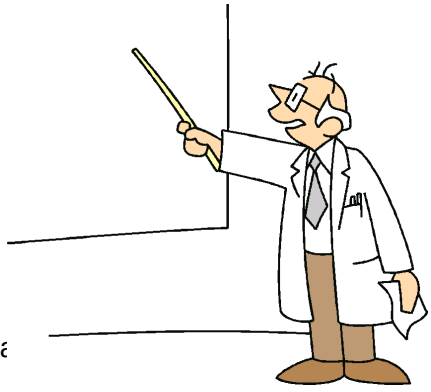
SATA-IP Introduction (Xilinx)

Ver2.5E

Magician of the Storage!

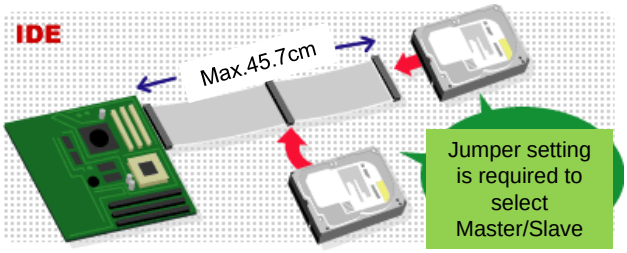
Agenda

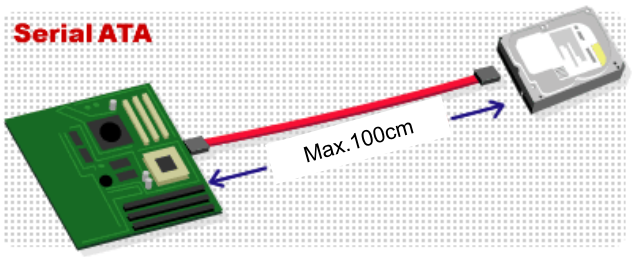
- **SATA Overview**
  - **Summary, Features and Trend**
  - **Merit and Solution**
- **SATA-IP Introduction**
  - **Summary**
  - **Application**



What is SATA?

- **Standard storage interface of HDD/SSD**
  - **SATA1.0 released in year 2000, the latest standard is SATA3.0.**
- **Improved from IDE (Parallel-ATA)**
  - **Cable (from 80 line 46cm to flat narrow cable 1m)**
  - **High-speed (PATA: Max.133MB/s -> SATA: Max.600MByte/s)**
  - **Jumper setting is not required anymore.**





Features of SATA device

- **Popular**
  - **Compatibility. Easy to replace.**
  - **Commodity. Easy to buy.**
- **Low price**
  - **2.5“SSD 480GB is 50USD**
  - **3.5”HDD 4TB is 80USD**

(06-Jan-2019 Amazon.com)

Trend of SATA device

- SATA storage is switching to SSD from HDD.
- SSD has advantage compared with HDD in toughness & silence.
- HDD has advantage compared with SSD in capacity and price.

	HDD	SDD
Life Expectancy	☆☆☆	☆☆☆☆☆
Operating Temperature	☆☆☆	☆☆☆☆☆
Storage Temperature	☆☆☆☆	☆☆☆☆☆
Operating Shock	☆	☆☆☆☆☆
Operating Vibration	☆	☆☆☆☆☆
Humidity	☆☆☆☆	☆☆☆☆☆
Altitude	☆☆☆	☆☆☆☆☆
Acoustic Noise	☆☆☆	☆☆☆☆☆
Raw Media Error Rate	☆☆☆	☆☆☆☆
Apps Data Error Rate	☆☆☆☆	☆☆☆☆
Performance -Sequential	☆☆☆☆	☆☆☆☆
Performance -Random	☆☆	☆☆☆☆
Power Idle	☆☆☆	☆☆☆☆
Power Read/Write	☆☆	☆☆☆☆
Capacity	☆☆☆☆☆	☆☆☆☆
Cost/IOPS	☆☆☆	☆☆☆
Cost /MBps	☆☆☆☆	☆☆☆
Cost/GB	☆☆☆☆☆	☆☆☆

Merit of SATA adoption

- **Huge non-volatile storage**
  - GigaByte/TeraByte capacity.
- **High-speed and Low cost**
  - Several Megabyte per second Read/Write speed
  - Mass produced goods
- **Compatibility**
  - Easy and quick to repair and recover, just replace.
  - Your product lineup will be various with different capacity storages

512GB	SSD-N512S/PM3P	￥94,815(税込)	￥90,300(税抜)
256GB	SSD-N256S/PM3P	￥50,085(税込)	￥47,700(税抜)
128GB	SSD-N128S/PM3P	￥25,620(税込)	￥24,400(税抜)

Just change storage capacity
to arrange various products
from high-end model to low cost model.

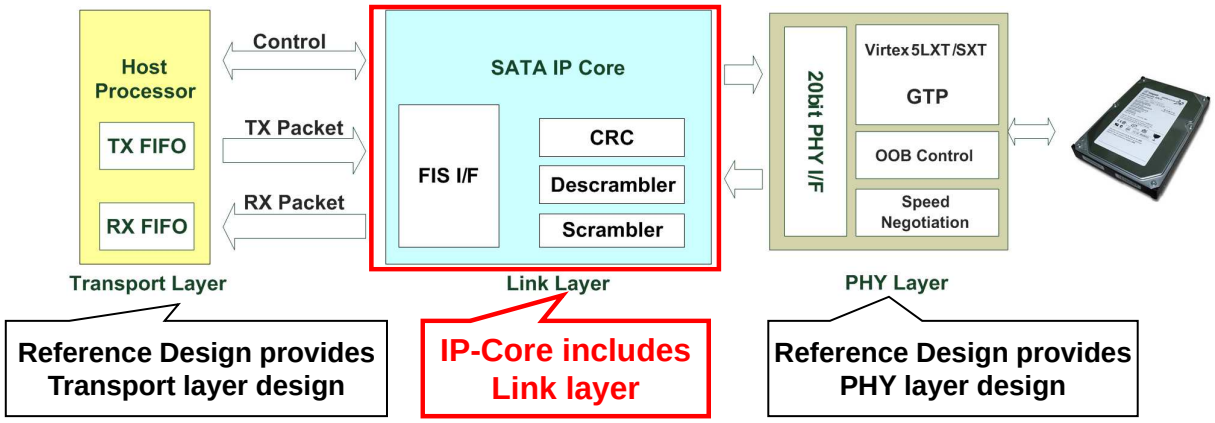
Solution for embedded system

- **1: Use Existing SATA chip (ASSP)**
  - **Merit: Device cost**
  - **Demerit: Limitation of MOQ, support and fixed function**
- **2: Use FPGA+SATA-IP core**
  - **Merit: Flexibility, support special usage such as RAID, MOQ etc..**
  - **Demerit: Device cost (In case of SATA function only)**

Conclusion:
If the system is simple function and the availability is acceptable,
ASSP may be better for you.
For other case, FPGA + SATA-IP core is best solution for you!!

