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3 in 2012

Confidential

09/10.19 ~ 10/10.19

SSD TEST EVOLUTION

(B/M Tool / Signal Integrity / Power Consumption)

Hynix Semiconductor Inc
Flash Development Division
19th Oct. 2009

ahead of Change

Contents

- Benchmark Tool
- Signal Integrity
- Power Consumption

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Contents

- Benchmark Tool
- Signal Integrity
- Power Consumption

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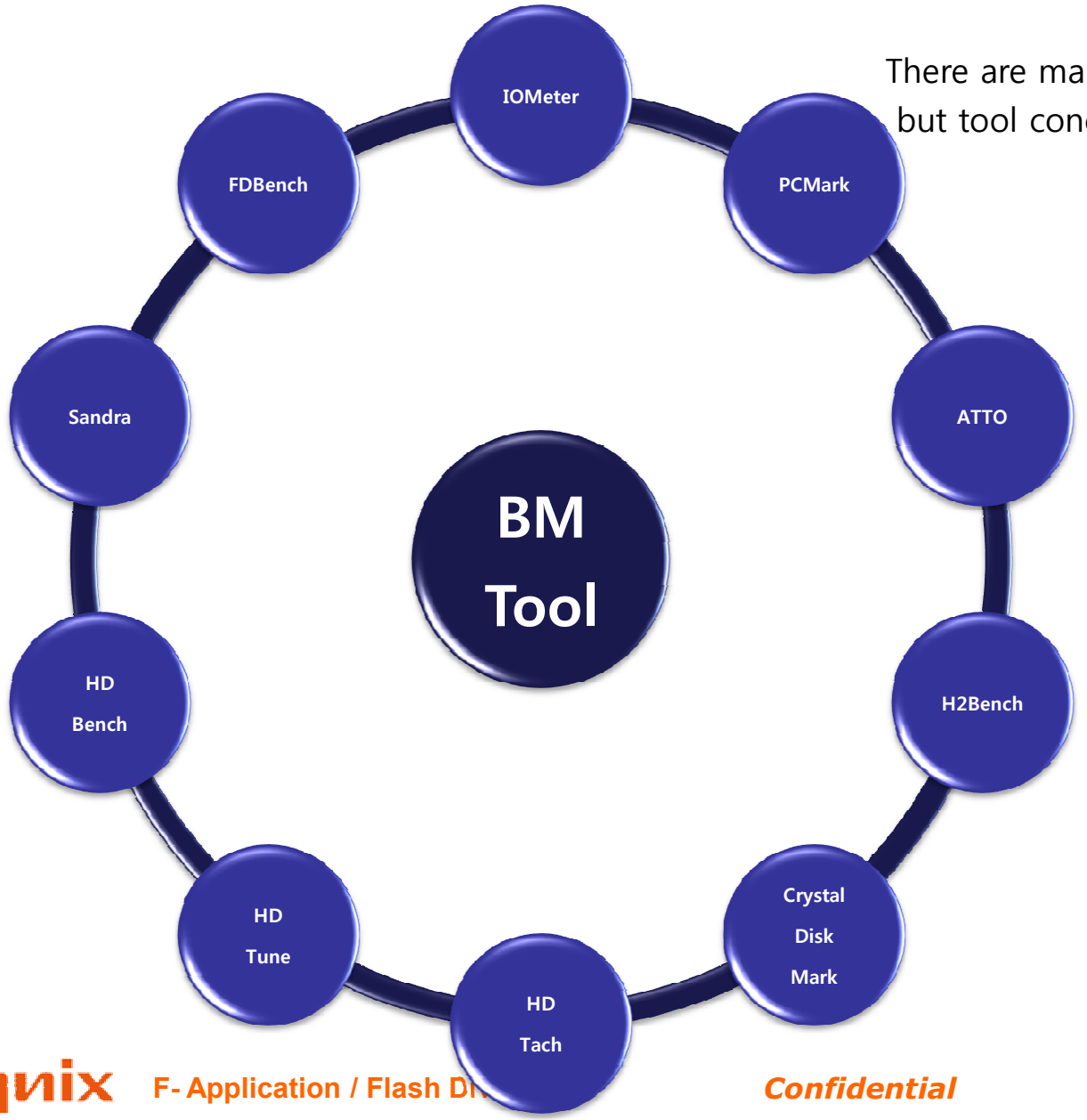
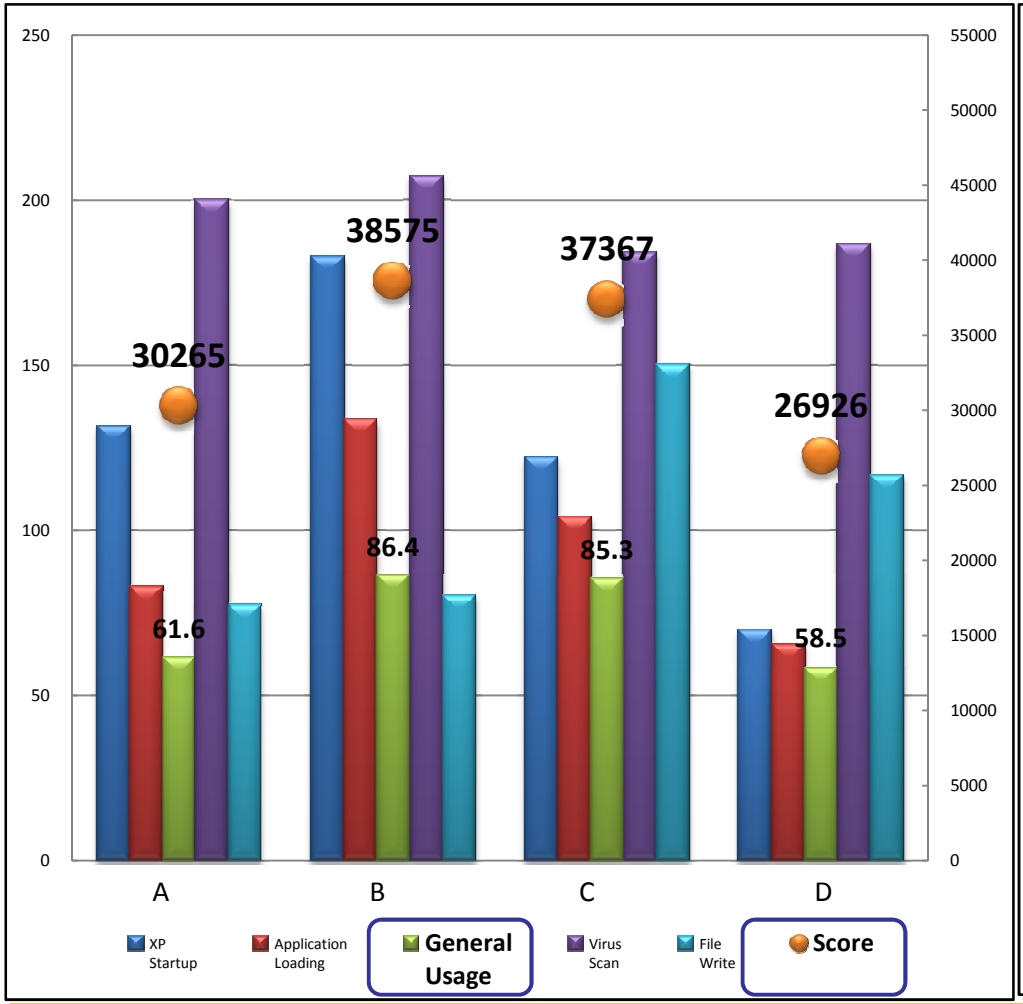
Introduction of various BM Tools

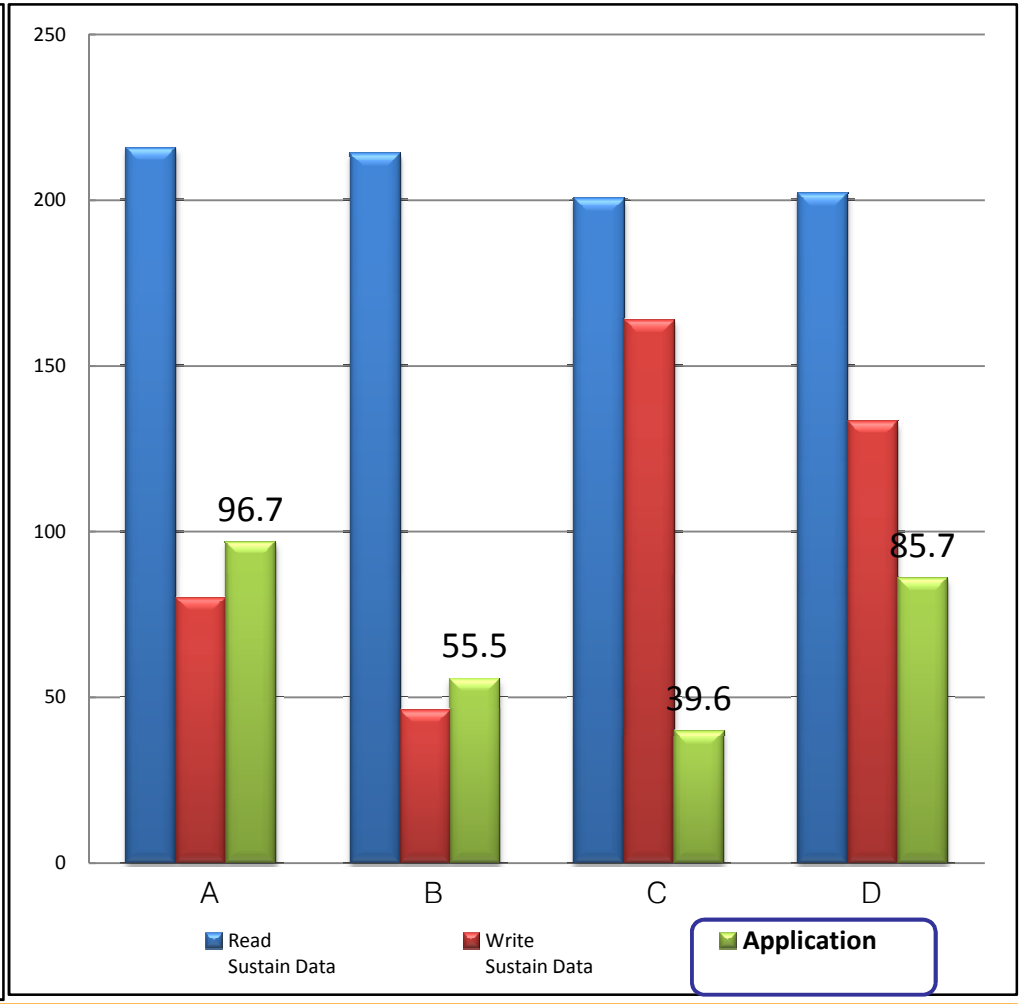


There are many performance benchmarking tools, but tool concept and result is **different** ??

