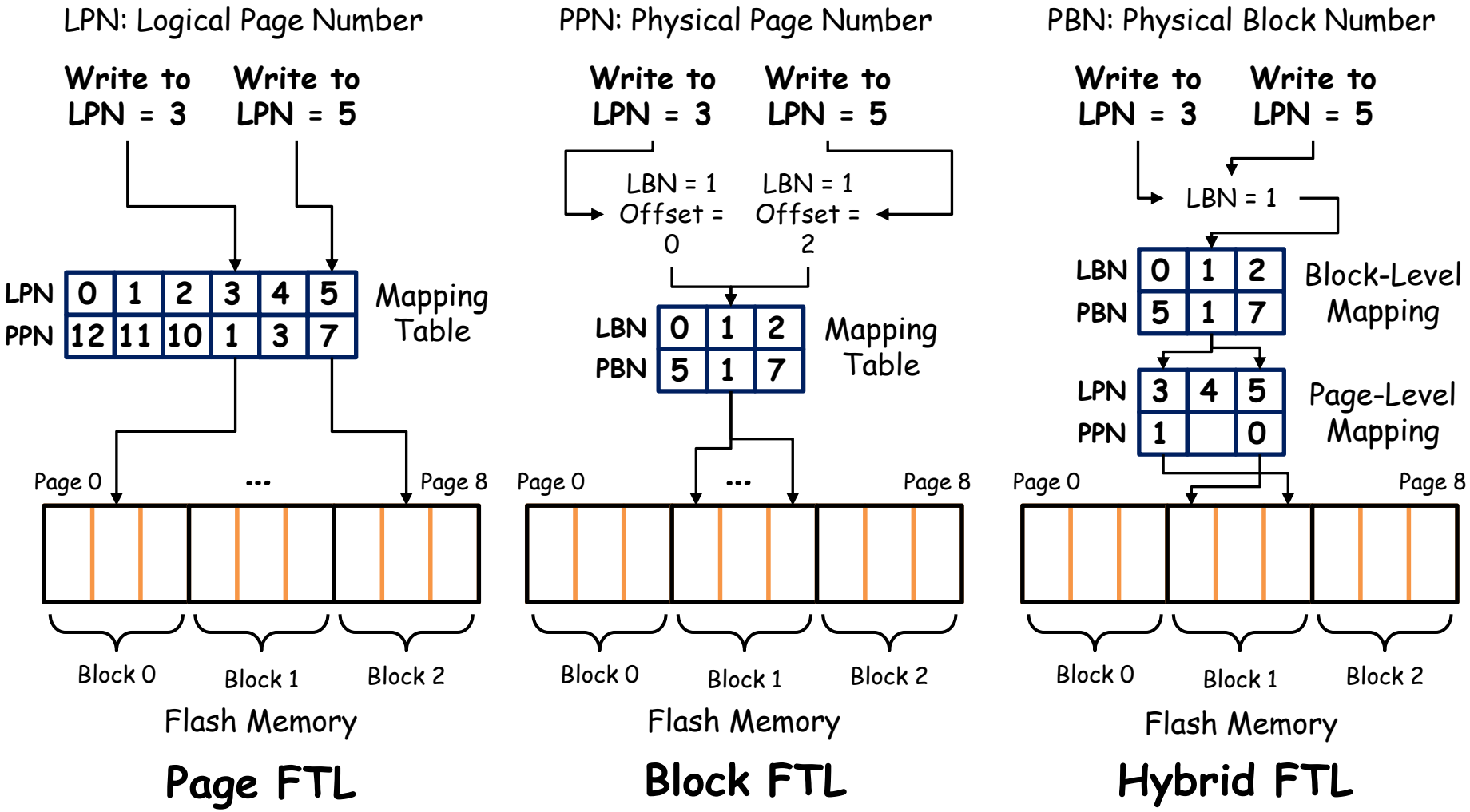
Model	Read (mA)	Write (mA)	Erase (mA)	Voltage(V)
MD332B (Intel)	20	20	20	3.3
K9XXG08XXM (Samsung)	25	25	25	3.3
MT29FXXG08CXXBB (Micron)	20	20	20	3.3

Power Consumption of Storage Devices: System Boot



FTL

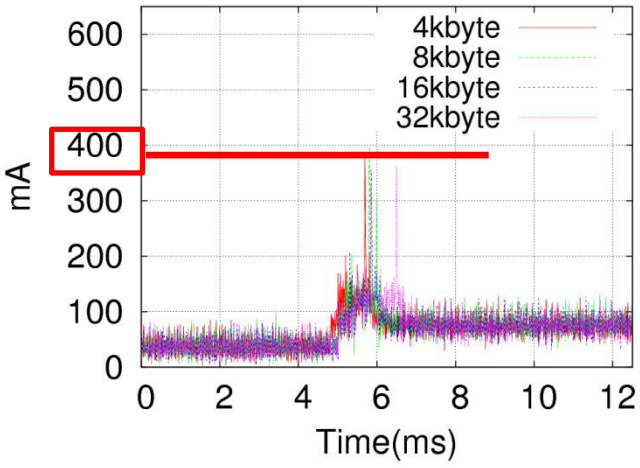
- FTL


LPN: Logical Page Number
Write to LPN = 3
Write to LPN = 5
LPN 0 1 2 3 4 5
PPN 12 11 10 1 3 7
Mapping Table
Page 0
...
Page 8
Block 0
Block 1
Block 2
Flash Memory
Page FTL
PPN: Physical Page Number
Write to LPN = 3
Write to LPN = 5
LBN = 1 Offset = 0
LBN = 1 Offset = 2
LBN 0 1 2
PBN 5 1 7
Mapping Table
Page 0
...
Page 8
Block 0
Block 1
Block 2
Flash Memory
Block FTL
PBN: Physical Block Number
Write to LPN = 3
Write to LPN = 5
LBN = 1
LBN 0 1 2
PBN 5 1 7
Block-Level Mapping
LPN 3 4 5
PPN 1 0
Page-Level Mapping
Page 0
Page 8
Block 0
Block 1
Block 2
Flash Memory
Hybrid FTL

Trivia in Measurement Methodology

Trivia of Measurement Methodology

- Sampling interval should be small enough.(Read/Program Latency)
- Smoothing the data to filter out measurement noise.



Smoothing