What is SATA-IP?

- **Implement SATA channel by MGT resource.**
- **IP-Core includes Link layer (and some part of Transport layer).**
- **Reference Design available for PHY layer and Transport layer.**



Product Lineup

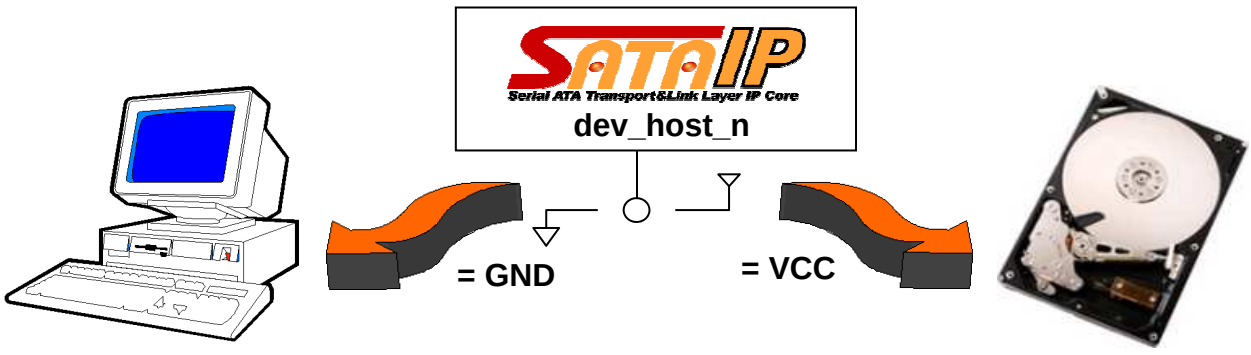
Prod. No.	Device	Speed	Available reference design
SATA-IP-ZUP	Zynq-UltraScale+	SATA-III	4chRAIDwithHCTL-IP, HCTL-IP
SATA-IP-VUP	Virtex-UltraScale+	SATA-III	4chRAIDwithHCTL-IP, HCTL-IP
SATA-IP-KU	Kintex-UltraScale	SATA-III	4chRAID, Host, HCTL-IP, 8chRAIDwithHCTL-IP
SATA-IP-VT7	Virtex-7	SATA-III	8ch/4chRAID, Host, HCTL-IP
SATA-IP-ZQ7	Zynq-7000	SATA-III	4chRAID, Host, Device, Linux(AHCI), exFAT, FAT32
SATA-IP-KT7	Kintex-7	SATA-III	4chRAID, Host, Device, HCTL-IP, Duplicator, FAT32
SATA-IP-AT7	Artix-7	SATA-III	Host, Device, HCTL-IP, Bridge

All device from 7-series or later can support SATA3.0 (6Gbps)

Many reference design available (Can check operation for evaluation)

Supports both of Host and Device

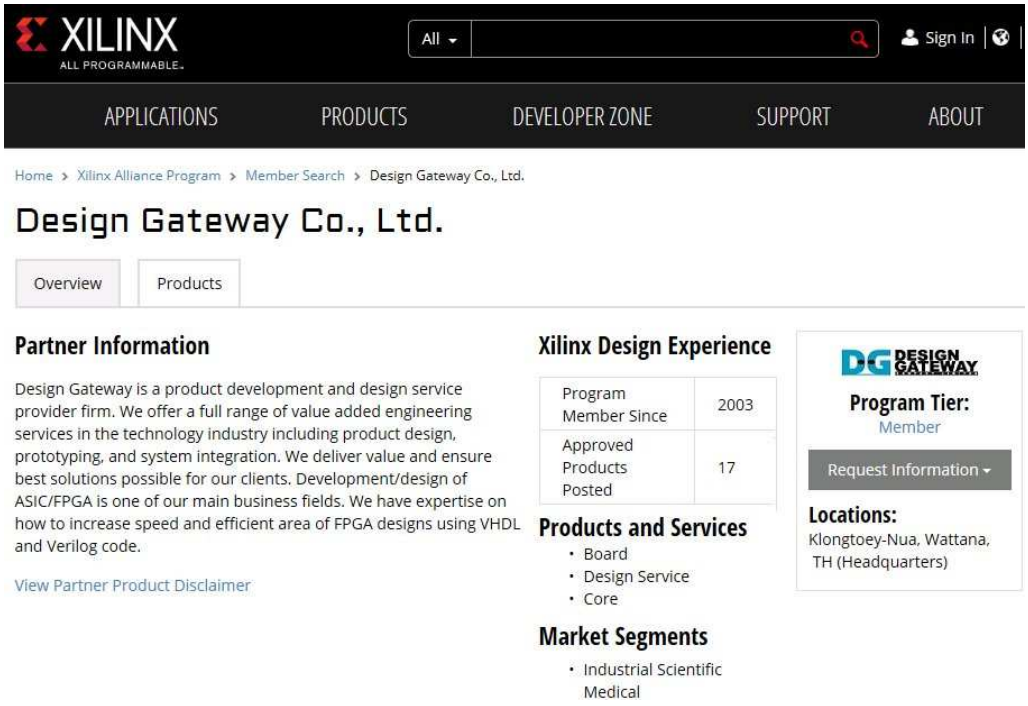
- **Single IP-Core supports both of Host (PC side) and Device (Disk side).**
  - **Switch between Host function and Device function by dev_host_n signal input.**