+ α

Example 1) PCMark 05 vs H2Bench Result



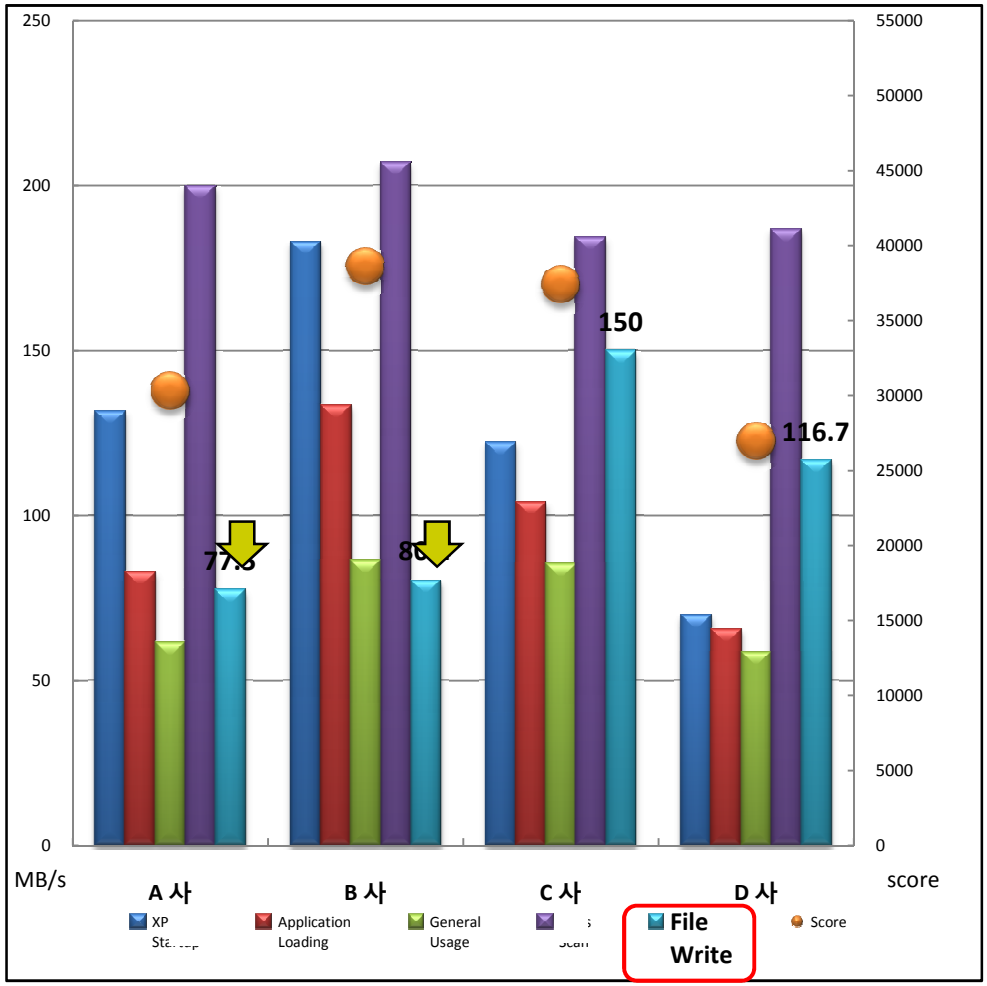


PCMark05
General Usage Score

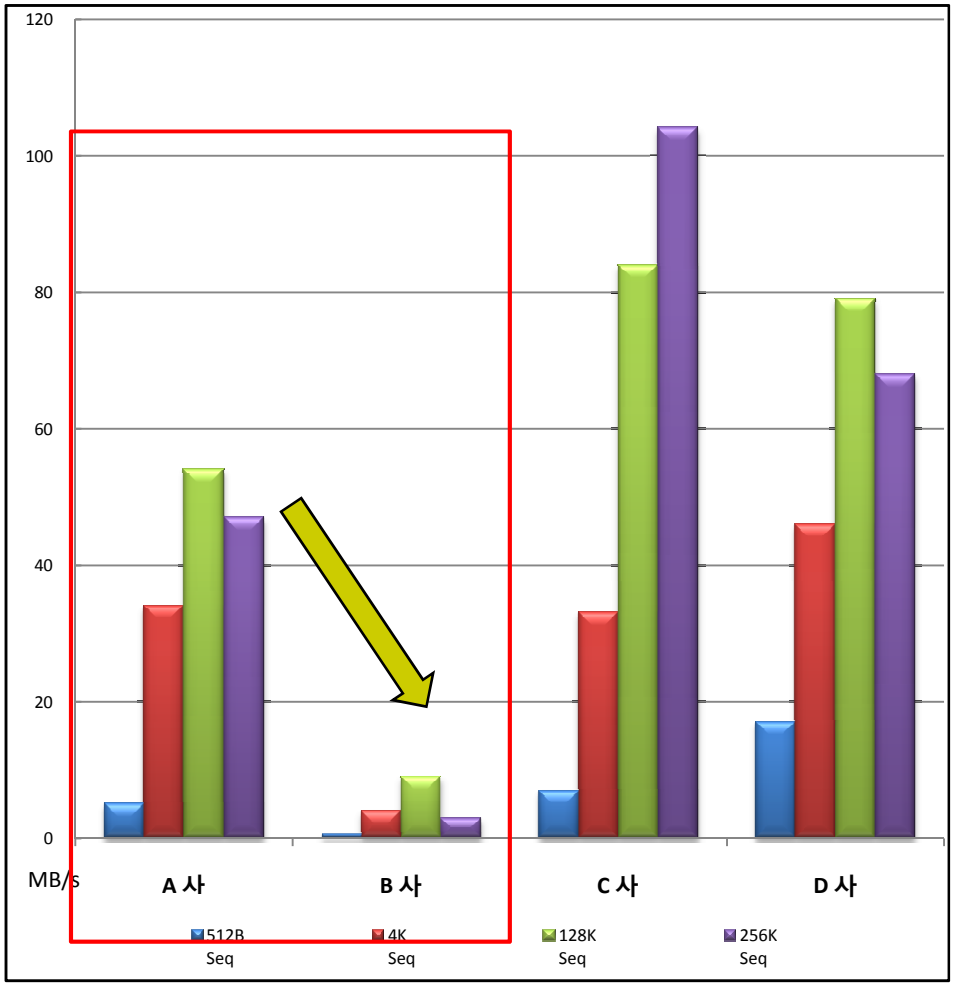
≠

H2Bench
Application

Example 2) PCMark 05 vs IOMeter 06 Result



PCMark05

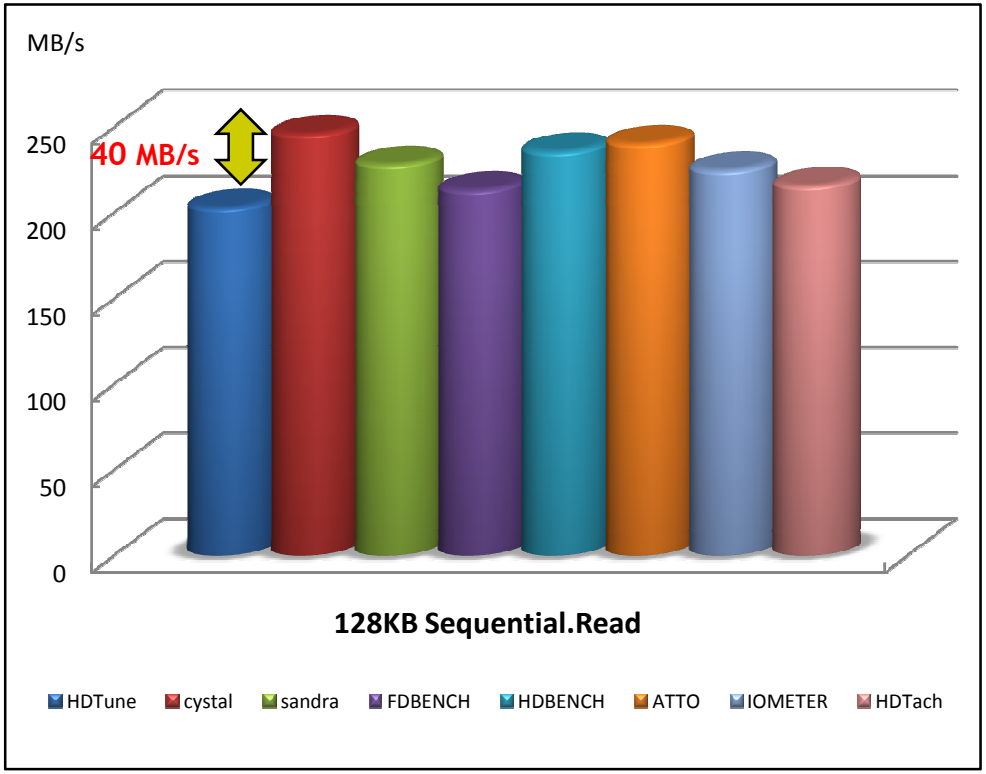


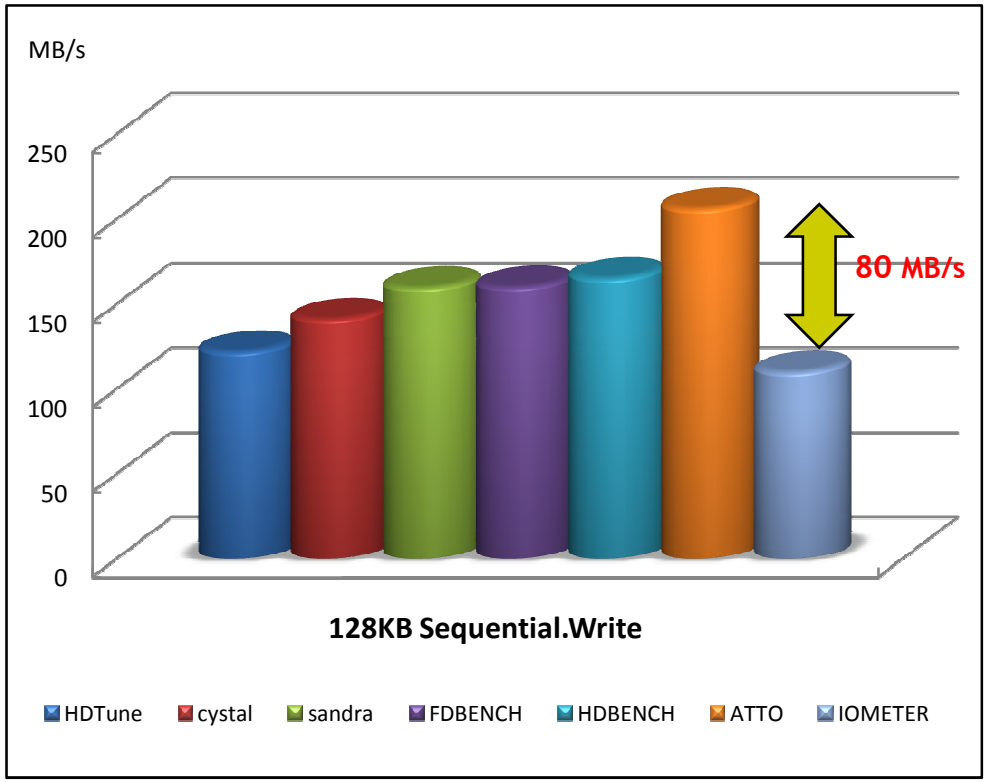
IOMeter06

- It shows that both "A" and "B" are similar performance of disk operation for File Write in the PCMark05 , but shows completely different results on the Sequential Write in the IOMeter 06. ➔ Different result between PCMark05 and Iometer06 even doing same operation.

WHY ?

Example 3) Performance Difference

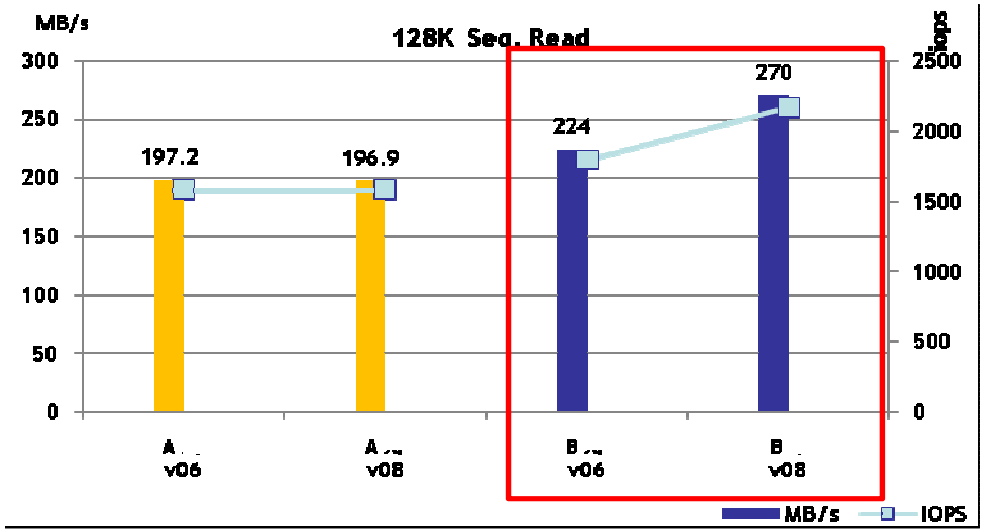


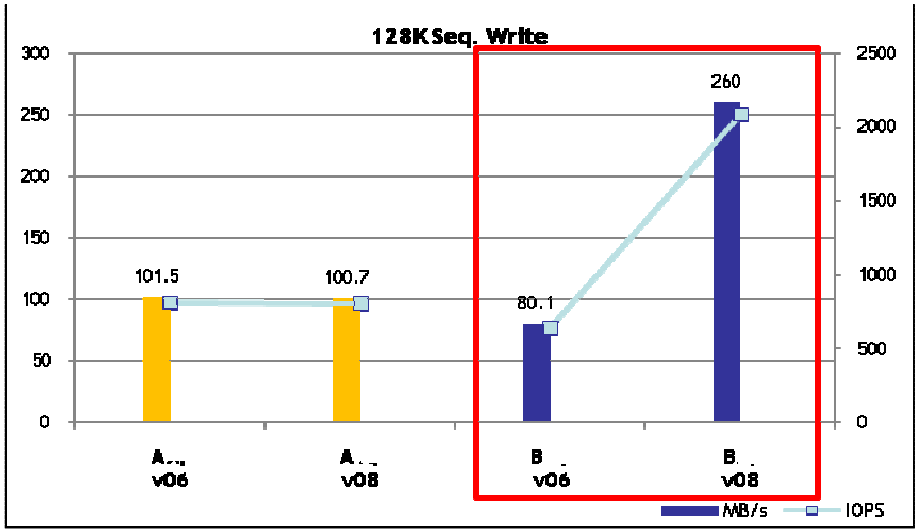


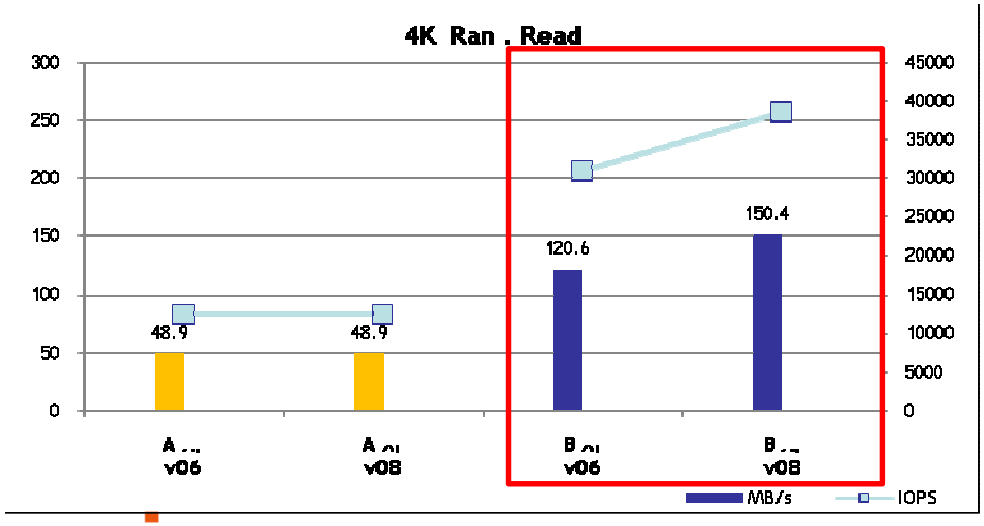
- Shows different results among the various BM Tools.
- This chart shows 40MB-80MB/s performance difference based on many tools, even though we used the exactly same SSD sample and same conditions.

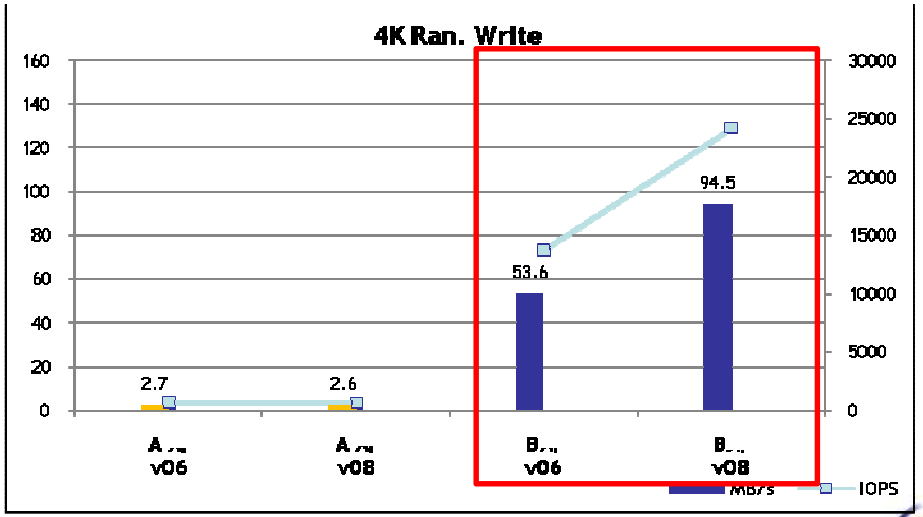
Example 4) Performance Difference @IOMeter

- B company shows better performance in the IOMeter 2008 than IOMeter 2006.
- The two versions of IOMeter generate drastically different data patterns. ➔ see APPENDIX









Analysis of various BM Tools

	IOMeter	PCMark	H2Bench	ATTO	HD Tach	HD Tune	Cystal diskMark	HDBench	Sandra	FDBENCH
Transfer Size	Variable	Fix (random)	Fix	Variable	Fix (64KB)	Fix (64KB)	Fix (seq. 128KB ran128/4KB)	Fix (seq. 128KB Ran 64KB)	Fix (128KB)	Fix (seq 128KB Ran 64KB)
DATA Pattern	06:RANDOM 08:2bit repetition	Almost ZERO pattern	Repetitive pattern	ALL ZERO	----	ALL ZERO	4bit repetition	Routine RANDOM Pattern	ALL ZERO	Routine RANDOM Pattern
CMD Read/Write	Read/write Seq/Ran	Read/Write Sea/Ran	Read./Write	Read/Write	Read Seq.	Read/Write Seq.	Read/Write Sea/Ran	Read/Write Sea/Ran	Read/Write Seq.	Read/Write Sea/Ran
OS	Windows Linux Netware	Windows	Windows (Win32 Console App)	Windows	Windows	Windows	Windows	Windows	Windows	Windows
Partition	physical/ Logical	logical	physical	logical	Physical/ logical	Physical/ Logical(read)	logical	logical	Physical/ Logical(read)	logical
Latency	V		V		V	V			V	
Multi process	V	V								
Queue Depth	V			V						
Precondition	V									
CMD Duty cycle	V									
B.G.C	V									
Remark	*freezing *MB/s, IOPS	*Real home usage *Application test	*DATA Integrity check *application test			*detail graph			*detail graph *comparison with other SSD	* copy

