Introduction to System-on-Chip and its Applications

Individual Project Report
Sony PlayStation 5

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Outline

1 Technology Analysis

1.1 Introduction

Figure 1: PS5 series, image source: https://youtu.be/_NX8F9FBvg0

PlayStation 5 (PS5) is a **home video game console** produced by **Sony Interactive Entertainment** (SIE). It is part of the **ninth generation of video game consoles**. It was launched on 2020/11/12. It has two editions: **the base edition** and **the digital edition**. The former includes optical disc drive compatible with Ultra HD Blu-ray discs for downloading video games, while the latter doesn't. The PS5 Digital Edition needs to download digital version of games via the PlayStation Store.

Figure 2: PS5 pack,
image source: https://direct.playstation.com/en-us/consoles/console/playstation5-console.1000031644

The PS5 pack includes a console, a wireless controller (DuelSense), a base and other cables.

The PS5 Console's AMD GPU capable of **4K resolution display up to 120 frames per second (fps)**. Its **raytracing** acceleration makes the light and reflections more realist in games. In addition, it has the **Tempest Engine** allowing **3D audio effect**. Particularly, PS5 using **solid-state drive (SSD)** for **high-speed data streaming** to improve storage performance. Last but not least, PS5 support **backward compatibility**, so player can play PS4 games using PS5.

The wireless controller, also known as **DuelSense**, features **haptic feedback** with voice coil actuator, which will change the frequencies and amplitude of vibration to simulate the environment game character encounters. It has **adaptive triggers** in L2, R2 buttons. The force feedback that can change the resistance supports player experience such as virtually drawing an arrow from a bow. The hardware of these two functions are placed at both sides of the DuelSense. Thus, it can have different feedback for different sides. Finally, it offers **built-in microphone** so that players don't need external one.

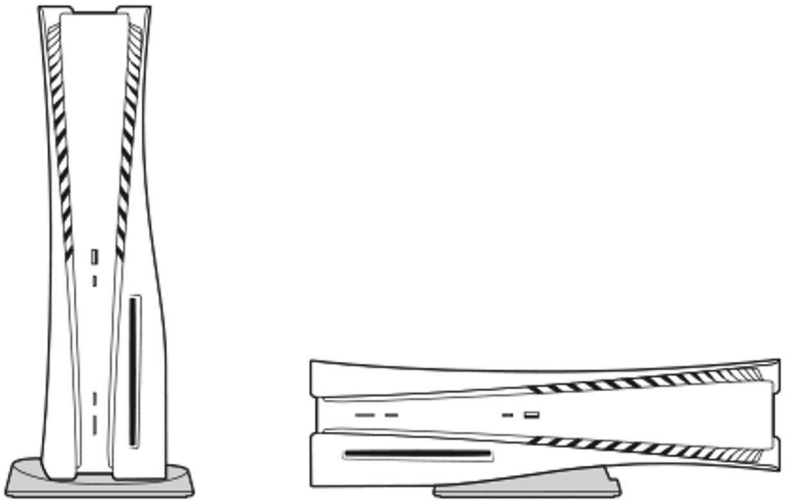

Figure 3: PS5 setup,
image source: https://www.playstation.com/en-us/support/hardware/ps5-get-started-set-up/

At last, with this base, PS5 can lay down vertically or horizontally as users wishes. PS4, the predecessor of PS5, can only set horizontally and take up much space of the desk. Set PS5 vertically using the base can save the space more.

1.2 Scenarios

Figure 4: user scene, image source: https://youtu.be/1YrzNF01I6A

PS5 is particularly made for **video game players** to play games. It is one of the best game consoles until now. The Sony's developer custom designed chips and other hardware to improve game performance of every kind. Furthermore, it supports **high quality resolution** and **3D audio effect** to improve user experience.

The dimensions of PS5 is $390mm \times 260mm \times 92mm$, and it weighs 3.9kg. Apparently, it's not hard to imagine that PS5 is hard to move once it is set, so PS5 is suitable for **playing at home**.

1.3 Motivation/Background/System evolution/Current Status

1.3.1 Evolution

PlayStation is a **video gaming brand** produced by SIE. It consists of five home video game consoles, two handhelds, a media center, and a smartphone, as well as an online service and multiple magazines.

Nintendo and Sony worked together to create a CD-ROM version of the Nintendo Super Famicom in 1991. Then, Sony revealed a Super Famicom with a built-in CD-ROM drive called "Play Station", also known as SNES-CD. However, Nintendo broke its partnership with Sony and chose to work with Philips instead due to some commercial considerations. **Ken Kutaragi**, known as "The Father of the PlayStation", was appointed to develop the PlayStation project to rival Nintendo by Sony President Norio Ohga.

Figure 5: PS1, image source: https://en.wikipedia.org/wiki/PlayStation

Playstation (PS1), the first PlayStation console, was released in 1994/12/3. It was part of the fifth generation of video game consoles competing against the Sega Saturn and the Nintendo 64. PS1 is composed of a console with a **5-inch LCD screen** and a controller. The main microprocessor is a 32-bit LSI R3000 CPU, which provide to render complex 3D graphics, while the SCPH-9000 GPU draw 2D polygons and apply shading and textures. By December 2003, the PlayStation and PS1 had shipped a combined total of 102.49 million units, eventually becoming the first video game console to sell 120 million units.