SATA Host Core

SATA Device Core

Approved IP-Core by Xilinx

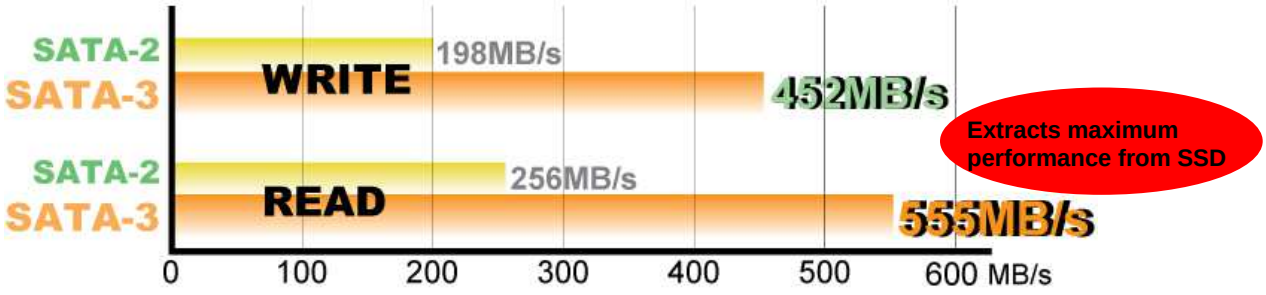


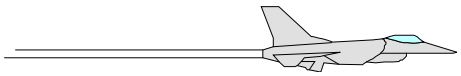
http://www.xilinx.com/alliance/memberlocator/1-8dv3-6.html

SSD performance

- **More than 200MB/s transfer speed by the latest SSD.**
- **Achieves SSD specification performance.**
  - **Best for high-speed large-capacity storage application.**

SATA-2/3 SSD performance result

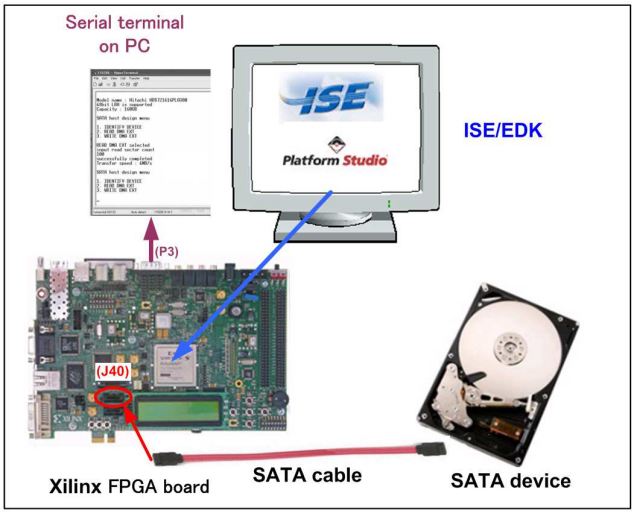


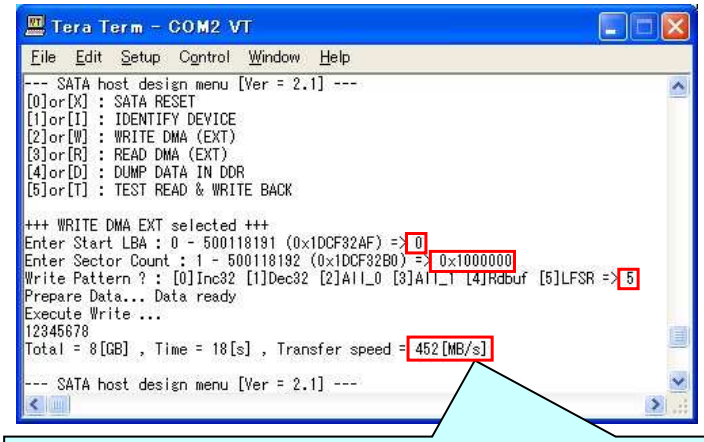


* Evaluation result by KC705
* SATA-2 SSD: Intel SSDSA2SH032G1GN
* SATA-3 SSD: Samsung SSD840PRO
* 8GB sequential access performance using psudo random data pattern

Free Bit-file for Evaluation (1)

- Serial communication with PC as Host side.
- Write/Read access to/from SATA device.
- Measure transmission speed.

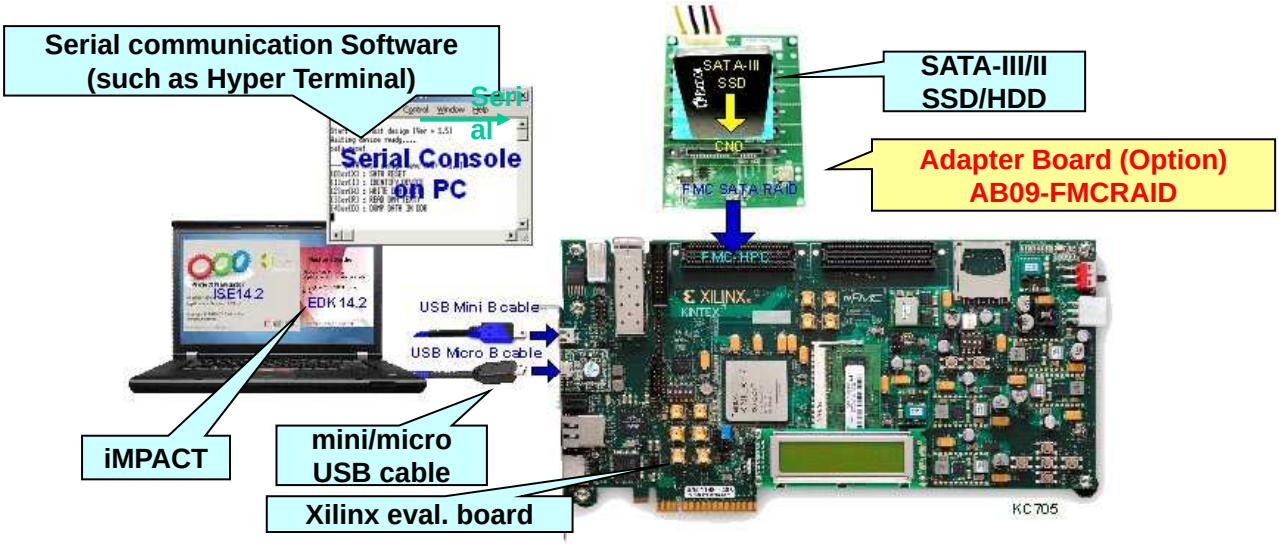




Example of write transfer
- **Set address, sector count and type of data pattern**
- **Measure transmission speed and display the result**

Free Bit-file for Evaluation (2)

- Free bit-file for Evaluation on Xilinx FPGA boards.
- Downloadable from SATA-IP Web page.