- Quick hit BM Tool / Simple point and click
- Not consistent results / just Simple Read/Write test
- Not support specific & critical option
- Not give a larger perceptive of performance

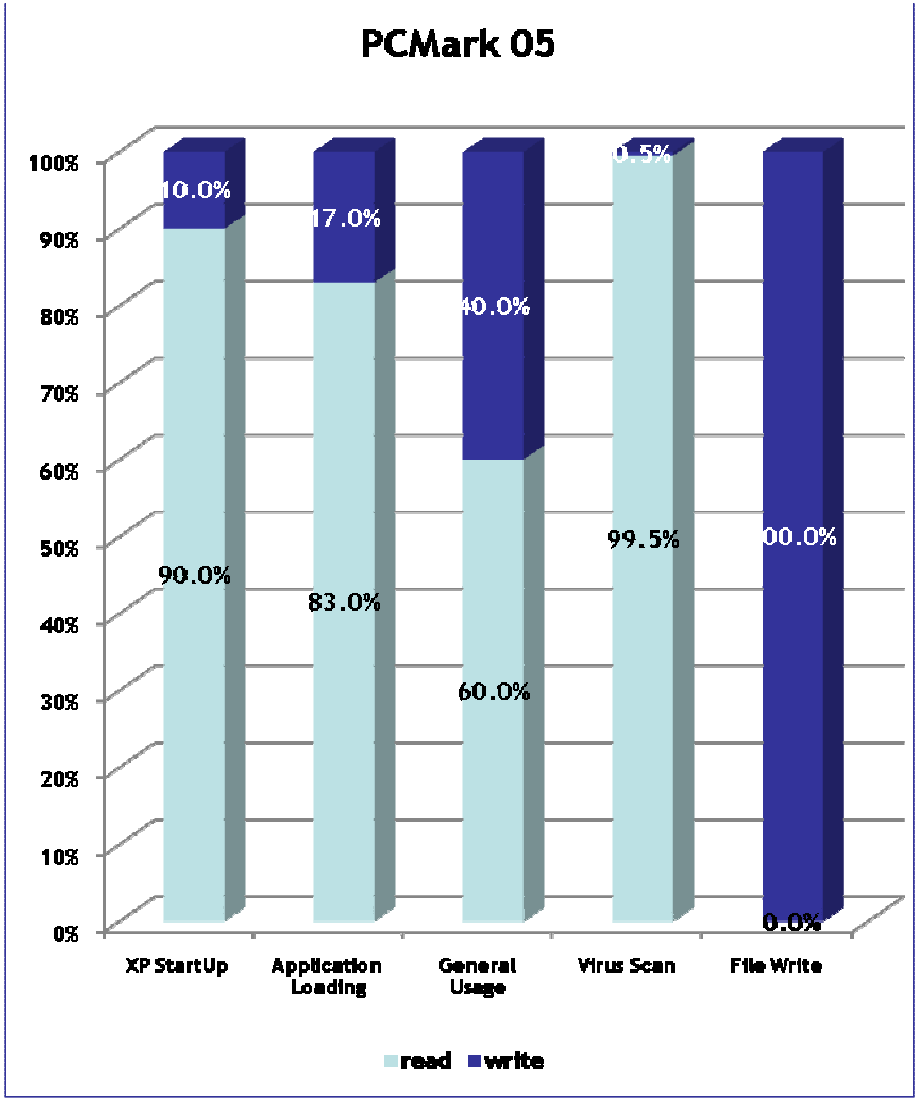
PCMark05 vs. Vantage

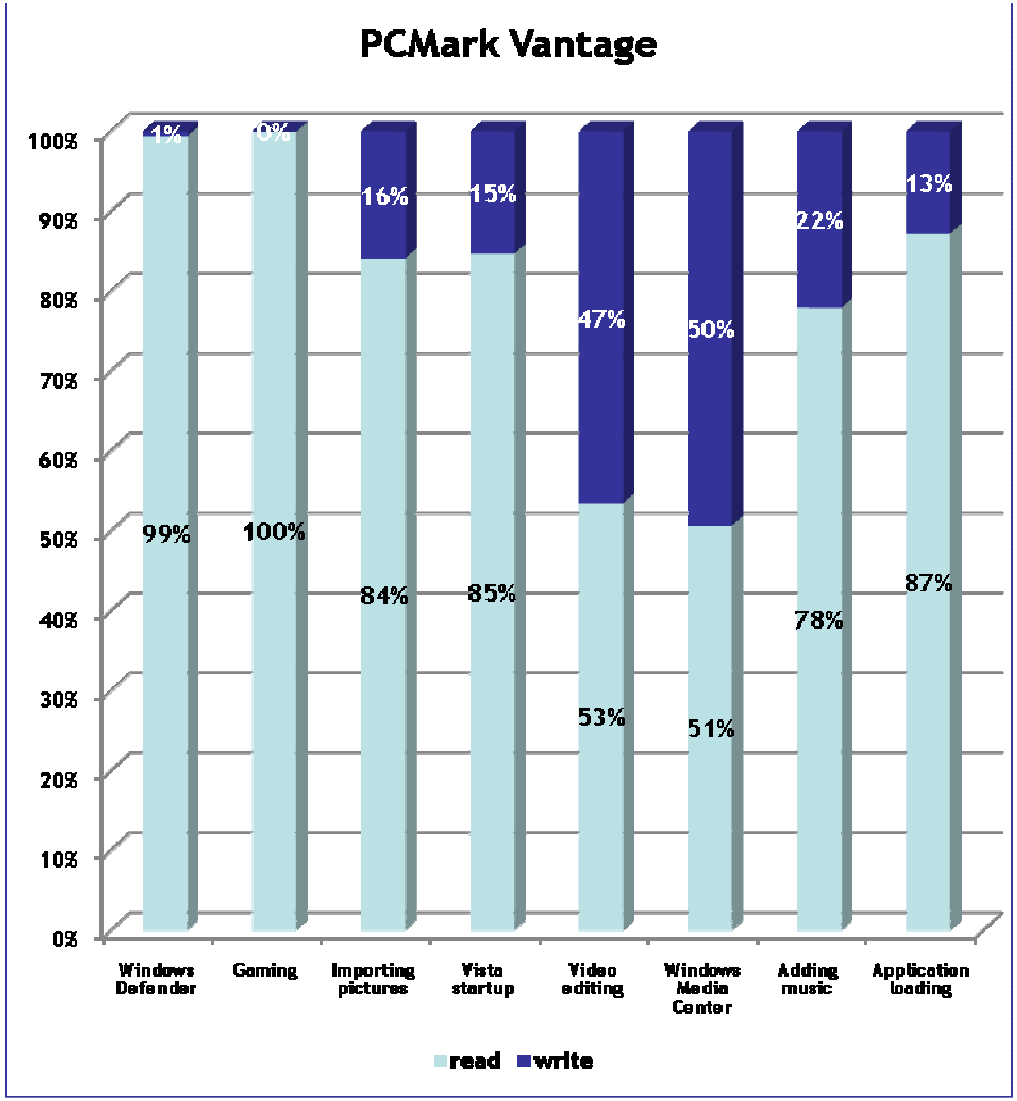
	PCMark05	PCMark Vantage
OS	Windows XP 32bit (SP2) Windows Vista 32bit	Windows Vista 전용
TEST ITEM (HDD Suite)	1. XP startup 2. Application Loading 3. General Usage 4. Virus scan 5. File write	1. windows defender 2. game HDD 3. importing pictures 4. Window Vista start-up 5. Video editing 6. Media center 7. Adding music to Windows Media Player 8. Application loading
SCORE	300 x (geomean of the HDD test suit results)	214.65 x (geomean of the HDD test suit results)

HDD Score = 300 * [geomean of the HDD test suite test results]

➔300 * {(XP Startup * Application Loading * General Usage * Virus Scan * File Write)^1/5}

PCMark (05 & Vantage)

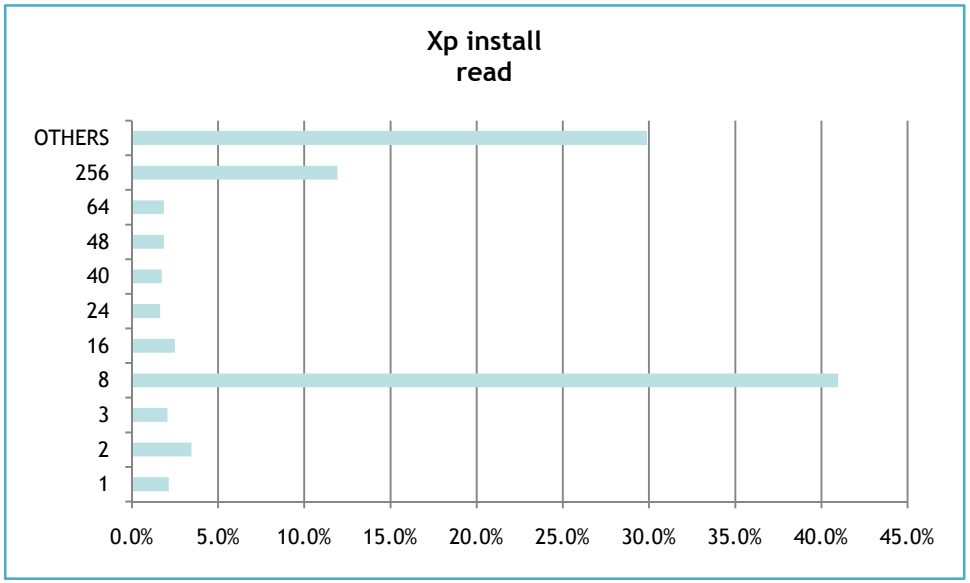


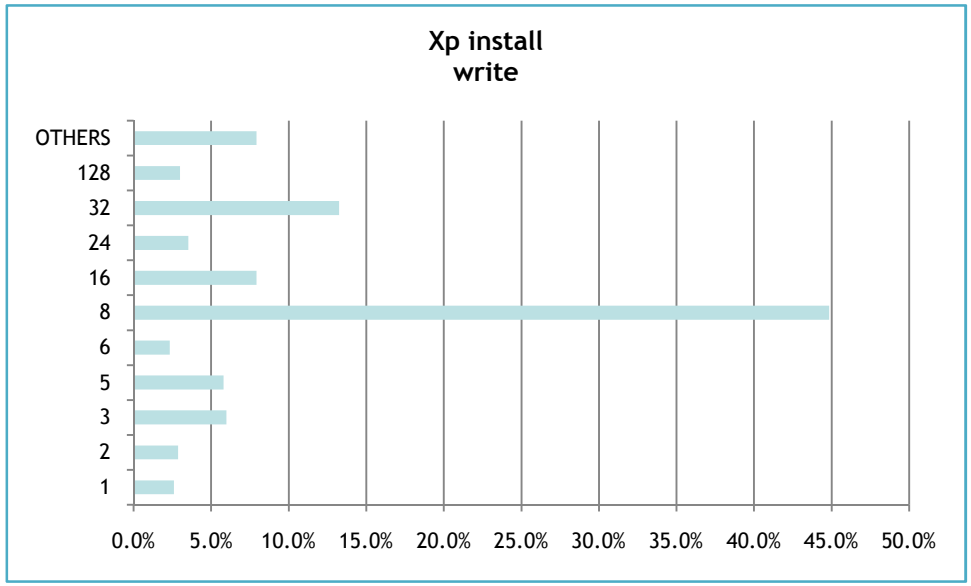


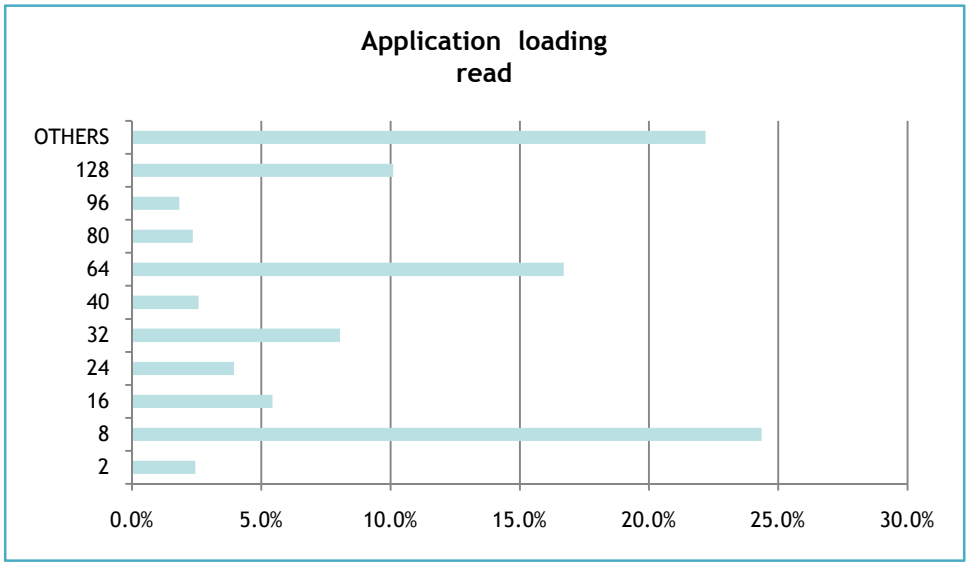
Total Ratio → 53% Read + 47% Write

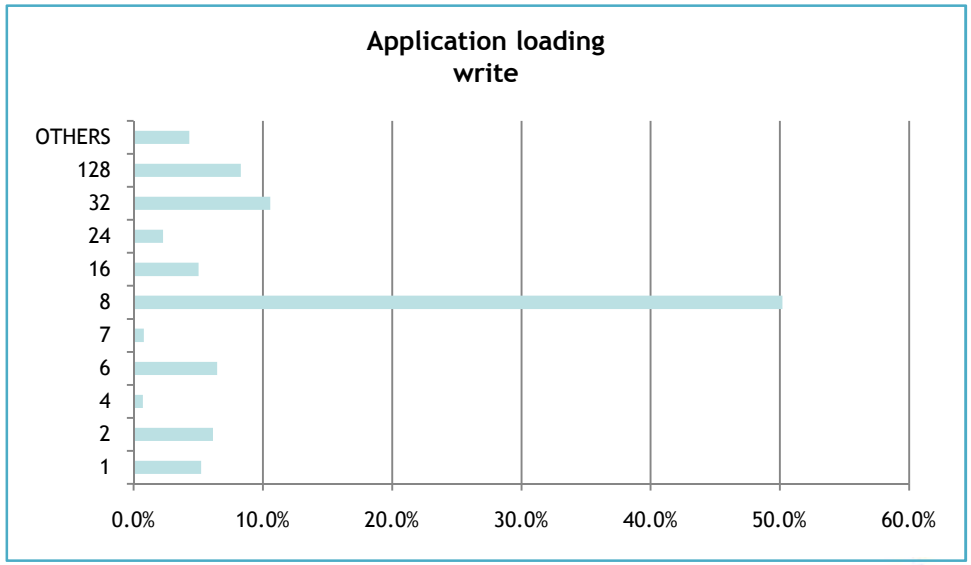
Total Ratio → 79.5% Read + 20.5% Write

PCMark05_Transfersize









Hynix B/M Tool (Hi-Score)

Current Performance Measurement Issue

↓

Various Performance B/M Tools

Introduction of Common BM Tools	Analyzation of BM Tools

↓

What's Problem?

