University of Chinese Academy of Sciences

Design IP and Verification IP

DIP and VIP

Chun-Zhang Chen, Ph.D.

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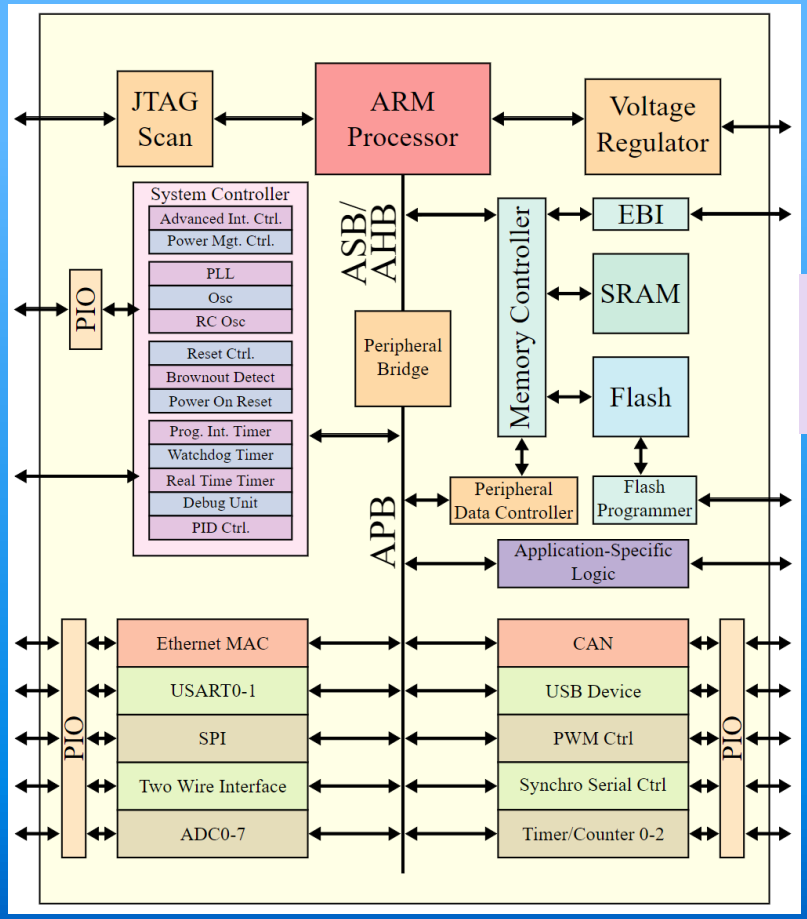
Aspects of IP Design