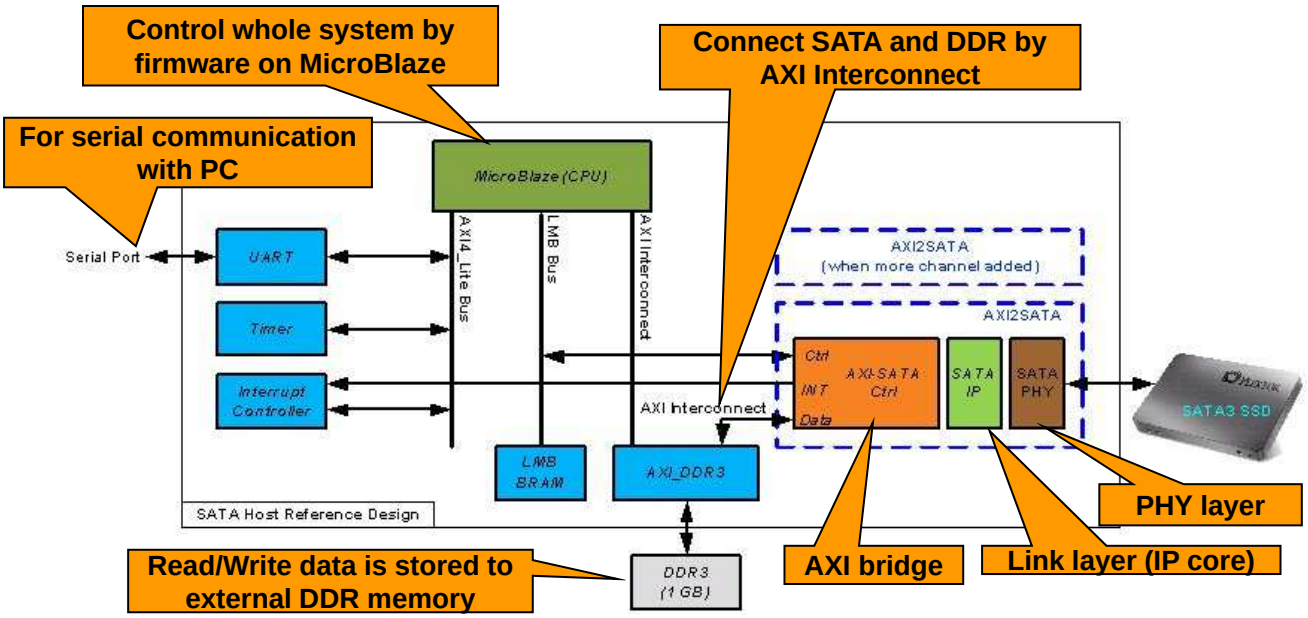
SATA-IP evaluation environment

Reference Design (Summary)

- **EDK Project Design of Evaluation bit-file.**
- **Full source code (VHDL) except IP core**
- **Can save user system development duration**
  - **Confirm real board operation by original reference design.**
  - **Then modify a little to approach final user product.**
  - **Check real operation in each modification step.**

No risk to back to rebuild, able to develop for short term!

Reference Design (Structure)



Block diagram of SATA-IP reference design

Resource Usage

XPS Synthesis Summary (estimated values)			
Report	Flip Flops Used	LUTs Used	BRAMS Used
system	31150	31277	53
system axi42sata 0 wrapper	1968	2020	17
system ddr3 sdram wrapper	11069	14651	
system rs232 uart 1 wrapper	305	451	
system dual timer counter wrapper	217	311	
system debug module wrapper	131	140	
system microblaze 0 wrapper	2156	2004	4
system lmb bram wrapper			16
system interrupt cntlr wrapper	56	92	
system axi4lite 0 wrapper	118	249	
system axi mm mb wrapper	834	498	
system axi4 0 wrapper	14219	10749	16
system proc sys reset 0 wrapper	69	56	

Design total= 31150DFF & 53BRAM

SATA 1channel= 2000DFF & 17BRAM

+

Use about 2500DFF for SATA in 14219DFF of AXI wrapper (No BRAM consumption at SATA)

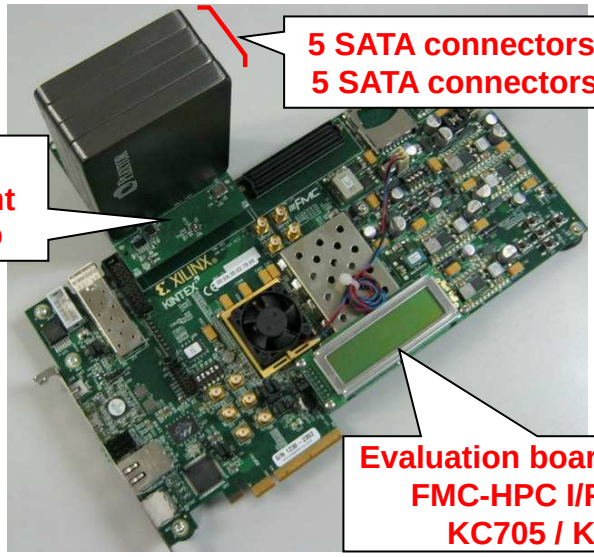
4500DFF & 17BRAM for 1 SATA channel

1% of total DFF=407,600
4% of total BRAM=445
in XC7K325T

SATA-IP reference design resource usage

Development tool for RAID

- Adapter board with 10 SATA Host connectors.
- Connector for FMC-HPC of Xilinx Eval Bd.
- Direct connect to 2.5 inch SSDs or HDDs.