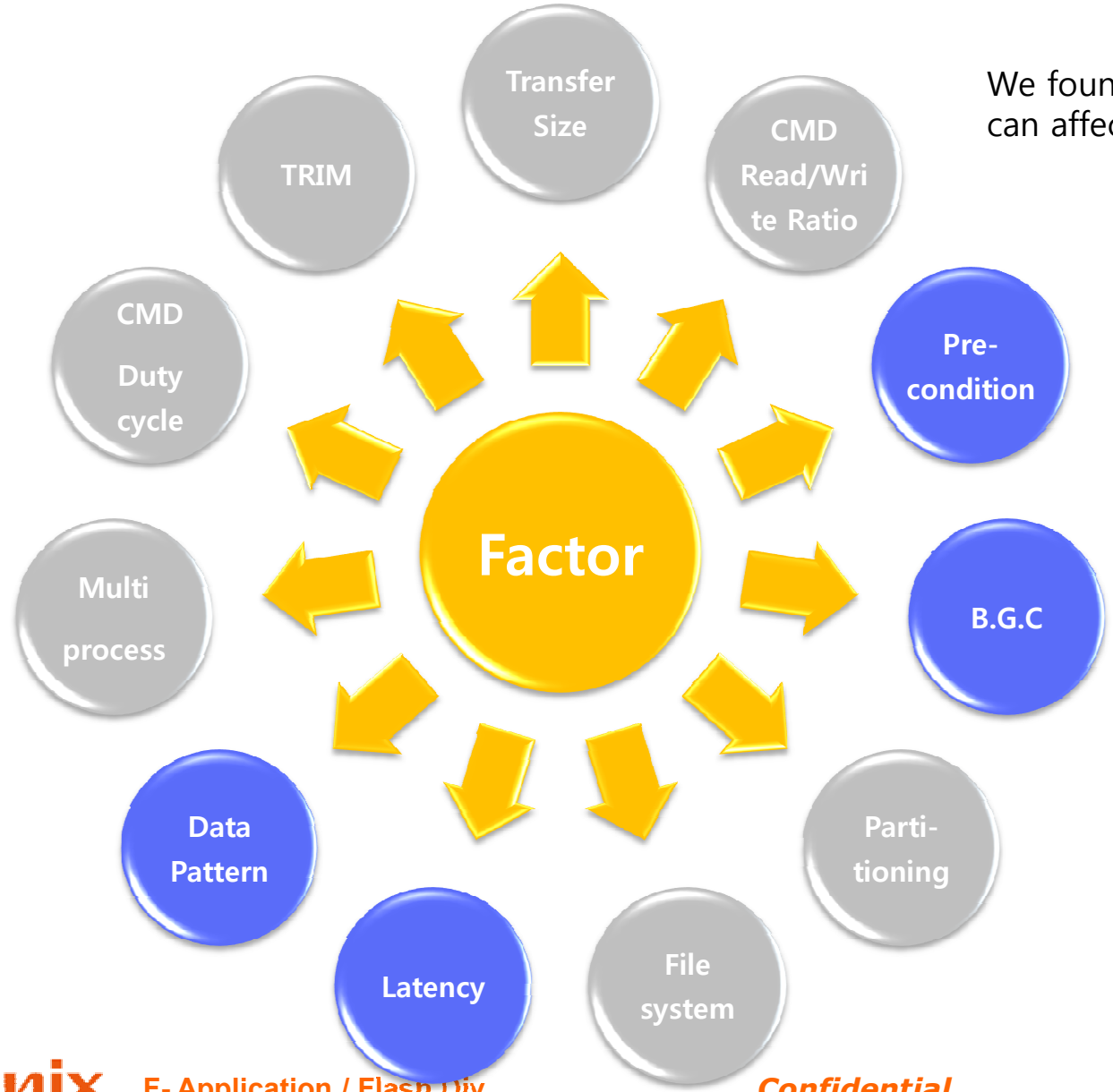
different results depending on which BM tool used or hardware.

↓

What we need to do?

Standardization of Hardware and Software

Analysis of various BM Tools



We found out about 12 type of factor, which can affect SSD's Read/Write performance .

What's the Problems ?

I. Benchmarking tools show totally different results each others.

II. In lack of consistency, reliability, objectivity for performance result.

III. Need to standard regardless of test environment and features of the BM Tool.

Introduction of "HI-SCORE"

Real Operation Trace Capture

- Boot up
- XP Install
- Compression
- Decompression
- Virus Scan
- Office Install
- Hibernation-In
- Hibernation-Out
- Freezing(Mix)

Simulation

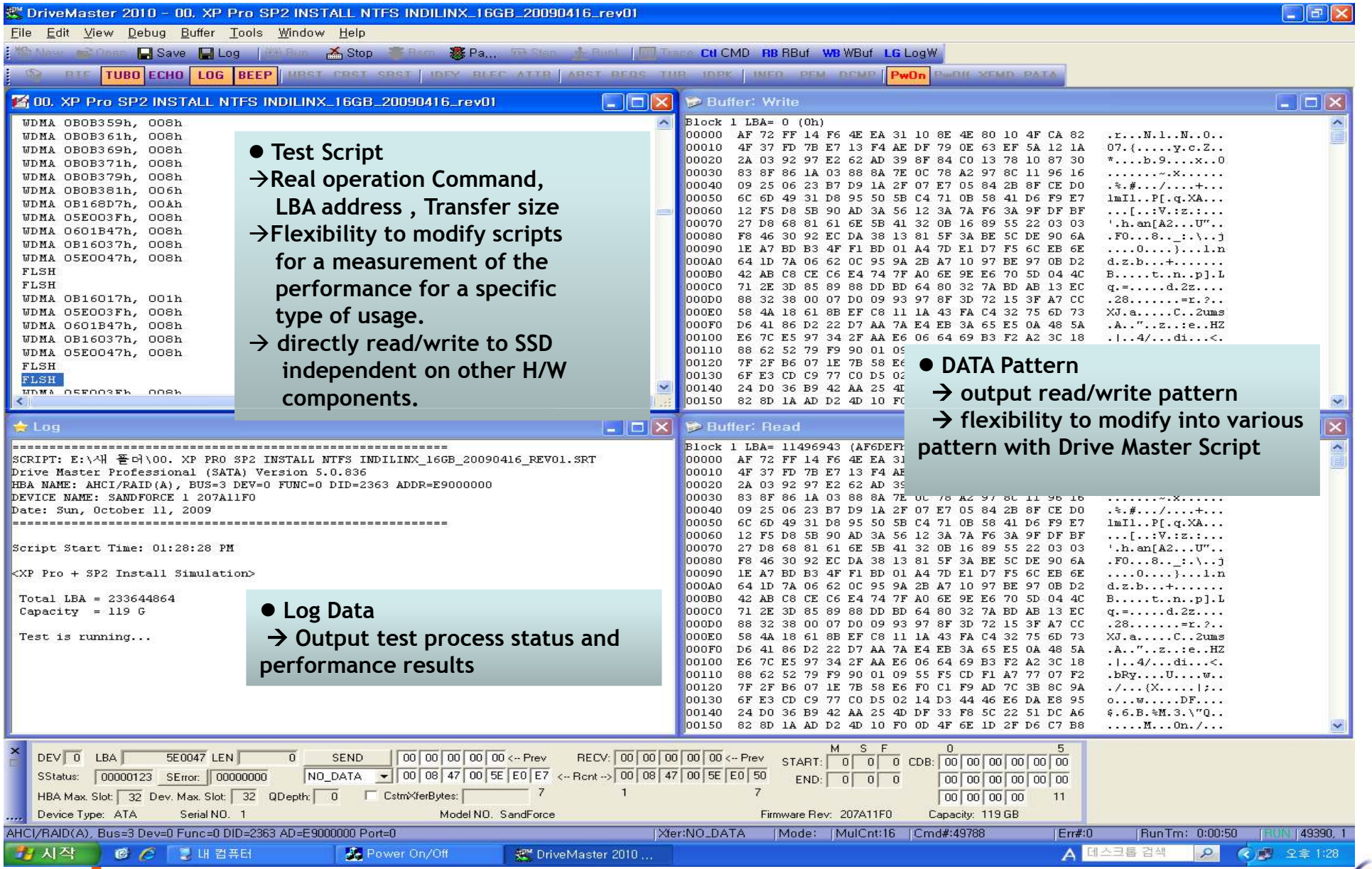
- Adjust Format for Test Program
- Execution

Standard Unit

- MB/s
- IOps
- Time (H : M : S)

Protocol Analyzer + Drive Mater = Result

Introduction of “HI-SCORE”



- Test Script
  → Real operation Command, LBA address , Transfer size
  → Flexibility to modify scripts for a measurement of the performance for a specific type of usage.
  → directly read/write to SSD independent on other H/W components.

- DATA Pattern
  → output read/write pattern
  → flexibility to modify into various pattern with Drive Master Script

- Log Data
  → Output test process status and performance results

Standardization of Benchmarking performance

Standardization of Hardware

- It is important for SSD performance measurement to be independent from hardware, especially CPU, RAM, Graphic, Motherboard.

Standardization of software

- Have to develop software including as various factors as possible to evaluate a broad perspective of performance.

HYNIX is developing our own optimized benchmarking index to achieve consistent result and accurate evaluation. We call that is "HiScore"

Contents

- Benchmark Tool
- **Signal Integrity**
- Power Consumption

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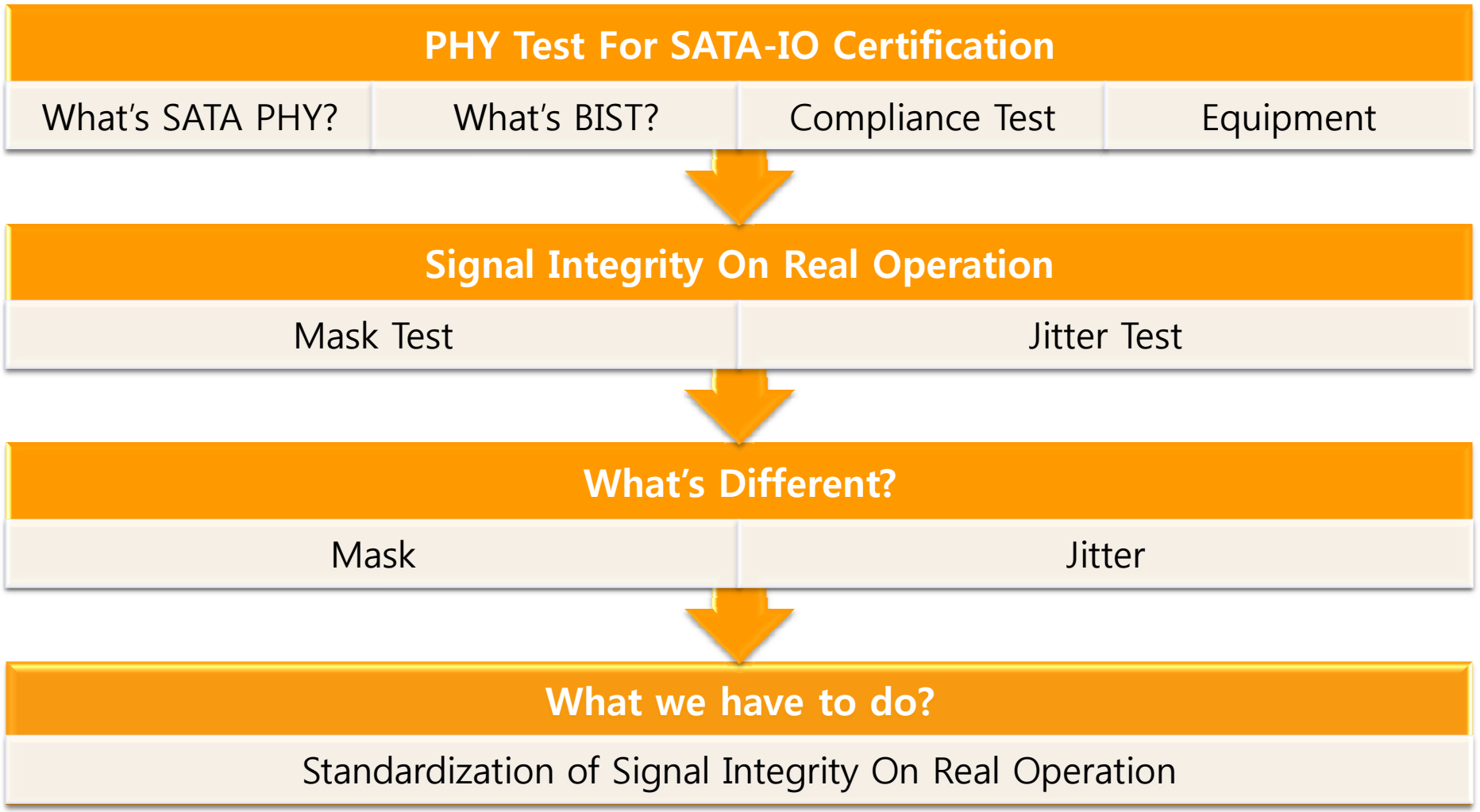
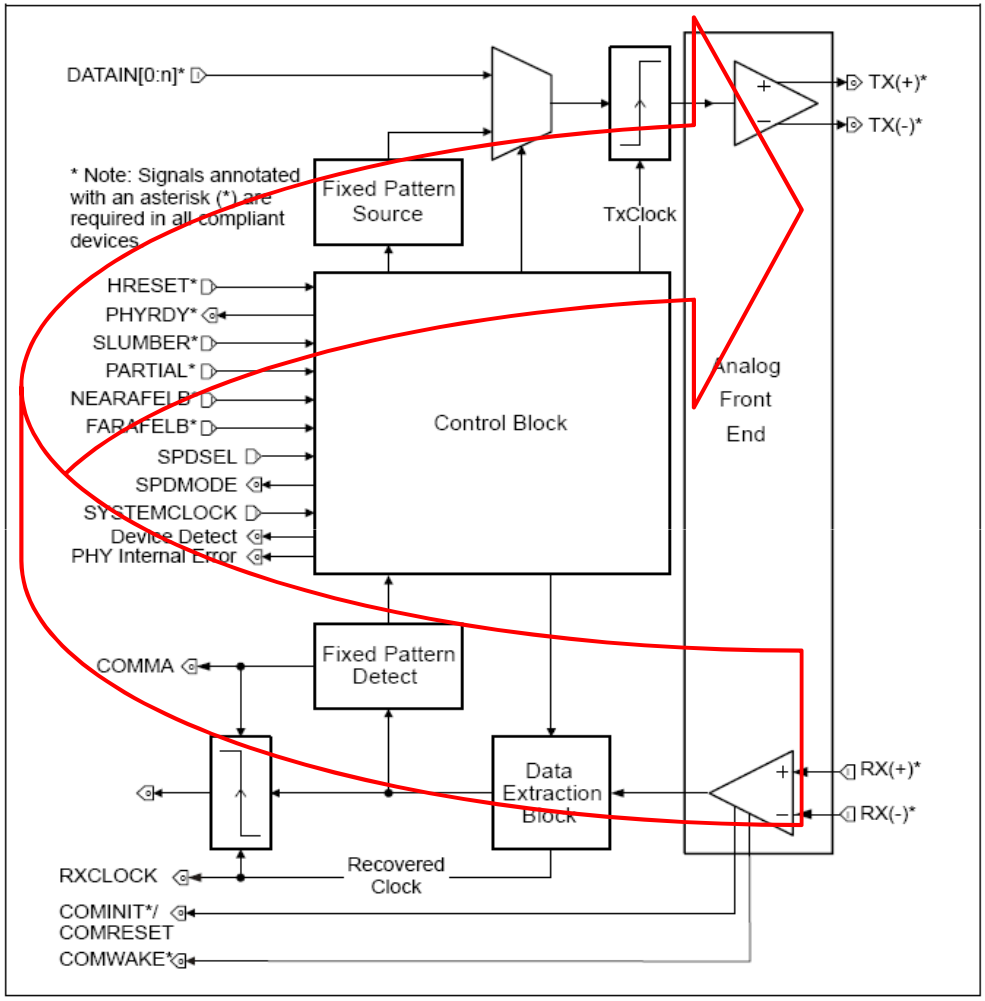
Signal Integrity



What is the SATA PHY?