Contents in a SoC

- CPU
- Logic
- Input/Output (I/O)
- Memory IP
- COT Block
- Interface (I/F) IP

COT: custom-owned tooling

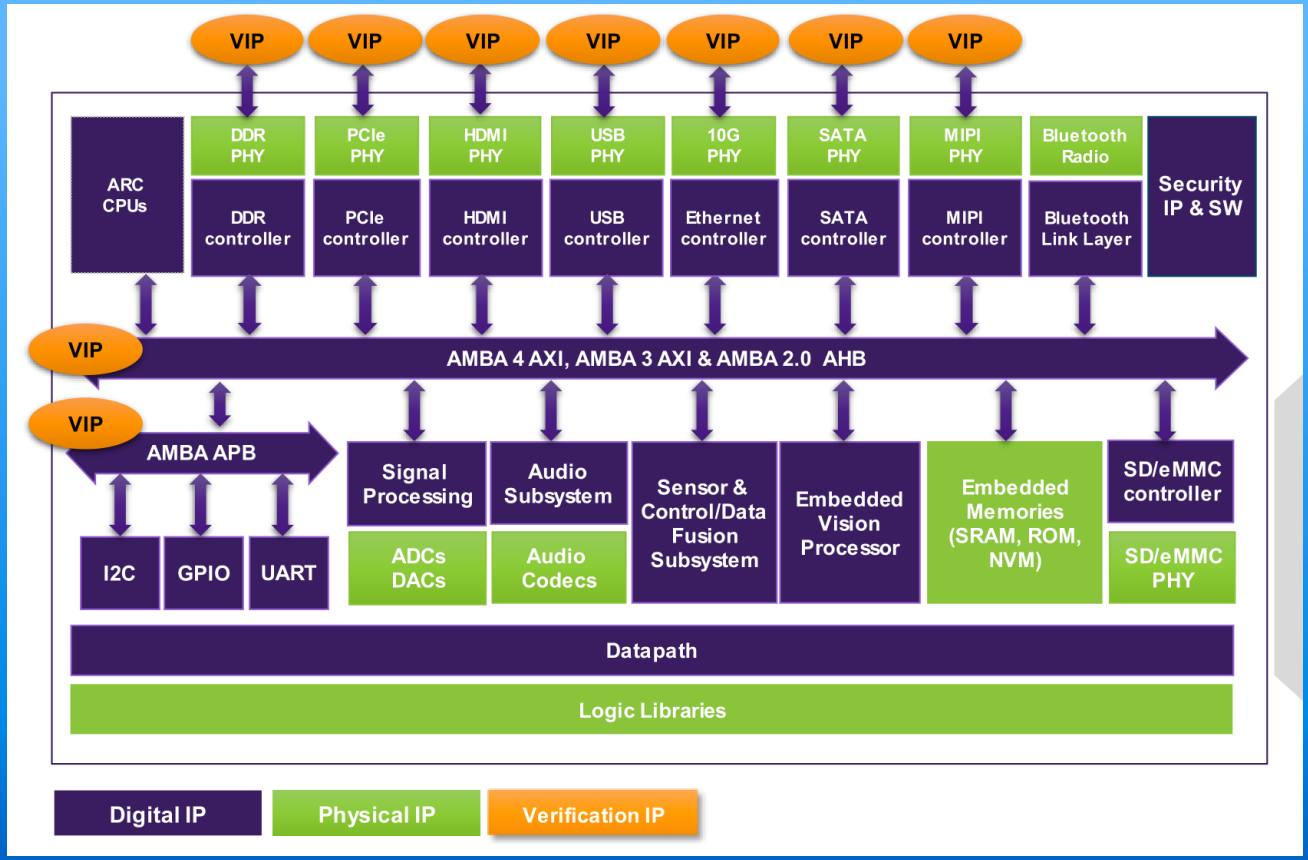


A sample SoC Design Architecture

Types of IPs: Functions

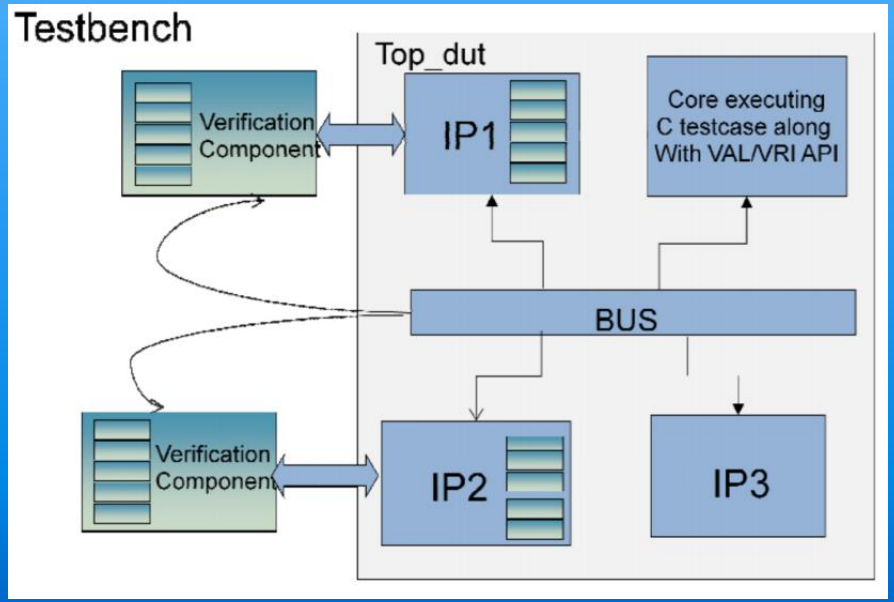
- Processors
- Memory IPs
- Other IPs
  - Embedded/Integrated, non-memory
  - I/O IP, I/F IP

SNPS DesignWare IP Portfolio



IP Reuse in SoC

- 3C to SoC in 19C/20C
- IP Reuse | Design-Reuse



IC Market Space (3C's)

- ◆Computer – Intel, IBM, ATI, nVidia, Via
  - CPU (PC, Server, Workstation, Mainframe)
  - Graphic Accelerator
  - Chip Set (for PC,Server, …)
- ◆Communication – Motcrola, Broadcom
  - Wireless (Cellular phone, WLAN)
  - Wired (LAN, Fiber backbone)
- ◆Consumer – Many
  - ◆TV, Car, MP3, Toys, Game, …..