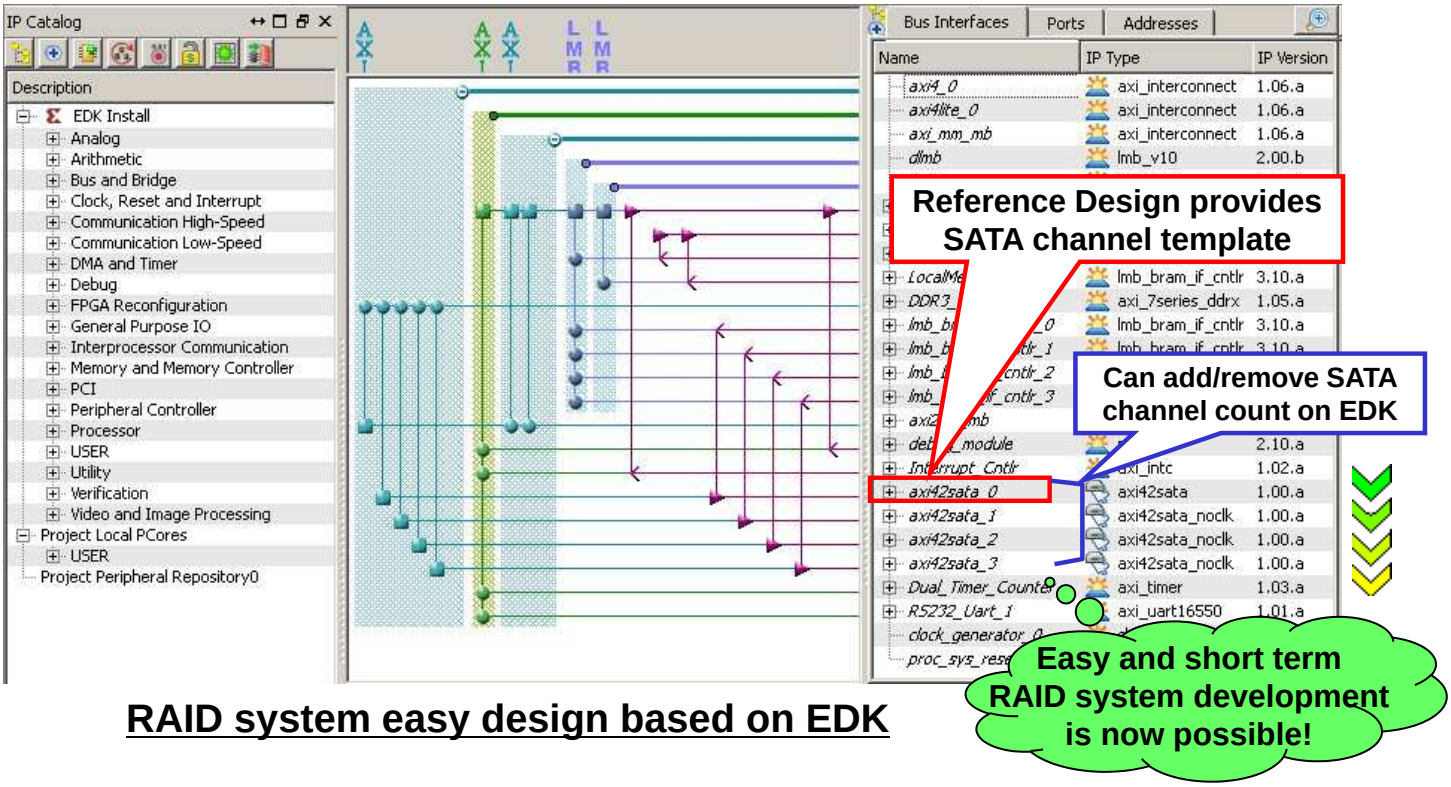


5 SATA connectors on top side and 5 SATA connectors on bottom side

Adaptor Board for RAID development P/N: AB09-FMCRAID

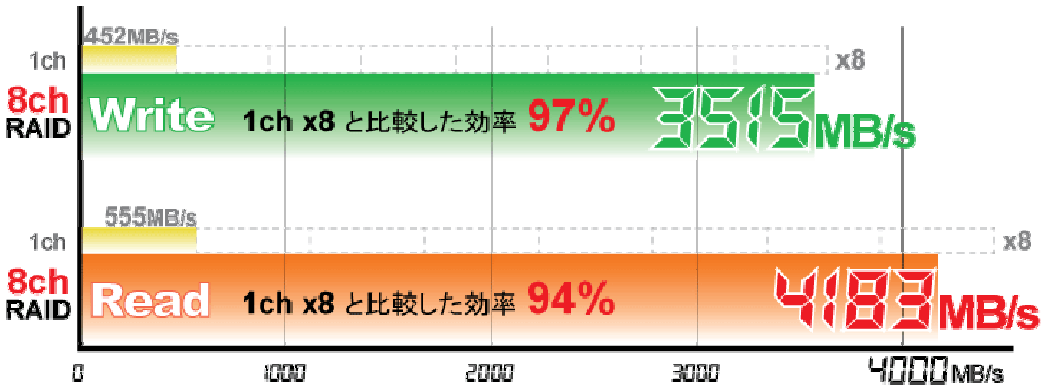
Evaluation board supporting FMC-HPC I/F (such as KC705 / KCU105)

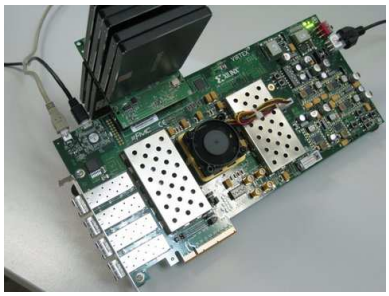
RAID Design Project



RAID system easy design based on EDK

RAID System Performance



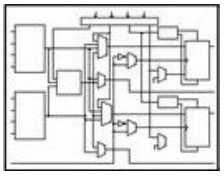


*** SSD : Samsung SSD 840PRO**
(Standalone performance is Write=452MB/s and Read=555MB/s)

VC709 + 8 SSDs RAID system performance

SATA-IP Optional Product

- **HCTL-IP Core**
  - Pure hard-wired host controller core
  - Automatic read/write execution without CPU
  - Best performance because firmware overhead not exist