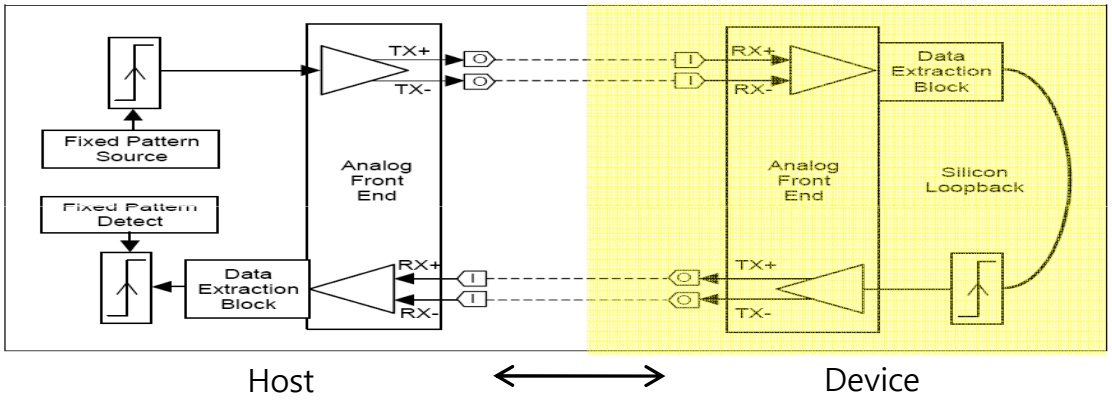
Physical Plant Block Diagram

- The PHY layer is simply divided to a transmitter, Internal Interface, and a receiver.

What is BIST?

1. BIST Mode

1. What is the BIST?
   - A Built-In Self-Test is a mechanism that permit a machine to test itself.
   - To verify an integrated circuit of internal feature.
   - Devices shall provide BIST-L mode for SATA Compliance Test.



2. BIST–L Mode (Far End Retimed Loopback Mode)
   - Data stream, at BIST-L mode, is extracted by the deserializer and data recovery circuit(DRC)
   - Data is being sent back through the Pattern Generator with appropriately inserted retiming ALIGNp primitives.
   - Provided data is decoded and descrambled.

Compliance Test (Electrical Test)

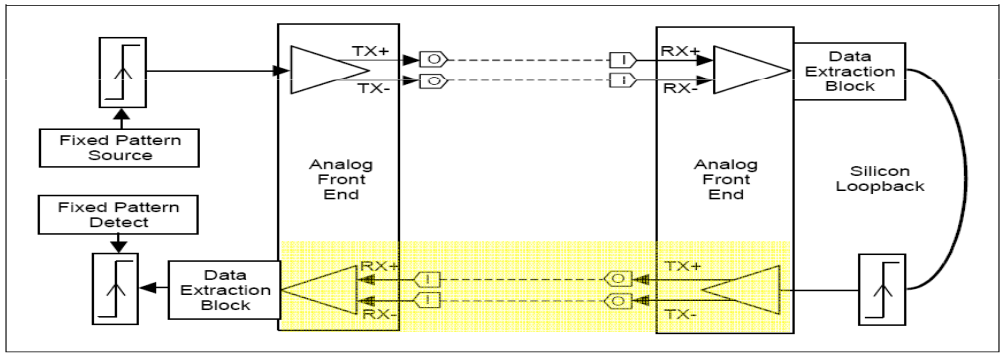
1. Transmitter Test

- PHY : Signal timing stability and SSC Analysis
- TSG : Rise/Fall Time, Transmitter AC parametric, Skew, Jitter, Amplitude
- OOB : Out of Band Signal Validation

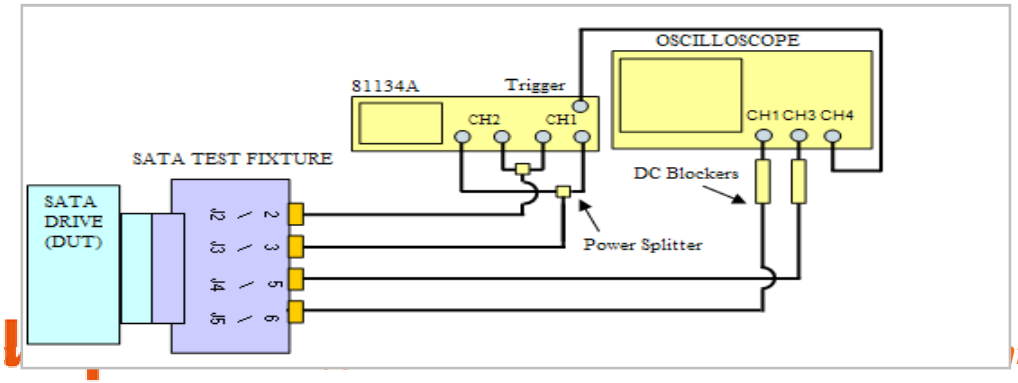
2. Receiver Test (Jitter Tolerance Test)

- RSG : Receiver Jitter, Amplitude sensitivity compliance,
- RMT : RSG Margin test

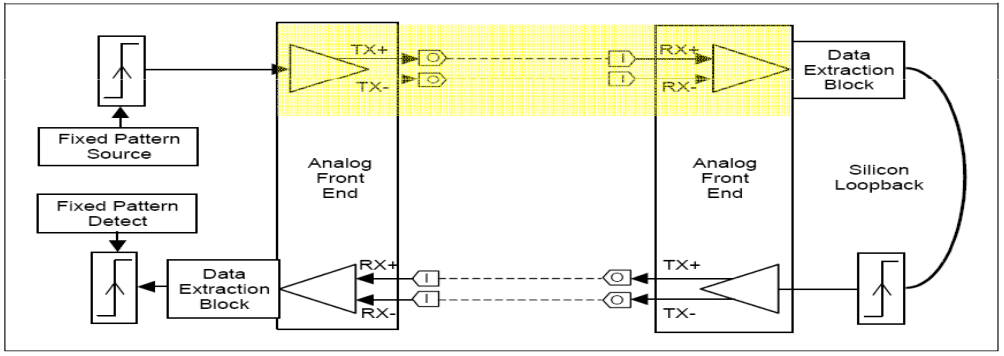
TSG



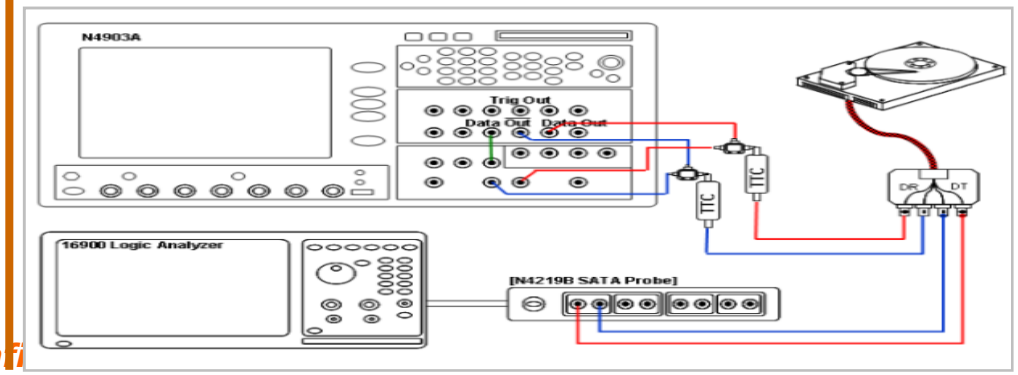
Host ⟷ Device



RSG



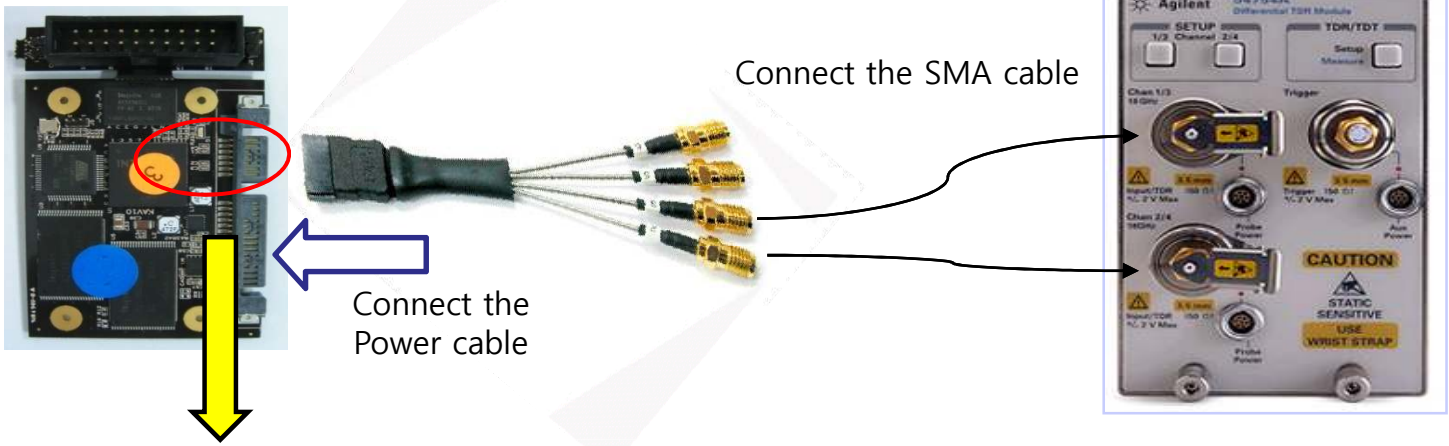
Host ⟷ Device



Compliance Test (Electrical Test)

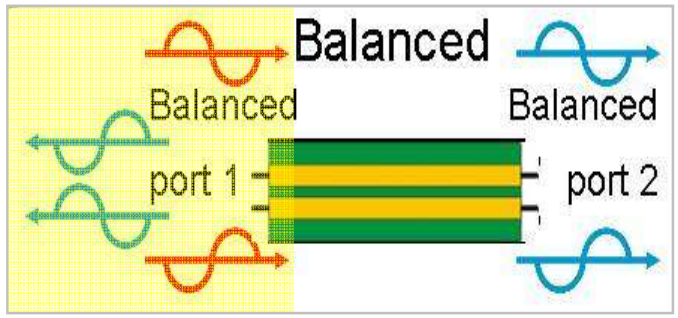
3. Channel Test (Impedance Test)

- Rx/Tx : Device and Host electrical channel performance



PHY	PACKGE	PCB	CONNECTOR

Test area may be divided four province



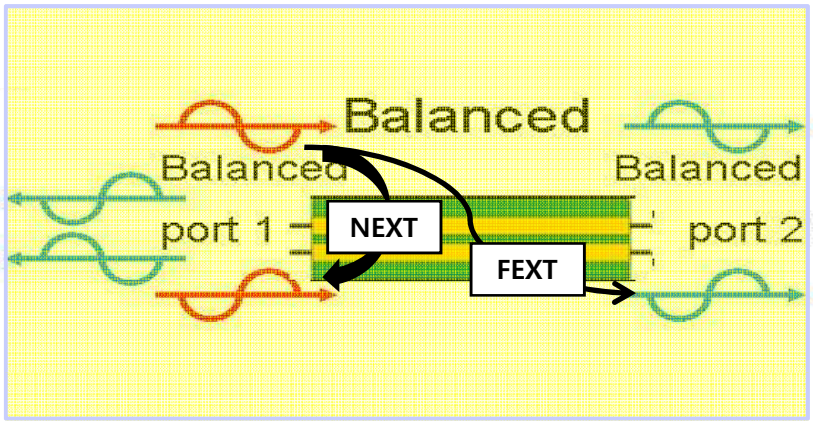
- SDD11 (Differential Return Loss) : The magnitude measure of the differential mode reflection given differential mode excitation on each port.
- SCC11 (Common mode Return Loss) : The magnitude measure of the common mode reflection given a common mode excitation on each port.
- SDC11 (Impedance Balance) : The magnitude measure of the differential mode deflection given a common mode excitation on each port.

Note
* Naming Convention : $S_{(mode\ response,\ mode\ stimulate)(port\ response,\ port\ stimulate)}$
1) Mode - Differential mode : DD / Common mode : CC / Mode Conversion : CD, DC
2) Port - Reflection(Impedance) : 11, 22 / Crosstalk(Cable test) : 12, 21

Compliance Test (Electrical Test)

4. SI Test (Standard Internal Cable Test)

- SI Test : Cable Crosstalk, skew & frequency domain measurements



- NEXT (Near –End Crosstalk)
  - NEXT is interference between two pairs of a cable measured at the same end the cable the transmitter.
- FEXT (Far-End Crosstalk)
  - FEXT is interference between two pairs of a cable measured at the other end of the cable from the transmitter.
- The occurrence of any type of crosstalk can lead to communication issues such as loss of signal and transformation of frequency
- It's possible to improve if it is using shielded conductor on transfer path.