Microelectronic Circuit Design McGraw-Hill Chap 7 - 75

Features of IP, Design aspects

- Soft Core IP (rare)
  - RTL + functional verification
- Hard Core IP (<65nm)
  - GDSII + physical verification
- **Firm Core** IP (common)
  - GLN + performance (verification)
- DTCO
  - Design Technology Co-Optimization

Features of IP, Progressive

- DIP
- VIP
- SIP
- RIP

Design IP (DIP) - Types of IP Design

- Processors
- Memory
- Standard Cells
- Analog and Mixed Signal
- I/O, IF IP, BUS IP
- High-Speed IP

Semiconductor IP:
16,000 IP Cores
from 450 Vendors
(Design-Reuse.com)

Verification IP (VIP)

IP Name	IP Type	Application	Node/Foundry	Vnedor
HIS	VC VIP HIS			SNPS
MIPI DigRFv4	VC VIP MIPI DigRFv4	Media		SNPS
AMBA 4 AXI	VC VIP AMBA 4 AXI	BUS/SoC		SNPS
Spansion S25FL	UVM for Serial Flash	Ext. memory		HDL D House
HDH PIF 32000	Verif Solution	PIF-based		HDL D House
PCIe Gen4	PCIe Gen4 VIP	IF		CDNS
HBM	HBM Memory Model	HBM/SiP		CDNS
Ethernet 25G/50G	Ethernet 25G/50G VIP	IF		CDNS
LPDDR4	LPDDR4 Memory Model	Embedded		CDNS

Silicon-Proven IP (SIP) and DFY

- Silicon/Semiconductor IP
- A known mature product IP
- In massive production and application
- Verification coverage [>97%-98%]

Reliability IP (RIP) and MTTF

Causes, Targets and Scenarios

- ESD, TVS, EMI, **IR**
  - **IR** produced SEE (SEU, SET, SEL)
- FinFET, SRAM/DRAM/eRAM, NAND
  - SOI n-/p- FinFET;
  - Flash NAND in SSD
- Scenarios
  - Automotive, DC/SC, Military/Space

MTTF:
mean time to failure
MTBF:
mean time between failure

Types of Reliability Issues in IC/IP

- Soft Errors in IC/IP
  - On combinational logic; sequential logic
  - On chip level; system level
- Wear-out Mechanisms
  - EM, HCI, TDDB, NBTI
- Latchup
  - Silicide vs Salicide,
  - Bulk CMOS vs SOI
- ESD
- RadHard in advanced application

Characterization of Memory IP
[90% Embedded Memory in a SoC]
ESD (electro static discharge),
LUP (latch-up),
TDDB (time-dependent dielectric breakdown**)**
EM (electro-migration) Effect

Aspects of IP Design

Analog, MS and RF IPs

- Analog and MS IPs
  - **ADC**, DAC, Comparator, Op-Amp, LDO, I2C, Drivers,…
  - **SerDes**, SATA, **USB**, **PCIe**, **Ethernet**, …
- RF IPs
  - **RF PA**, LNA, Mixer, Oscillator, Filter, BT, ZigBee, RF ID, …

Example: AFE or AFE Controller (AFEC)

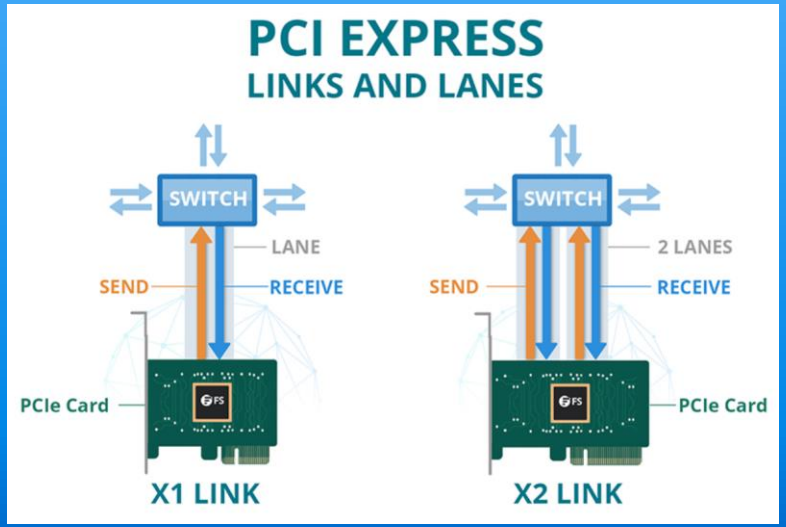
- Ultrasound AFE
  - Resolution (bits), ch., LNA Gain (dB), Input Imped. (Ω), …
- HS (high-speed) AFE
  - Speed (MSPS), SNR (dB), … V (1.8-3.5)
- ADI data sheet: AD8450 (pp41)
- TI:
- Microsemi:

PCI and PCIe

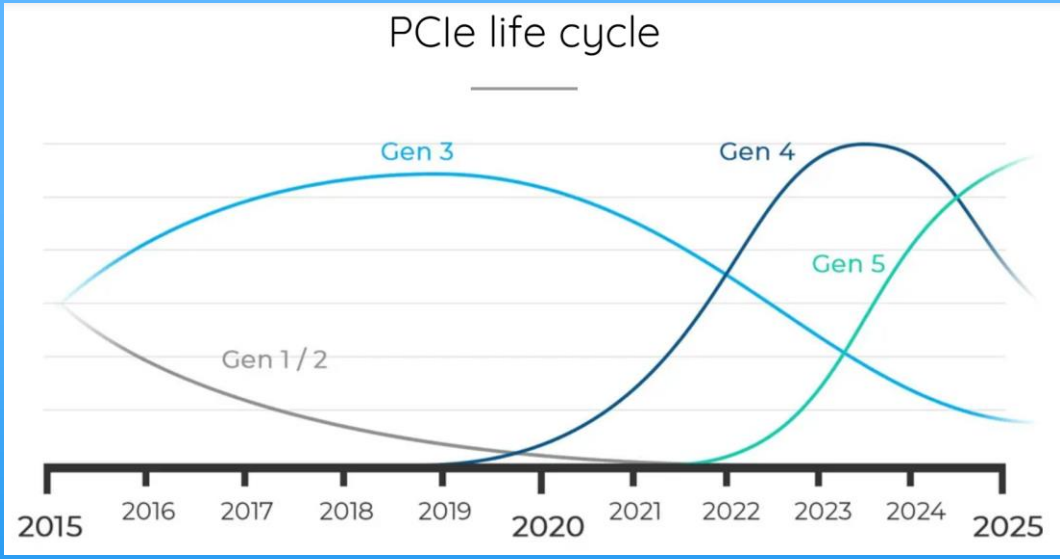
- **PCI**
  - *a standard for connecting computers and their peripherals*
- **PCIe**
  - *a standard type of connection for internal devices in a computer*

PCIe

- PCIe links and lanes
- PCIe connector
- PCIe card



PCIe 1.0-4.0



PCIe	Bandwidth per link	PCIe x1	PCIe x4	PCIe x8	PCIe x16	Line Code
1.0	2.5 GT/s | 2.5 GBit/s	250 MByte/s	1 GByte/s	2 GByte/s	4 GByte/s	8b10b
2.0	5 GT/s | 5 GBit/s	500 MByte/s	2 GByte/s	4 GByte/s	8 GByte/s	8b10b
3.0	8 GT/s | 10 GBit/s	0.9846 GByte/s	3.938 GByte/s	7.877 GByte/s	15.754 GByte/s	128b/130b
4.0	16 GT/s | 20 GBit/s	3.9 GByte/s	7.877 GByte/s	15.754 GByte/s	31.508 GByte/s	128b/130b

PCIe PHY IP

- VeriSilicon:
  - 1-lane, 4-lane PCIe PHY IP for chips and PCB
- Xilinx

Ethernet Controller IP

- Intel 800 Series, up to 100GbE
- Microchip
- Broadcom: 25, 50, 100, 200GbE

Gigabit Ethernet PHY IP

- OSI Layers
- 40, 100GbE

USB IP

- USB Versions: 1.0, 2.0/eUSB2, 3.0, 3.1, 3.2, 4,
  - 110G, 65G, 55LP, 40LP, 28
- USB Controller IP: 2.0, 3.0, 3.1, 3.2, 4
- USB PHY: 2.0, 3.0, 3.1, 3.2, 4
- *Supports and Compatibility:*
  - USB Type-C, Lighting
  - *HDMI | DisplayPort*