Figure 6: PS2 & PS3, image source: https://en.wikipedia.org/wiki/PlayStation

PS2 was released in 2000/3/4. Since PS2 was the fastest game console at that time, it became **the most successful console in the world**. It had sold over 155 million units as of December 28, 2012. PS3, released in 2006/11/11, is the first console in the series to introduce the use of **motion-sensing technology** through its Sixaxis wireless controller. The console also incorporates a **Blu-ray Disc player** and features **high-definition resolution**. In addition, PS3 introduced the **digital download** function from PlayStation Store.

Figure 7: PS4, image source: https://en.wikipedia.org/wiki/PlayStation

PS4 was announced on 2013/2/20. It introduced the **x86 architecture** to the PlayStation series. Sony also debuted **PlayStation Now** game streaming service, making it possible to view in-game content being streamed live from friends.

1.3.2 Motivation

Mark Cerny, the PS5 chief architect implement a **two-year feedback cycle** after the launch of the PS4. Sony's developers found out what game developers concern the most by this way. They found the key issue was the **loading time** for games, so they put more attention on improving **storage hardware**. Besides, they implemented **new graphic hardware technology**, like **raytracing**, on PS5 to improve the graphic performance.

1.3.3 Current Status: PS5 Shortage

PS5, as well as Xbox Series X/S, was in **limited supply** immediately after their launch. The fist reason is that a **global semiconductor shortage** in 2021, they can't steadily produce the hardware of the consoles. The second reason is that **COVID-19 pandemic**, people all stuck at home. These two reasons cause the demand is always higher than the supply. This rise a new critical problem: scalpers buy too many consoles to sell them at a higher price.

In August 2022, Sony even announced that it would **increase the price** of the PlayStation 5 by up to 20% due to **high global inflation rates** and supply chain pressures. Microsoft, along with Sony, increased the price of Xbox Series X/S. As a result, players find it much harder to purchase them. Bloomberg News reported in January 2022 that Sony was continuing to produce the PS4 rather than discontinue it at the end of 2021 as to help alleviate the shortage of PS5.

the total sales of PS5 has reached 27.5 million unit by November 2022.

1.4 Specifications /System Architecture

1.4.1 Specification

Component	Specification	Remarks
CPU	x86-64-AMD Ryzen™ Zen	8 cores/16 threads, frequency up to 3.5GHz
GPU	AMD Radeon™ RDNA 2	36 compute units, Ray Tracing acceleration, frequency up to 2.23GHz theoretical performance to 10 TFLOPS
Memory	GDDR6 SDRAM 16GB	Maximum bandwidth 448GB/s
Internal Storage	Custom 825GB PCIe 4.0 NVMe SSD	IO throughput 5.5GB/s
Optical Drive	PS5: Ultra HD Blu-ray	
External Storage	PCIe 4.0 NVMe M.2 SSD	
Power	PS5: 350W PS5 Digital Edition: 340W	
Display	HDMI: up to 4K UHD, 8K UHD	
Sound	Custom Tempest Engine 3D Audio	
Connectivity	Wi-Fi IEEE 802.11ax Bluetooth 5.1 Gigabit Ethernet 2× USB 3.2 Gen 2×1 1× USB 2.0 1× USB-C with USB 3.2 Gen 2×1 1× HDMI 2.1	
Online services	PlayStation Network PlayStation Plus	
Dimensions	PS5: 390mm x 104mm x 260mm PS5 Digital Edition: 390 x 92 x 260	
Weight	PS5: 4.5kg PS5 Digital Edition: 3.9kg	

1.4.2 System Architecture

The following paragraph illustrates the teardown process of PS5.

Figure 8: the edge of PS5,
image source: https://www.ifixit.com/Teardown/PlayStation+5+Teardown/138280

PS5 has ports: two USB-A 3.0, LAN, HDMI 2.1, and two-pin power. The HDMI 2.1 port can support 8K resolution video.

Figure 9, the outer side of PS5, image source: https://youtu.be/weOCONceK4E

For the outer side of PS5, there are **cooling fans** to draw lots of air from both sides. For each side, it has two **dust catchers**. The dust collected in it can be vacuumed out through it. Besides, there is a storage expansion, which supports **M.2 interface with PCIe 4.0**. PS5 base edition has **optical drive**. The drive unit is covered with a sheet metal case and mounted with two layers of insulators to **reduce drive noise and vibration** when discs spin.