- **AHCI-IP Core**
  - SATA access possible from LinuxOS
  - Support ARM Core for Zynq-7000 family

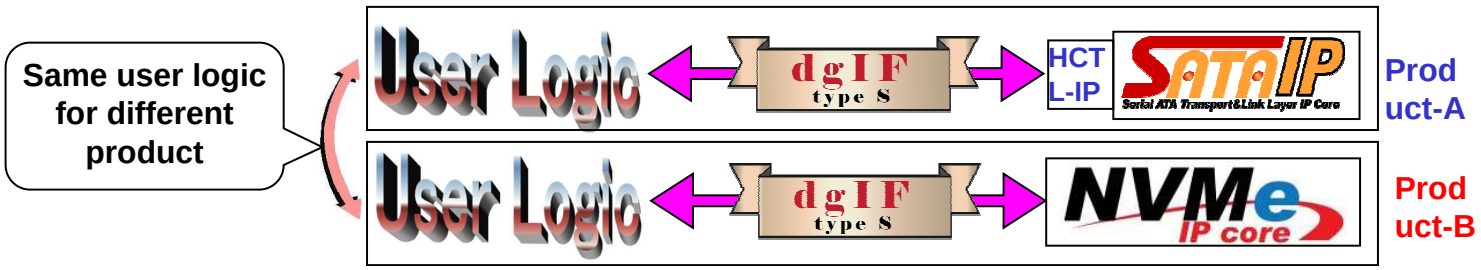
- **FAT32-IP/exFAT-IP**
  - Provide FAT32/exFAT access feature by hardwired logic
  - Can record data as 'file' -> PC can access to data via file

HCTL-IP Core (Optional Product)

- **Controller IP core designed by pure hard-wired logic**
  - Full autimatic SATA-IP control instead of CPU and its firmware
  - Can build storage system without CPU
  - Can save CPU time completely in SoC application system
- **Minimize overhead by high speed state machine**
  - Theoretically the best performance (especially for write)
  - Write improvement example: CPU control=465MB/s -> Host-IP=525MB/s
  - Provides reference design for both 1ch and 4ch-RAID0 on Intel board

HCTL-IP Core (Cont'd)

- **Common interface among all Storage IP-Core (dgIF typeS)**
  - Same user interface among other IP-Core (NVMe-IP) product
  - Can keep same user logic for different storage between SATA and NVMe



- **Simple user interface for easy use**
  - Set R/W type, address, sector count parameter and issue request pulse
  - Very popular data interface by general FIFO

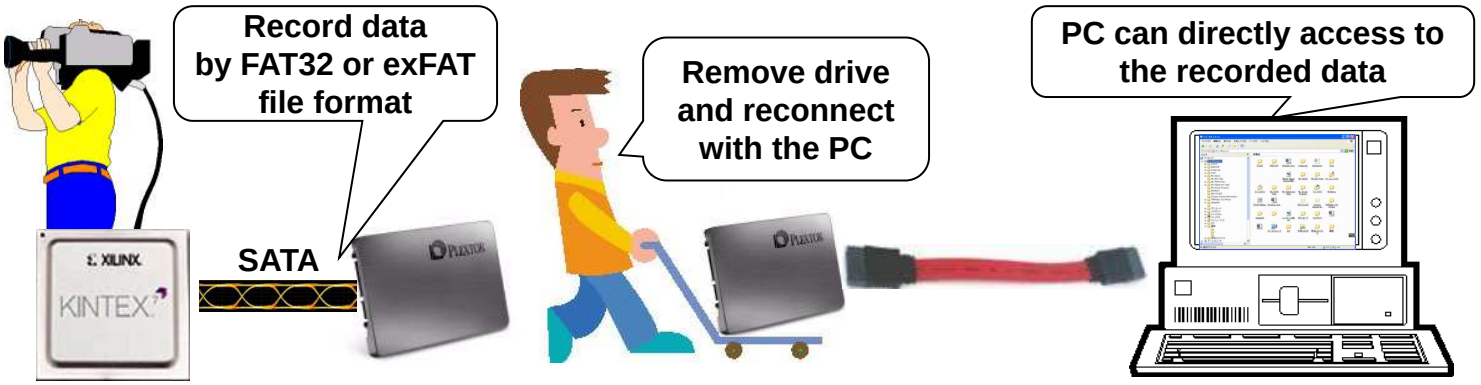
AHCI-IP Core (Optional Product)

- **Can access to SATA channel from Linux**
  - Reference design available for SoC device
  - Provide AHCI Linux driver C source code

- **Supports NCQ feature**
  - Queue re-order in multiple command
  - Minimum latency by using internal RAM for Queue table
  - Very high performance for random access
- **Multiple port count support by customization**
  - Standard product support 1 port
  - Port count can be increased by core customization

FAT32-IP/exFAT-IP Core (Optional Product)

- **Supports data recording by FAT32/exFAT file format**
  - **In combination with both SATA-IP and HCTL-IP core**
- **PC can directly access to recorded data as a file**
  - **FPGA writes data to device, reconnect with PC, then PC can read data**



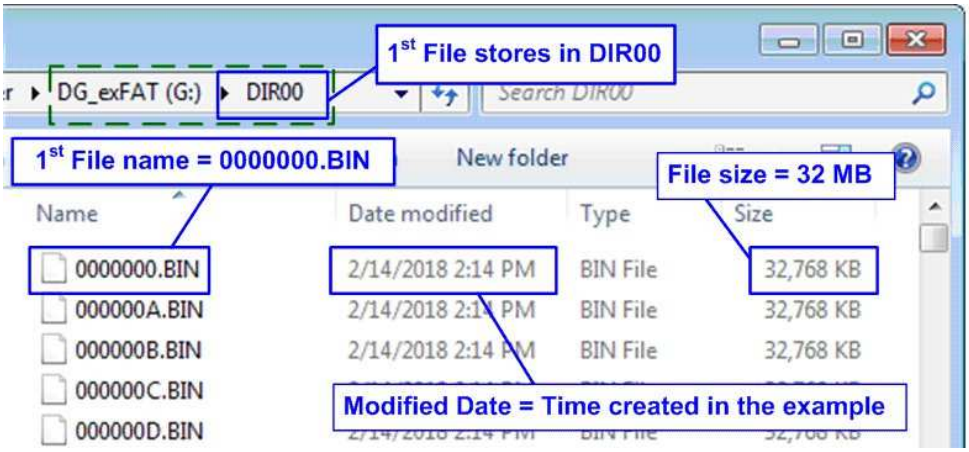
PC can directly read recorded data as a file