USB Features

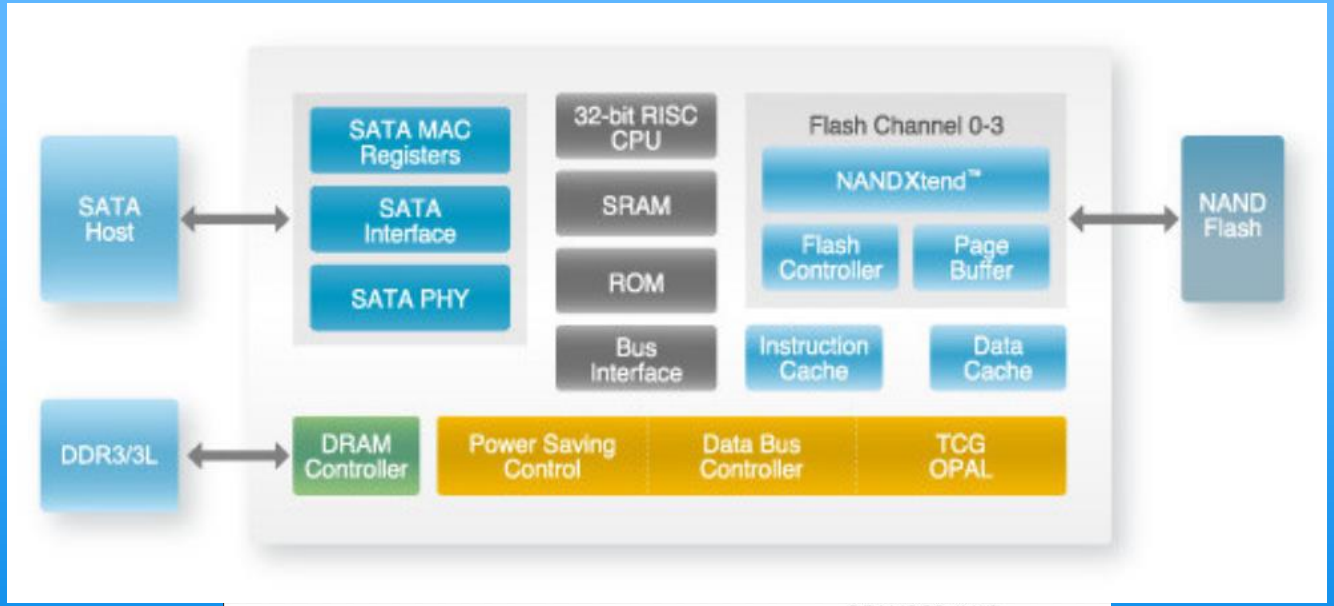
Table 2-18 Parameter comparison of different USB standards

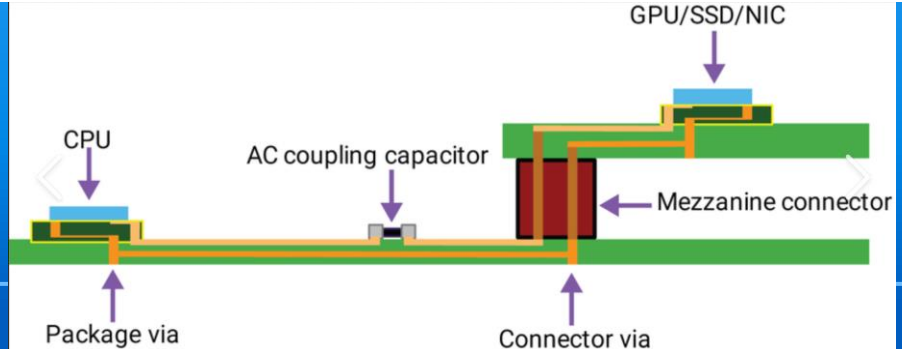
Version	Data transmission rate	Mode	Issue year
USB 1.0	1.5Mbit/s	Low Speed	1996
USB 1.1	12 Mbit/s	Full Speed	1998
USB 2.0	480 Mbit/s	High Speed	2000
USB 3.0	5 Gbit/s	Super Speed	2008
USB 3.1	10 Gbit/s	Super Speed+	2014
USB 3.2	20 Gbit/s	Super Speed+	2017
USB 4.0	40 Gbit/s	Super Speed+	2019

Role of PHY in I/F IP

- Used in
  - PCIe, Ethernet, RapidIO, etc.
- PHY has several components/modules
  - PCS, PMA, PMD, AN
- Medium
  - 1 Gb/s, 10 Gb/s, 40 Gb/s, or 100 Gb/s