Compliance Test (Electrical Test)

5. Test Items (Based on SATA 2.6 Specification)

SATA Gen1, Gen2 PHY/TSG/OOB Transmitter Testing
PHY-01 Unit Interval
PHY-02 Frequency Long Term Stability
PHY-03 Spread-Spectrum Modulation Frequency
PHY-04 Spread-Spectrum Modulation Deviation
TSG-01 Differential Output Voltage
TSG-02 Rise/Fall Time
TSG-03 Differential Skew
TSG-04 AC Common Mode Voltage
TSG-05 Rise/Fall Imbalance
TSG-06 Amplitude Imbalance
TSG-07 TJ at Connector, Clock to Data, Fbaud/10
TSG-08 DJ at Connector, Clock to Data, Fbaud/10
TSG-09 TJ at Connector, Clock to Data, Fbaud/500 (Gen1)
TSG-10 DJ at Connector, Clock to Data, Fbaud/500 (Gen1)
TSG-11 TJ at Connector, Clock to Data, Fbaud/500 (Gen2)
TSG-12 DJ at Connector, Clock to Data, Fbaud/500 (Gen2)
OOB-01 OOB Signal Detection Threshold
OOB-02 UI During OOB Signaling
OOB-03 COMINIT/RESET and COMWAKE Transmit Burst Length
OOB-04 COMINIT/RESET Transmit Gap Length
OOB-05 COMWAKE Transmit Gap Length
OOB-06 COMWAKE Gap Detection Windows
OOB-07 COMINIT Gap Detection Windows

SATA RSG/RMT Receiver Testing
RSG-01 Gen1 (1.5Gb/s) Receiver Jitter Test
RSG-02 Gen2 (3.0Gb/s) Receiver Jitter Test
SATA Gen1, Gen2 Rx/Tx Channel Testing
TX-01 Pair Differential Impedance
TX-02 Single Ended Impedance (Informative)
TX-03 Gen2 (3Gb/s) Differential Mode Return Loss
TX-04 Gen2 (3Gb/s) Common Mode Return Loss
TX-05 Gen2 (3Gb/s) Impedance Balance
TX-06 Gen1 (1.5Gb/s) Differential Mode Return Loss
RX-01 Pair Differential Impedance
RX-02 Single Ended Impedance (Informative)
RX-03 Gen2 (3Gb/s) Differential Mode Return Loss
RX-04 Gen2 (3Gb/s) Common Mode Return Loss
RX-05 Gen2 (3Gb/s) Impedance Balance
RX-06 Gen1 (1.5Gb/s) Differential Mode Return Loss
SATA SI Testing
SI-01 Mated Connector Impedance
SI-02 Cable Absolute Differential Impedance
SI-03 Cable Pair Matching
SI-04 Common Mode Impedance
SI-05 Differential Rise Time
SI-06 Intra-pair Skew
SI-07 Insertion Loss
SI-08 Differential to Differential Crosstalk: NEXT
SI-09 Inter Symbol Interference

Compliance Test Result

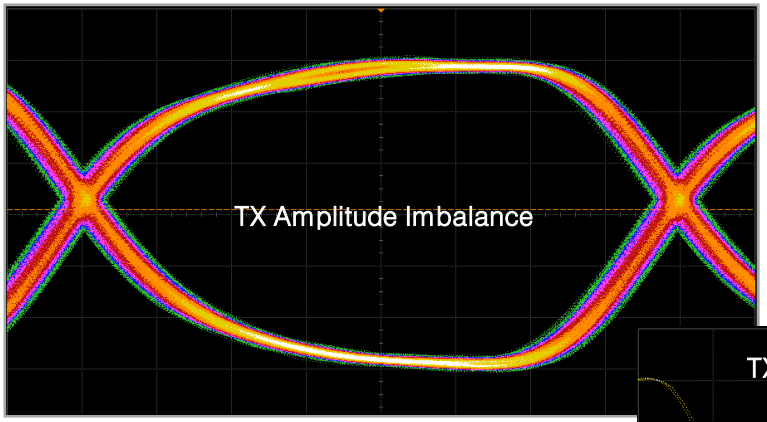
6. Compliance Test Result

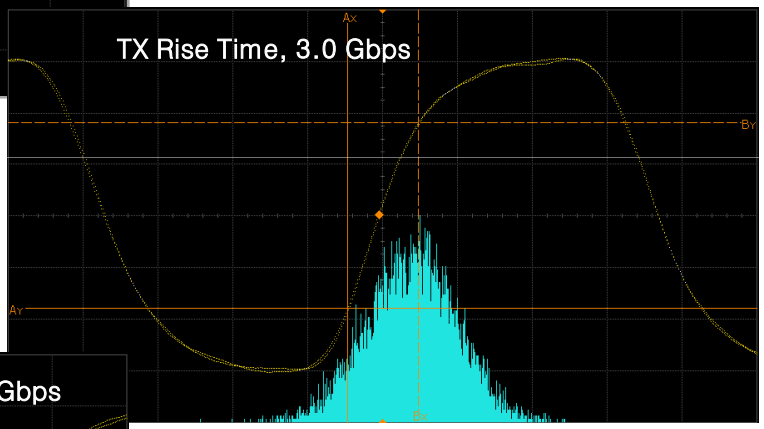
Test result summary

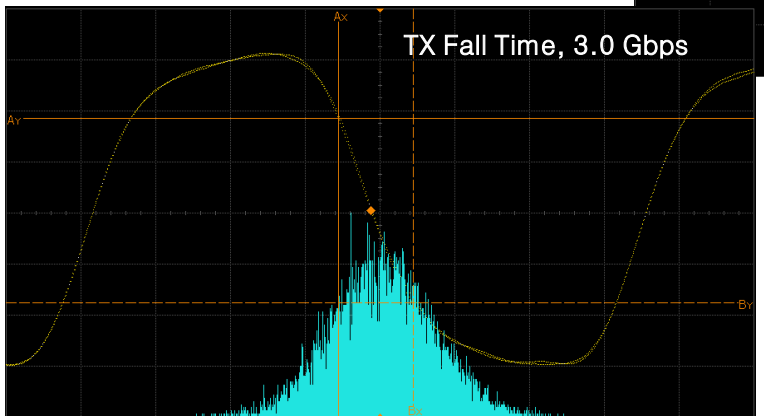
Shows the test results as an overview

Product Number:	SATA
Serial Number:	
Description:	
User Name:	Unknown User
User's Comment:	
Software Versions:	
ValiFrame	1.14.20090211
Sequencer	1.00.20090211
Instrument Manager	1.00.20090211
Serial Bus Family	1.00.20090211
Excel Graph Table Viewer	1.00.20090211
SATA	1.14.20090211

Test name	Result
JBERT MaxSJ Cal	Passed
Diff Voltage Calibration	Passed
Random Jitter Calibration	Passed
Sinusoidal Jitter Calibration	Passed
Tx Channel Speed_3G	Passed
Tx Rise Time_3G	Passed
Tx Fall Time_3G	Passed
Tx Diff Skew HFTP	Passed
Tx Rise Fall Imbal HFTP	Passed
Tx TJ Fb500 HFTP	Passed
Tx DJ Fb500 HFTP	Passed
Tx Min Diff Voltage_3G	Passed
Tx AmplitudeImbalance	Passed
Tx Diff Skew MFTP	Passed
Tx Rise Fall Imbal MFTP	Passed
Tx AC Com Mode Voltage	Passed
Tx TJ Fb500 LBP	Passed
Tx DJ Fb500 LBP	Passed
Tx D COMINIT TransGapLeng	Passed
Tx COMWAKE TransGapLength	Passed
Tx UI During OOB	Passed
Tx D COMINIT TransBurstL	Passed
Tx COMWAKE TransBurstLen	Passed
Tx Drive ResMaxInCOMRESET	Passed
Tx Drive ResMinInCOMRESET	Passed
Tx Drive RejMaxOutCOMRESET	Passed
Tx Drive RejMinOutCOMRESET	Passed
Tx ResMaxInCOMWAKE	Passed
Tx ResMinInCOMWAKE	Passed
Tx RejMaxOutCOMWAKE	Passed
Tx RejMinOutCOMWAKE	Passed







SI Equipment List

대 외 비
09/10/19 ~ 10/10/19

3 in 2012

Agilent vs. Tektronix

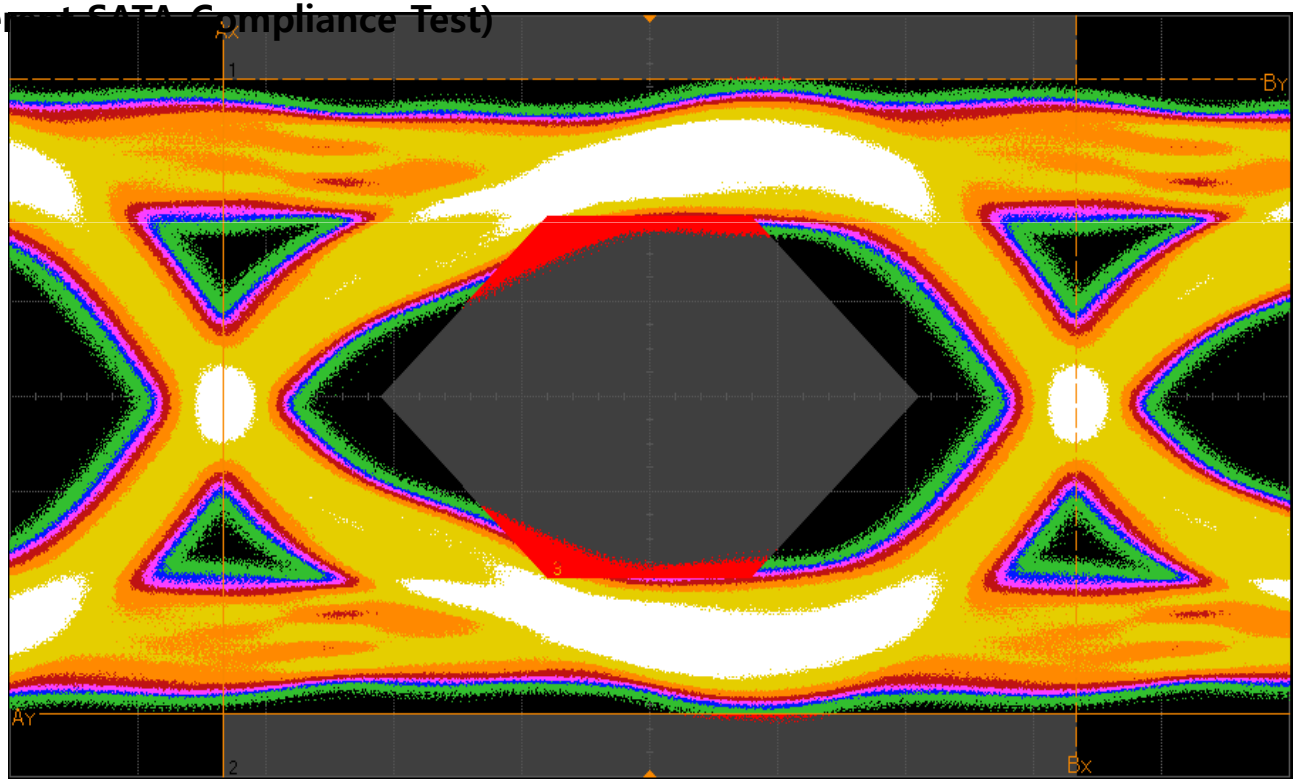
*Drive Master is positively necessary when RSG/RMT & OOB is tested with Agilent Solutions

Method Of Implementation	Tektronix 社	Agilent 社
PHY. TSG. And OOB Tests		
✓ PHY – Signal timing stability and SSC analysis ✓ TSG – Transmitter AC Parametric, Jitter, Amplitude ✓ OOB – Out Of Band signal validation	• Real-Time Oscilloscope(DSA72004) • Pulse Pattern Generator(AWG7102)	• J-BERT(N4903A) • Pulse Pattern Generator(81134A) • Real-Time Oscilloscope(91304A)
Rx/Tx Channel Tests		
✓ Rx/Tx – Device and Host electrical channel performance, impedance and return loss	• Sampling Scope + TDR Module(DSA8200)	• Sampling Scope + TDR Module (86100C)
SI Cable Tests		
✓ SI – Cable crosstalk, skew and frequency domain measurements, sdd21, sdd11	• Sampling Scope + TDR Module(DSA8200)	• Sampling Scope + TDR Module (86100C)
RSG/RMT Tests		
✓ RSG/RMT – Receiver jitter and amplitude sensitivity compliance and margin test	• Real-Time Oscilloscope(DSA72004) • Pulse Pattern Generator(AWG7102) • SATA BOX(C-H-S) • Logic Analyzer(TLA7000 Series)	• J-BERT(N4903A) • SATA BOX(N4219B) • Logic Analyzer(16900 Series)
For Automation		
✓ Added Equipment	• RF Switch ➔ Full Automation available • BER can't measure	• Full Automation not available (RF Switch has problems– occurrence of loss of signal integrity on Tx Test)

SI Test Result @ SSD Real Operation

Mask Test

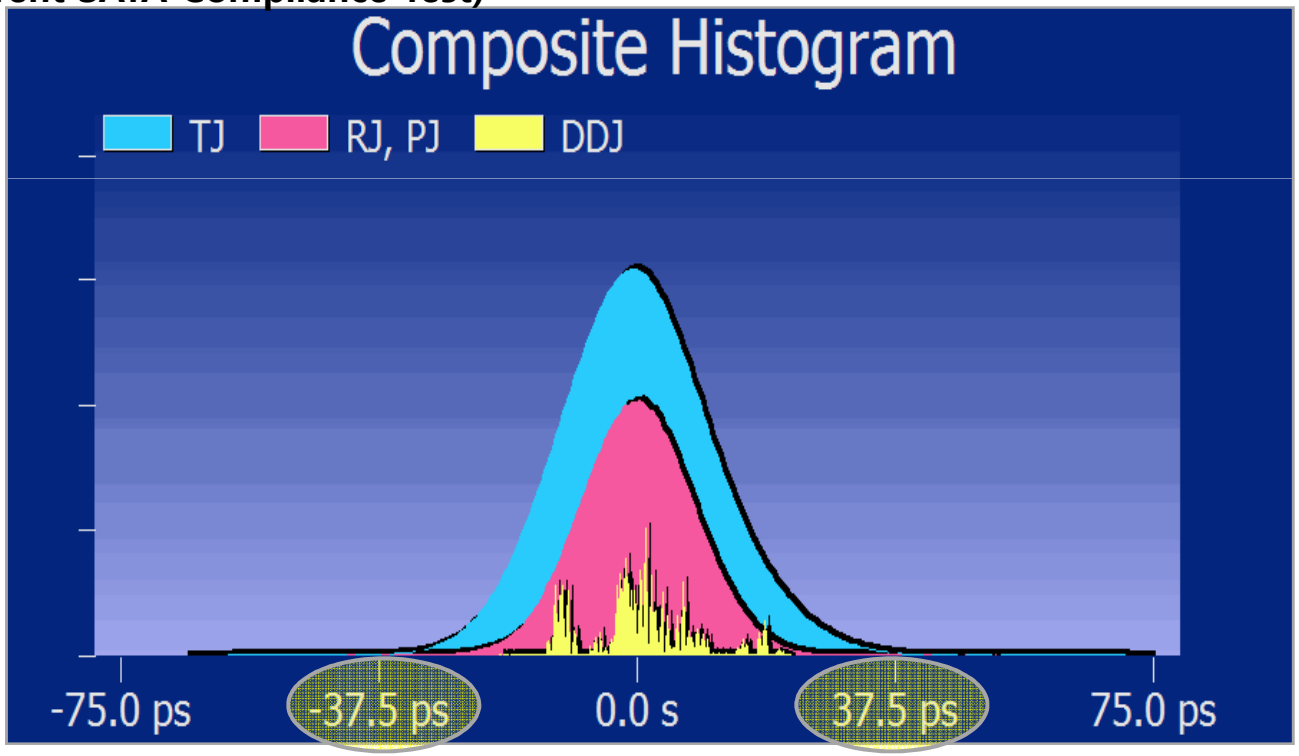
- Using the SATA-II 3Gbps Mask, the Eye Opening Margin of Device is measured.
- Not only SATA PHY, Eye Diagram is measured on real operation that is all operating a surround circuit.
  (It's diffe[illegible]ompliance Test)