FAT32-IP/exFAT-IP (Cont'd 1)

- **Feature description**
  - **Executes drive format and data write to file by pure hardwired logic.**
  - **IP core automatically generates file name.**
  - **User logic sends file data via FIFO interface.**
- **Limitation**
  - **Drive must be formatted by the IP core, not by the PC.**
  - **Files other than those generated by the IP core cannot be written to the drive.**
  - **File size is determined at format execution and cannot be changed.**

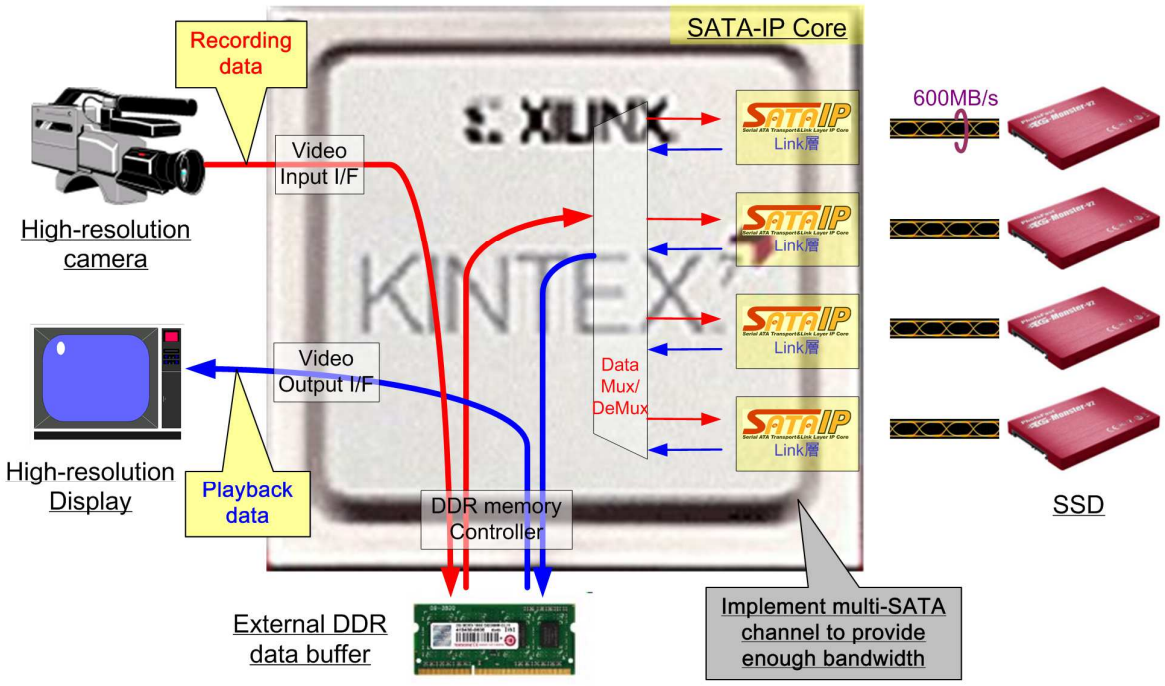
FAT32-IP/exFAT-IP (Cont'd 2)

- **Reference design for real operation available**
  - **Executes test file generation via serial console.**
  - **User can confirm file read compatibility by drive re-plug to the PC.**



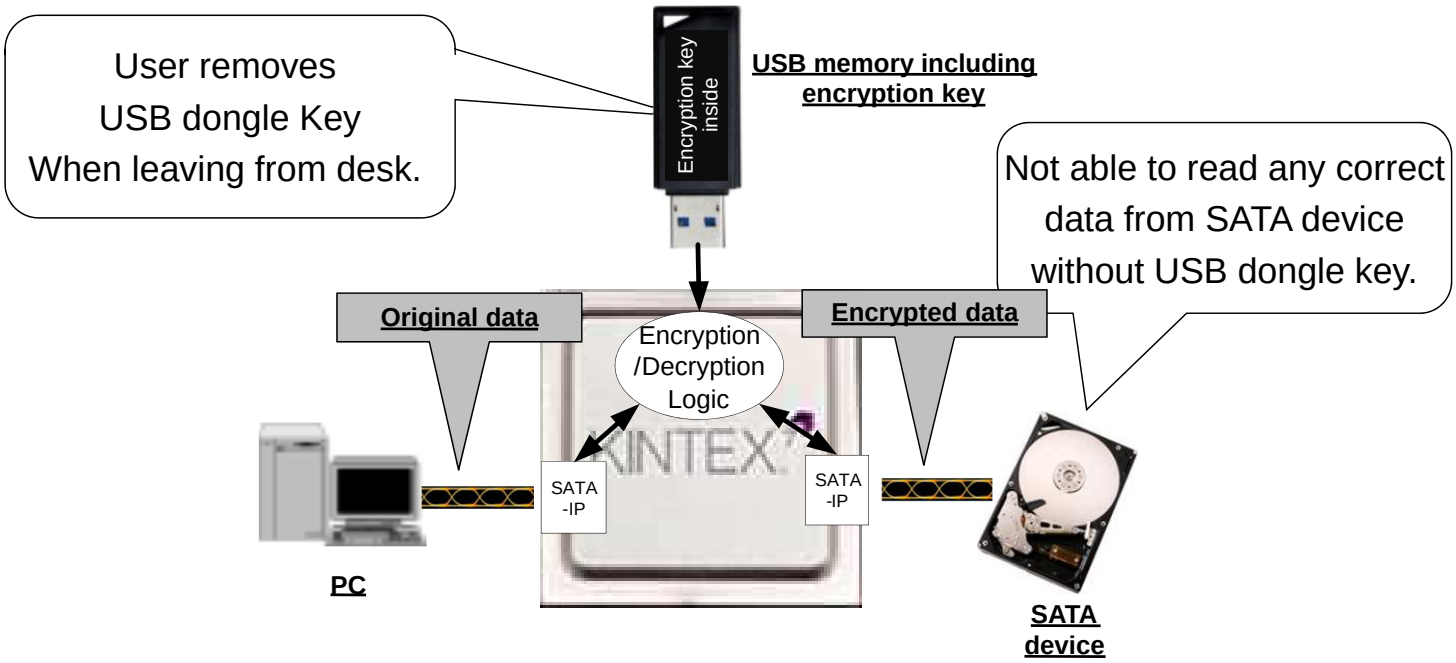
Generate test file, reconnect with PC, and can check file read compatibility