Which SSD tech is faster? NVMe vs SATA



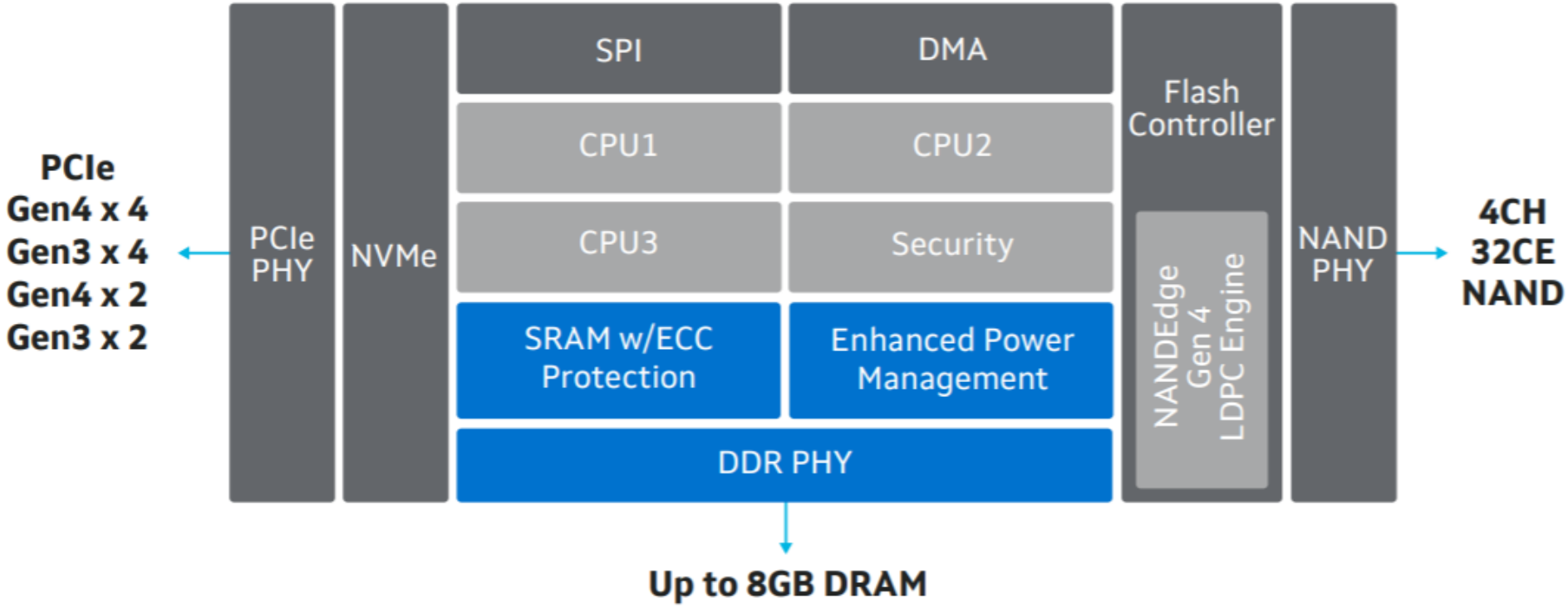


NVMe

Phison NVMe SSD Controller Comparsion

	E8/E8T	E13T	E19T	E12	E16	E18
Market Segment	Mainstream Consumer			High-End Consumer		
Manufacturing Process	40 nm	28nm	**28 nm**	28 nm		**12 nm FFC**
CPU Cores	2x Cortex R5	1x Cortex R5	**1x Cortex R5**	2x Cortex R5		**3x Cortex R5**
Error Correction	StrongECC	4th Gen LDPC		3rd Gen LDPC	4th Gen LDPC	
DRAM	E8: DDR3 E8T: No	No	**No**	DDR3/4	DDR4	**DDR4, LPDDR4**
Host Interface	PCIe 3.0 x2	PCIe 3.0 x4	**PCIe 4.0 x4**	PCIe 3.0 x4	**PCIe 4.0 x4**	
NVMe Version	NVMe 1.2	NVMe 1.3	**NVMe 1.4**	NVMe 1.3		**NVMe 1.4**
NAND Channels, Interface Speed	4 ch, 533 MT/s	4 ch, 800 MT/s	**4 ch, 1200 MT/s**	8 ch, 667 MT/s	8 ch, 800 MT/s	**8 ch, 1200 MT/s**
Max Capacity	2 TB	2 TB	**2 TB**	16 TB	16 TB	**16 TB**
Sequential Read	1.6 GB/s	2.5 GB/s	**3.75 GB/s**	3.4 GB/s	5.0 GB/s	**7.0 GB/s**
Sequential Write	1.3 GB/s	2.1 GB/s	**3.75 GB/s**	3.2 GB/s	4.4 GB/s	**7.0 GB/s**
4KB Random Read IOPS	E8: 240k E8T: 120k	350k	**440k**	700k	750k	**1M IOPS**
4KB Random Write IOPS	E8: 220k E8T: 130k	450k	**500k**	600k	750k	**1M IOPS**
Controller Power	1.8 W	1.2 W	**1.6 W**	2.1 W	2.6 W	**3.0 W**
Sampling	Q2 2017	Q2 2019	**Q4 2019**	Q2 2018	Q1 2019	**Q1 2020**
Retail SSD Availability	Q4 2017	Q4 2019	**Q1 2020**	Q4 2018	Q3 2019	**Q3 2020**