Signal Integrity On Real Operation

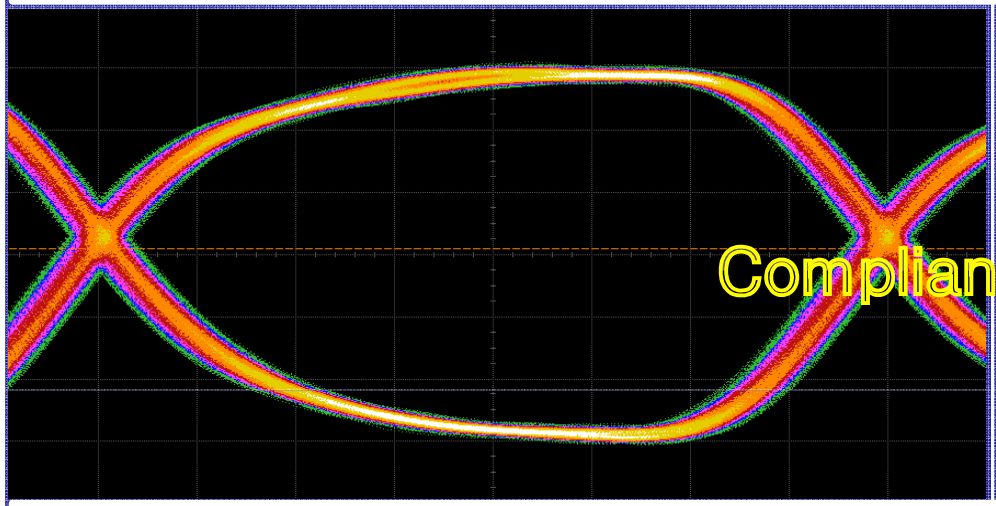
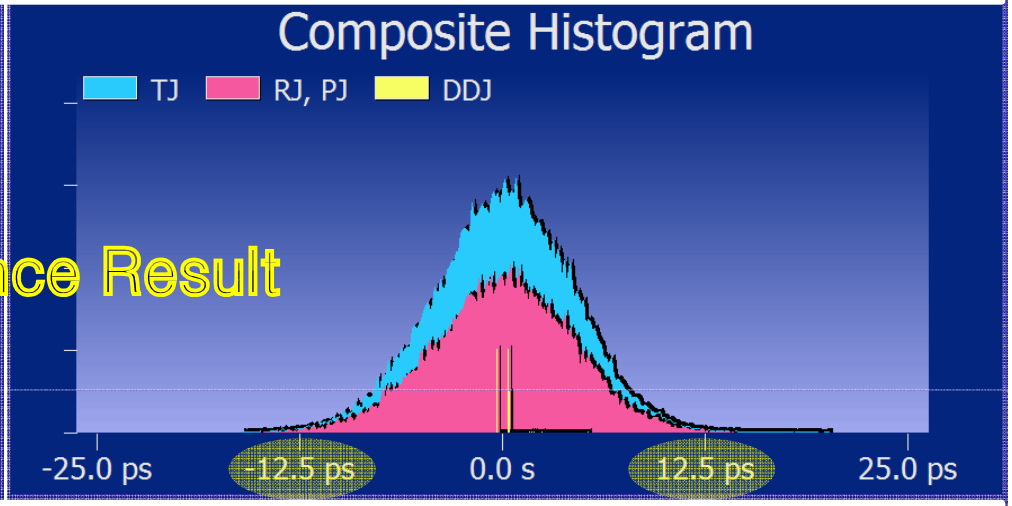
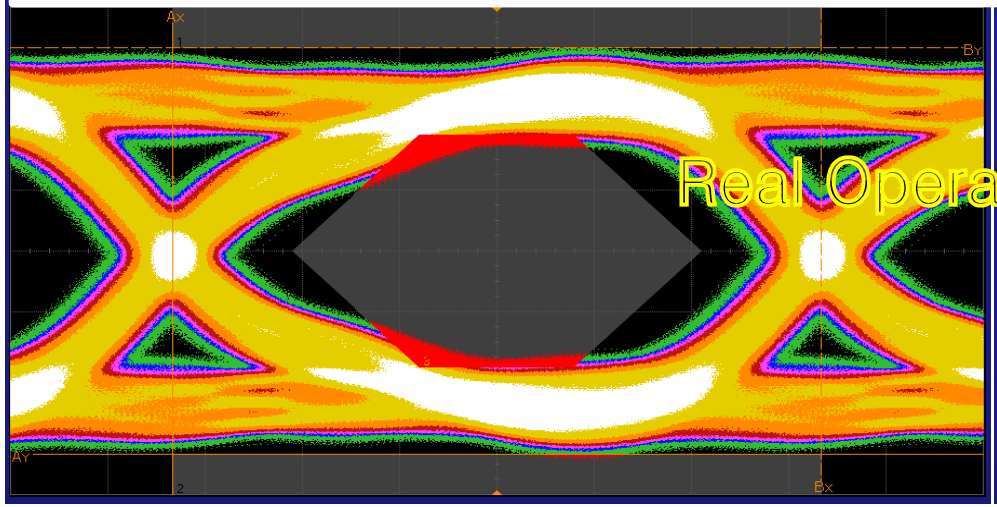
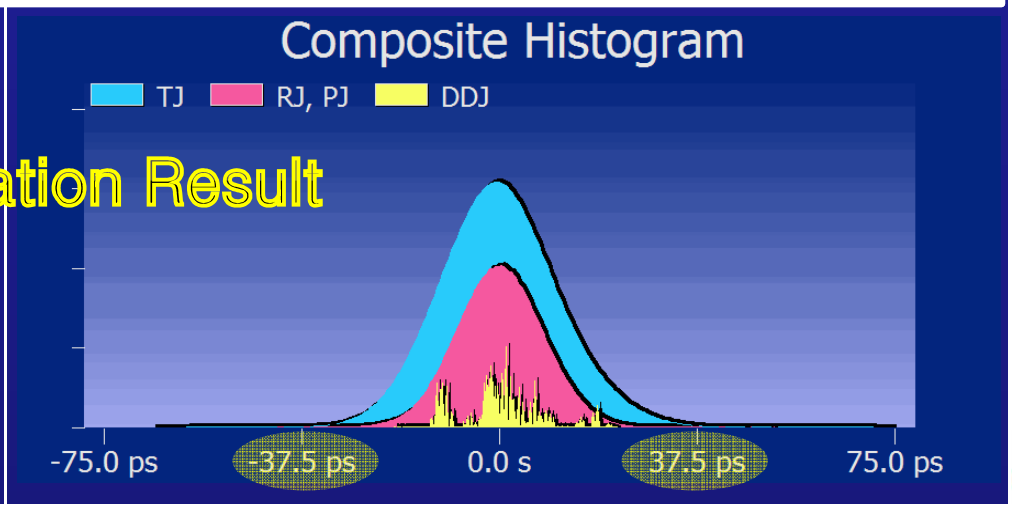
Jitter Test

- All jitter that inserted into the SSD is measured.
- Doing “write/read” a vulnerable pattern of SATA Interface that is captured jitter value
- Not only SATA PHY, Jitter is measured on real operation that is all operating a surround circuit.
  (It’s different SATA Compliance Test)



TJ : Total Jitter RJ : Random Jitter PJ : Periodic Jitter DDJ : Data Dependent Jitter

What is the different?

Eye Diagram	Jitter Histogram
SATA-IO Electrical Compliance Test	
	
Measure worst pattern doing Write/Read on Real Operation	
	

Standardization of SI On Real Operation

Standardization of SSD Signal Characteristics On Real Operation

- Various Character value is need to define comparing the real operation with the Compliance Test.

Standardization of Host Signal Characteristics On Real Operation

- Necessary, not only SSD but Host need to define the steady character value.

Development of Test Environment at Hardware and Software

- Now in used SATA Fixture it is impossible to signal capture during real operation.
- Software is need for CMD issue from Host to Device.

Signal Integrity Test Tool have to make base on Real Operation

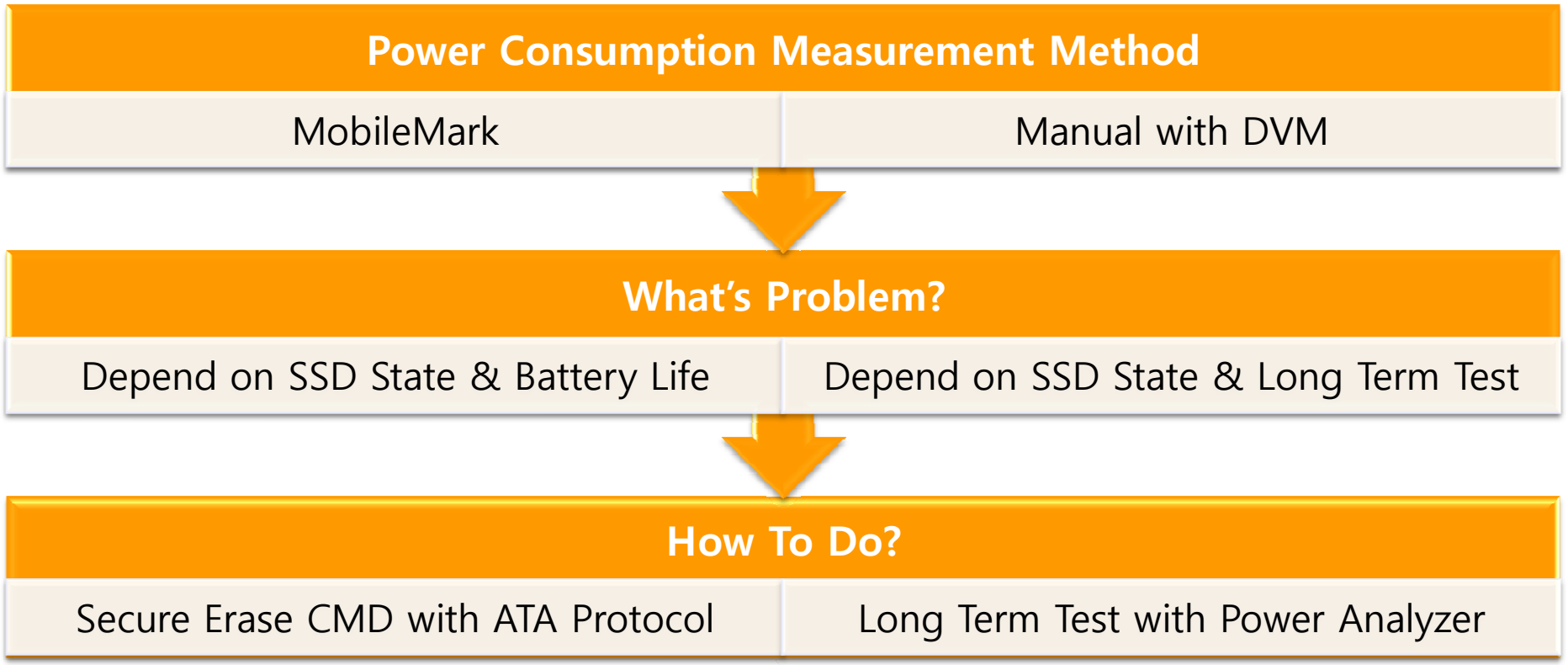
➔ Need to expedite to make the New SI Tool

Contents

- Benchmark Tool
- Signal Integrity
- **Power Consumption**

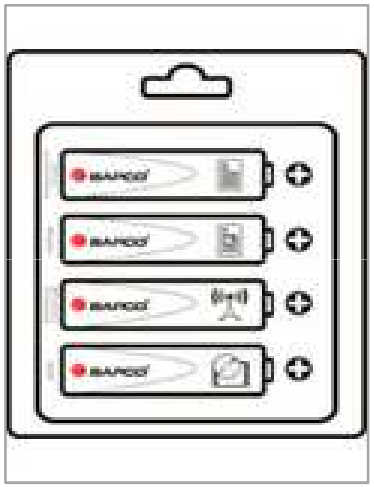
hynix

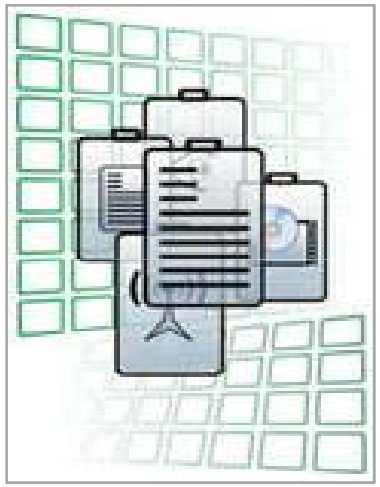
Power Consumption



Power Consumption Measurement Method

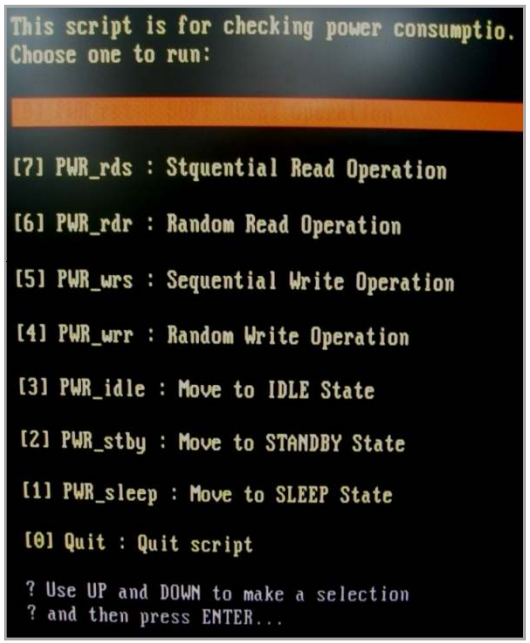
- MobileMark 2005 & 2007
- Major companies use to measure their Notebook Battery life
- A measurement tool of the Notebook Battery life by the General workloads

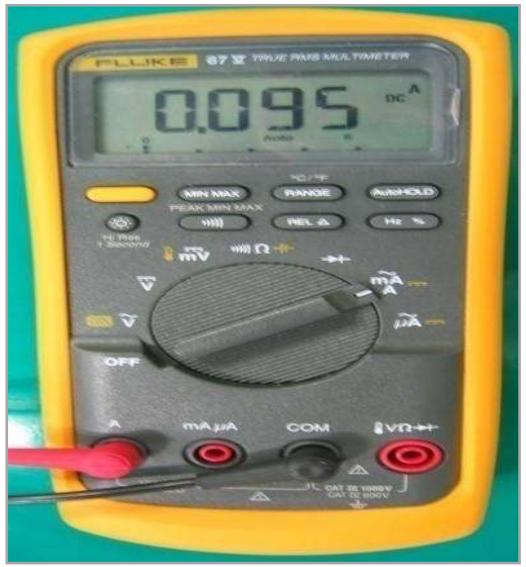




AMD ARCintuition TOSHIBA Seagate vnu ZDNet intel hp invent COMPUTER SHOPPER DELL TRANSMETA ATHEROS ATI ZIFF DAVIS Microsoft NVIDIA cnet