SATA-IP Application (1)



Advanced High-definition Video Recorder

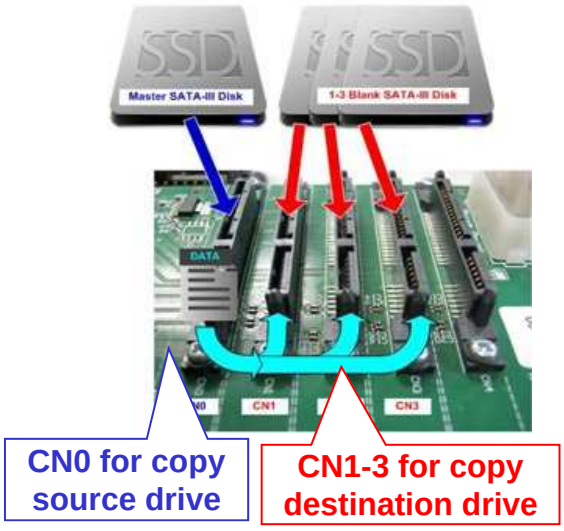
SATA-IP Application (2)

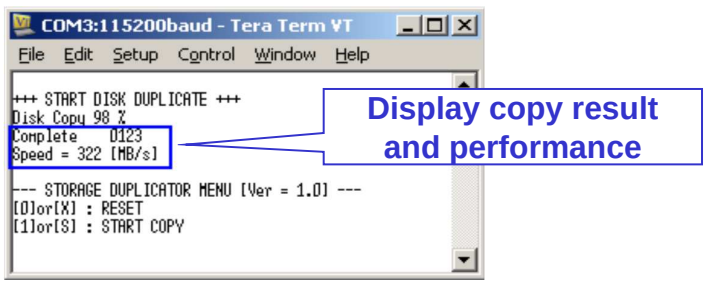


Security Drive System

SATA-IP Application (3)

- **Duplicator Application Reference Design**
  - **Copy whole data from Master drive to multiple Slave drives**
  - **Reference design for KC705 board**
  - **Design project available for formal SATA-IP customer**

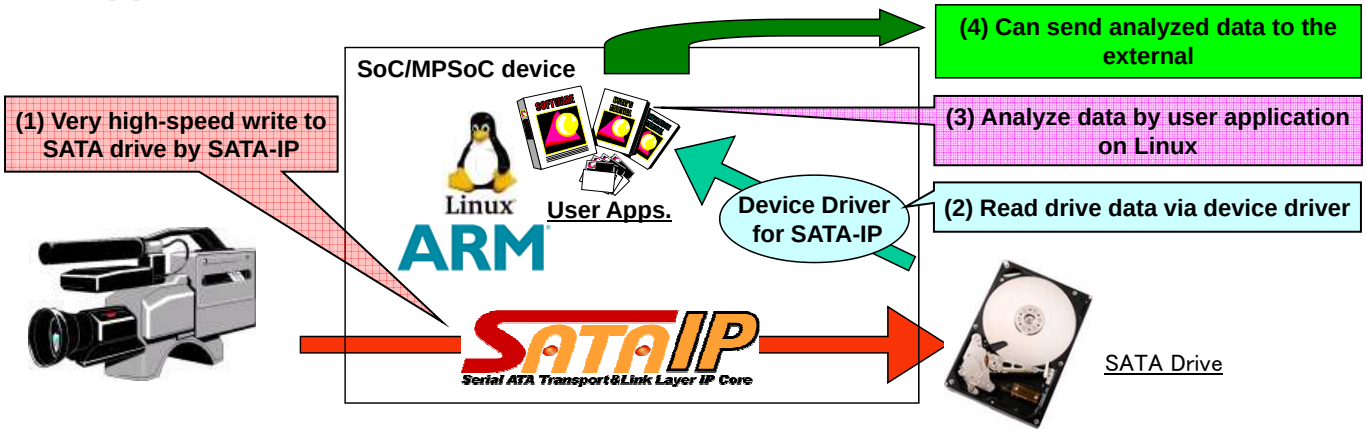




Display result by LCD/Serial console

SATA-IP Application (4)

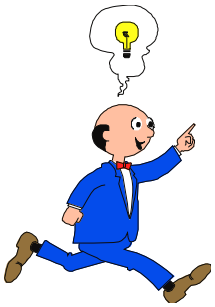
- **Recording and Analysis system on Linux**
  - Mount Linux and user analysis application on SoC/MPSoC device
  - Very high-speed data recording to SATA drive via SATA-IP core
  - Data read from SATA drive via device driver and analyze by user application



Recording and Analysis sytem on Linux (device driver and reference design available)

For more detail

- **Detailed documents available on the web site.**
  - http://www.dgway.com/SATA-IP_X_E.html
- **Contact**
  - Design Gateway Co,. Ltd.
  - E-mail : sales@design-gateway.com
  - FAX : +66-2-261-2290



Revision History

Rev.	Date	History
1.0	4-Feb-2009	English version initial release
1.3	31-Jul-2012	Add introduction of summary of SATA Update explanation of RAID development tool (AB09-FMCRAID board)
1.4E	21-Feb-2013	Added SATA-3 by Kintex-7support
1.7E	1-May-2013	Added exFAT reference design (SATA-IP-exFAT-X) introduction
2.2E	27-Jul-2016	Added Kintex-UltraScale support and followed update in Japanese presentation
2.3E	03-Apr-17	Add common user interface (dgIF typeS) and its merit description for SATA Host-IP
2.4E	06-Jan-19	Add FAT32-IP/exFAT-IP for SATA-IP optional products
2.5E	04-Oct-19	Add Linux application example