Marvell SSD Controller



Aspects of IP Design

Digital IP List

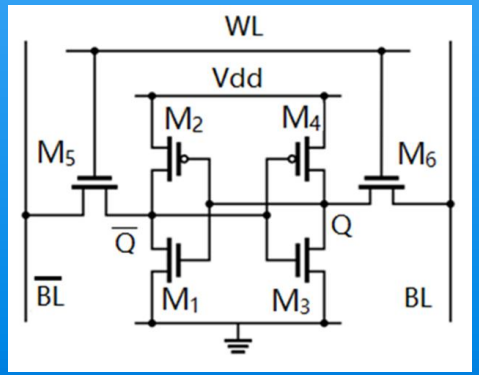
- Audio/Video, Clock
- Communications, Controllers
- DSP, Mathematic Functions
- Memories, Microcontrollers
- Network-on-Chip, Processors
- Programmable Logic, Security
- Standard Cell Libraries, Subsystems

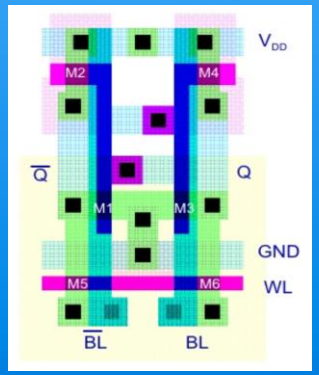
Processors

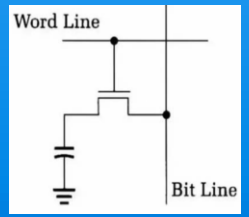
- CPU
- DSP
- MCU
- PowerPC
- RISC-V

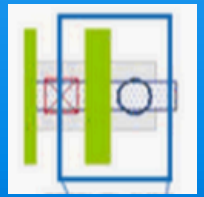
Memory Providers

- Samsung
- Hynix
- Micron









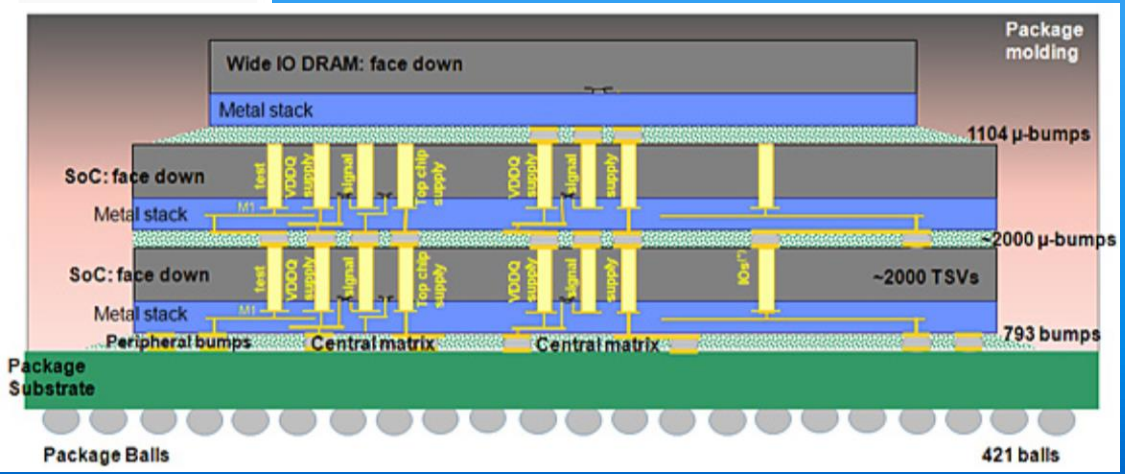
Aspects of IP Design

IP Market

- IP Vendors: ARM, Synopsys, Cadence
- IP Category:
  - Processors (CPU, DSP, GPU)
  - I/F IP
  - I/O IP