- Manual with DVM
- Sequential and Random Read/Write Operation measurement
- (Min. / Avg. / Max.) current value measures and compares with DVM





Mobile Mark Test Concept

System Requirements

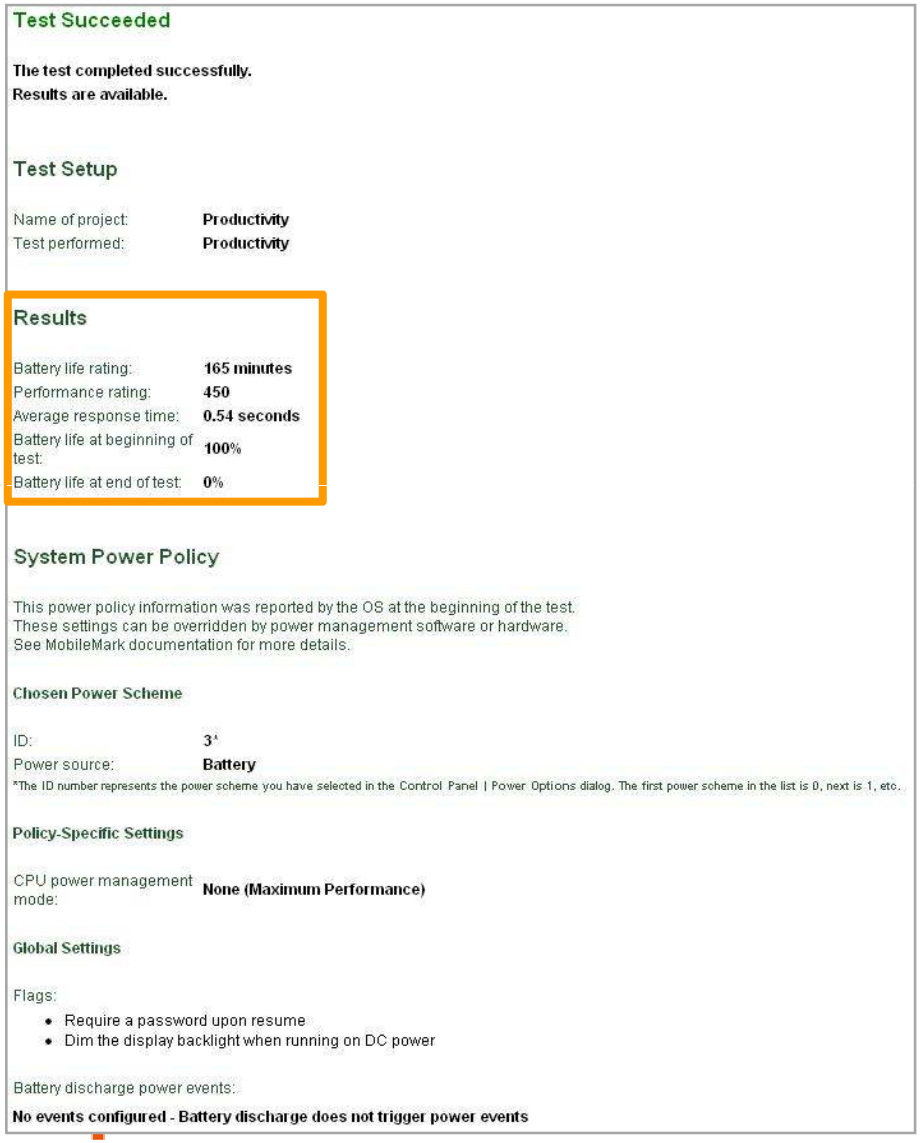
	2005	2007
CPU	• Intel® Pentium® III processor running at 300 MHz or equivalent	• Intel® Pentium® M processor 1600 MHz or equivalent
Memory	• 256 MB	• 1 GB
Display setting	• 1024x768, 16-bit color	• 1024 x 768, 16-bit color
Operating System	• Microsoft Windows XP with Service Pack 2 These versions of Windows XP are supported: Chinese (Traditional) , Dutch, English, French, German, Italian, Japanese, Portuguese, Spanish	• Microsoft Windows XP with Service Pack 2 (32-bit and 64-bit) • Microsoft Windows Vista (32-bit and 64-bit) • MobileMark 2007 is supported only on English operating systems.
Hard drive space	• 3.0 GB free hard disk space	• 30 GB free hard disk space
DVD-ROM drive	• Available	• Available

Application

Applications	• Adobe® Photoshop® 6.0.1 • InterVideo® WinDVD® 6.0 • Macromedia® Flash 5.0 • Microsoft® Internet Explorer • Microsoft® Office® 2002 • Netscape® Communicator® 6.01 • Network Associates® McAfee® VirusScan® 5.13 • WinZip Computing WinZip® 8.0	• Adobe® AcrobatReader 7.0 • Adobe® Illustrator® CS2 • Adobe® Photoshop® CS2 • Apple® Quicktime 7.1 • Intervideo® WinDVD® 8 • Macromedia® Flash 8 • Microsoft® Office® 2003 Pro • Microsoft® Project 2003 • Winzip® 10.0

Test Result (MobileMark & DVM)

MobileMark05



Test Succeeded

The test completed successfully.
Results are available.

Test Setup

Name of project:	**Productivity**
Test performed:	**Productivity**

Results

Battery life rating:	**165 minutes**
Performance rating:	**450**
Average response time:	**0.54 seconds**
Battery life at beginning of test:	**100%**
Battery life at end of test:	**0%**

System Power Policy

This power policy information was reported by the OS at the beginning of the test.
These settings can be overridden by power management software or hardware.
See MobileMark documentation for more details.

Chosen Power Scheme

ID:	**3***
Power source:	**Battery**

*The ID number represents the power scheme you have selected in the Control Panel | Power Options dialog. The first power scheme in the list is 0, next is 1, etc.

Policy-Specific Settings

CPU power management mode: **None (Maximum Performance)**

Global Settings

Flags:

- Require a password upon resume
- Dim the display backlight when running on DC power

Battery discharge power events:

No events configured - Battery discharge does not trigger power events

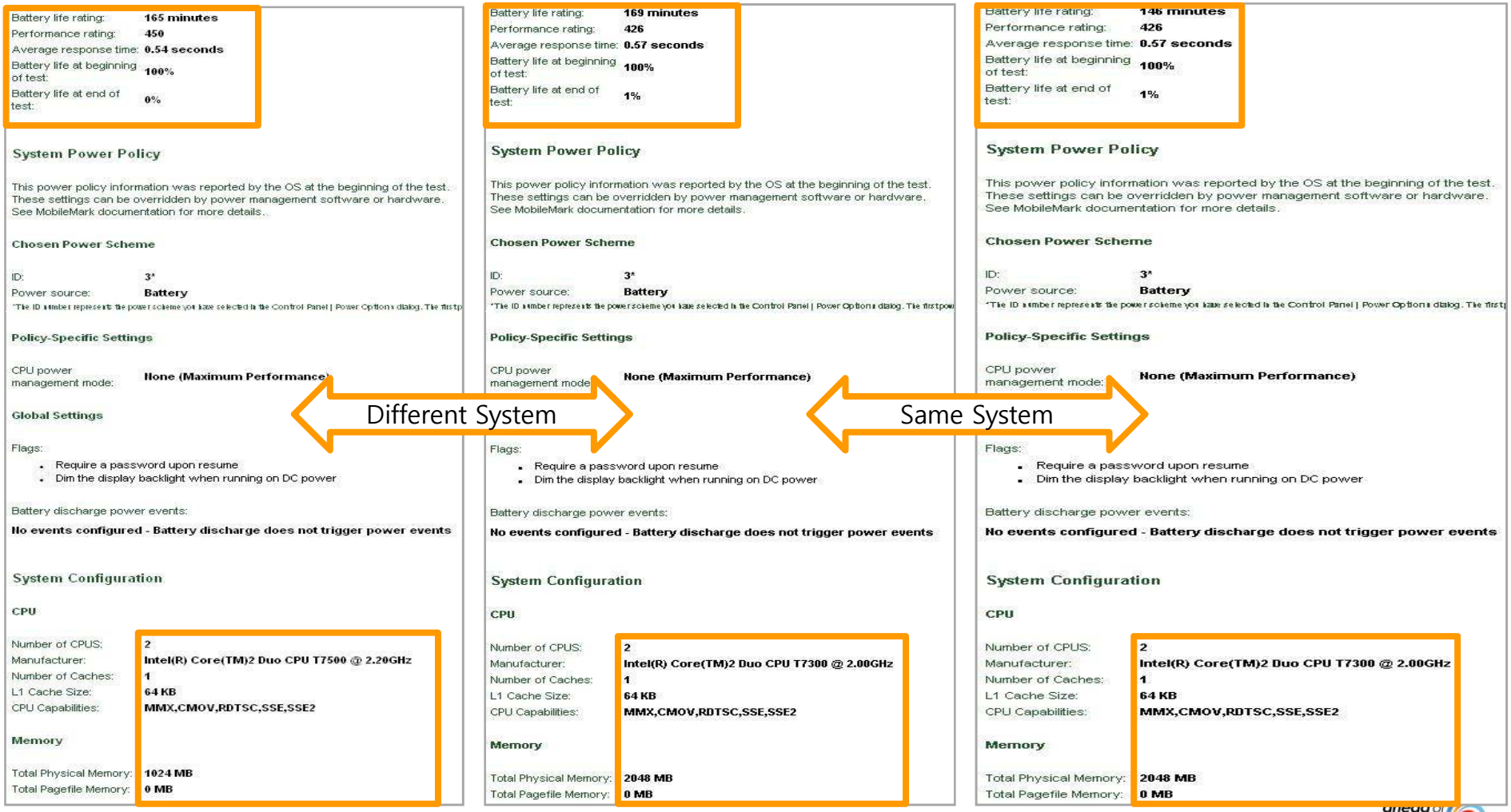
Manual

Manual with DVM		
Sequential	Read	256Sectors (128KBytes)
	Write	256Sectors (128KBytes)
Random	Read	1Sector (512Bytes)
	Write	1Sector (512Bytes)

		Case 1	Case 2	Case 3
Booting		98	95	97
Base		98	95	97
Power Mode	Idle	98	95	97
	Standby	98	95	97
	Sleep	98	95	97
Sequential Read		150	152	151
Sequential Write (Avg. / Max.)		290 / 311	313 / 329	306 / 318
Random Read		108	112	113
Random Write (Avg. / Max.)		180 / 201	211 / 225	205 / 247

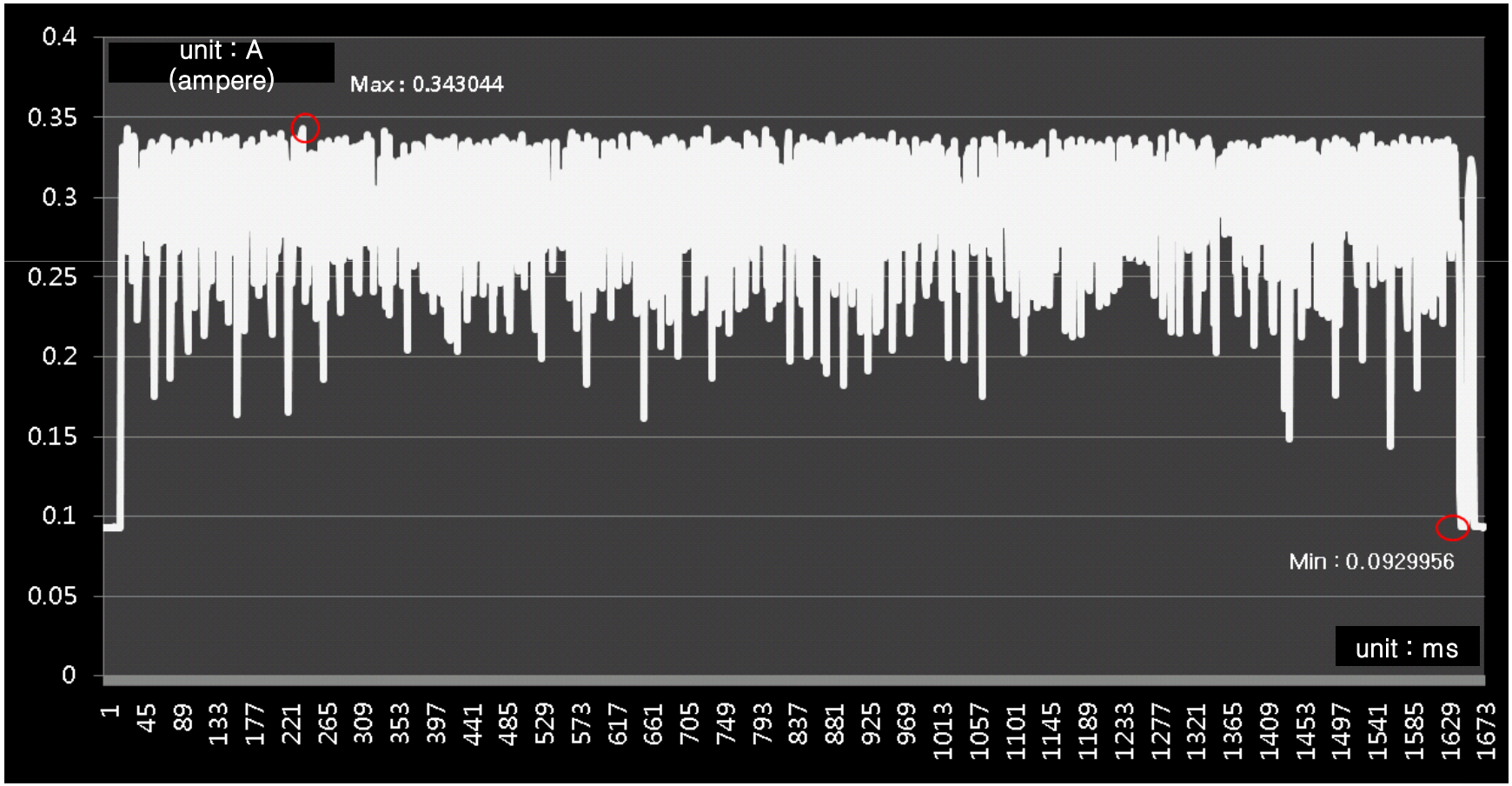
What's Problem? : MobileMark

- MobileMark measures battery life of the entire Notebook system.
- A kind of Notebook system, as well as the same Notebook system, has a different results.



What's Problem? : Manual vs DVM

- The measured values depend on the status of the device
- During a Dirty State operates Background Garbage Collection or Erase so it consumes more power than a Clean state
- Need to the Long Term (Clean State → Dirty State) measurement



Standardization of Power Measurement Tool

I. Cann't believe the Mobile Mark & DVM Result

II. In lack of consistency, test method difference , Need to make New tools & Please provide your ideas.