I/O IP

- I/O with ESD Protection
- GPIO
- RapidIO
- WideIO

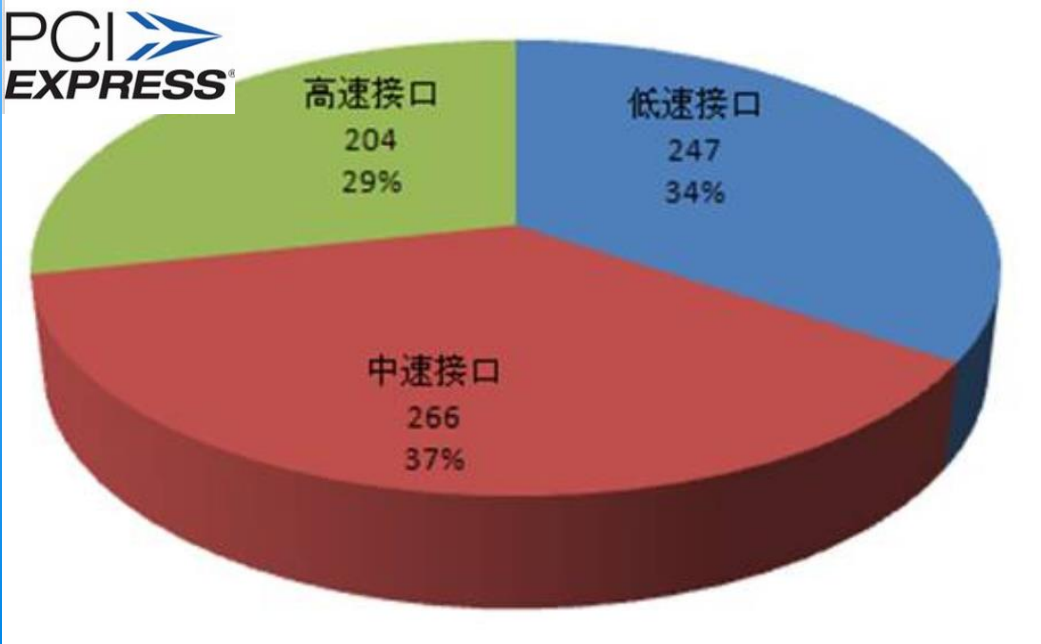


I/F IP

- I/F IP types
  - USB, PCIe, Ethernet, *SerDes*
  - Protocol-Based, Speed-Based
- Memory I/F IP
- CCIX IP (chip-to-chip, new)

Speed-Based I/F IP

- Low
  - CAN, LIN
- Mid
  - LVDS, HDMI 1.3
- High
  - USB 3.0, PCIe 3.0
  - MIPI, RapidIO



Popular IPs

- BANDGAP for LDO & PWM DC-DC, Silicon Gate
- Temperature Sensor ADC, Silicon Gate
- 14b-4.32Gsps ADC, T2M
- 112G LR SerDes PHY, Rambus
- VTSXXXX, Vidatronic
- 18OSMIC_TS_O2, NTLab

- *Ref: https://www.chipestimate.com/Semiconductor-IP-Catalog*

Aspects of IP Design

IP Market

- Top 10 IP Company

Rank	Company	2017	2018	Growth	2018 Share	Cumulative Share
1	**ARM (Softbank)**	**1659.9**	**1610**	**-3.0%**	**44.7%**	**44.7%**
2	Synopsys	527.6	629.8	19.4%	17.5%	62.2%
3	Cadence	159.5	188.8	18.4%	5.2%	67.4%
4	Imagination Technologies	126.9	119.7	-5.7%	3.3%	70.7%
5	Ceva	87.5	77.9	-11.0%	2.2%	72.9%
6	Verisilicon	54.7	66.3	21.2%	1.8%	74.7%
7	Achronix	15.0	52.5	250.0%	1.5%	76.2%
8	Rambus	54.0	52.1	-3.5%	1.4%	77.6%
9	eMemory Technology	45.0	47.9	6.4%	1.3%	79.0%
10	Waves Computing	43.0	41.0	-4.7%	1.1%	80.1%
	Top 10 Vendors	2,773.1	2,886.0	4.1%	80.1%	80.1%
	Others	**627.0**	**716.6**	**14.3%**	**19.9%**	100.0%
	Total	**3,400.1**	**3,602.6**	**6.0%**	**100.0%**	**100.0%**

Source: IP Nest (May 2019)

IP Vendors

- Prime IP Partners
- Choice IP Partners
- Select IP Partners
- Standard IP Partners

Summary

- IC/IP
- EDA and IP
- VIP
- Focused Application