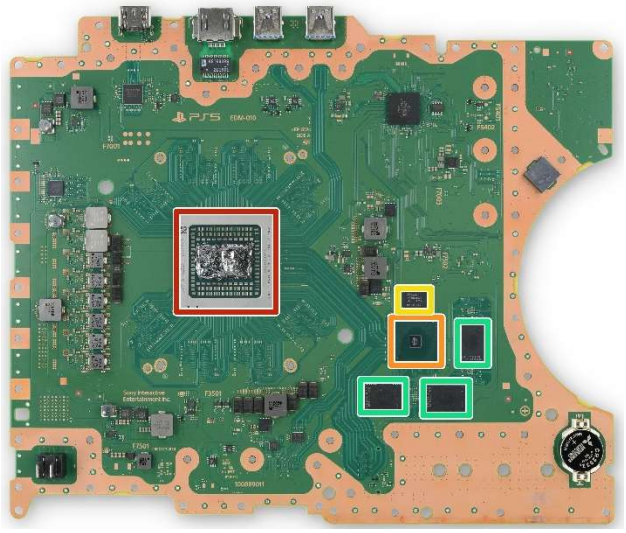

Figure 10: the upper side of PS5 motherboard,
image source: https://www.ifixit.com/Teardown/PlayStation+5+Teardown/138280

After removing the black plastic shell, it reveals the PS5 **motherboard**. The biggest chip is the motherboard is the **main custom chip** consisting of CPU, GPU, and a Custom I/O Unit. **CPU** is **x86-64-AMD Ryzen™ Zen 2**, a computer processor microarchitecture by AMD. It has 8 cores and 16 threads and runs at up to 3.5GHz. **GPU**, also a microarchitecture designed by AMD, is **AMD Radeon RDNA™ 2-based graphics engine**. GPU is driven at up to 2.23GHz and delivers 10.3 TFLOPS. These two AMD microarchitectures are specially designed for gaming. As for the **custom I/O chip**, it is designed to i**ncrease the loading efficiency**. The SoC was covered by a **Thermal Interface Material (TIM)** called **Liquid Meta**l to take away the thermal heats.

The bottom right side is the **internal storage** part. There are **on board 825 GB SSD**. The **custom SSD controller** in the middle handle the high data transfer work and can read as fast as 5.5GB per second at raw data transfer rates.

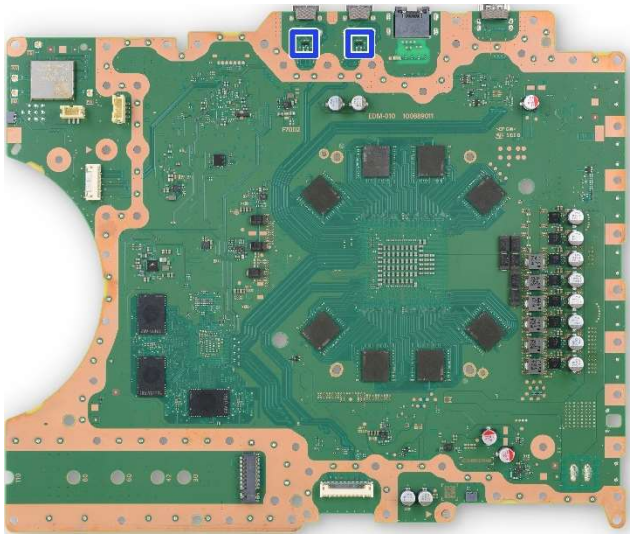

Figure 11: the lower side of PS5 motherboard,
image source: https://www.ifixit.com/Teardown/PlayStation+5+Teardown/138280

For PS5 **memory**, it has 8 **GDDR6 SDRAM** with 2GB for each. The Memory delivers a maximum bandwidth of 448GB per second.

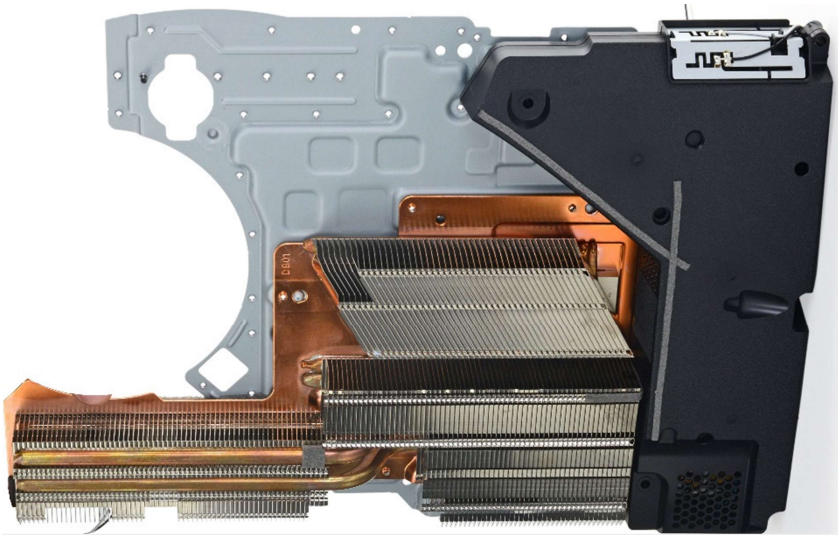

Figure 12: the lower side of PS5,
image source: https://www.ifixit.com/Teardown/PlayStation+5+Teardown/138280

The lower side of PS5 consists of a **heatsink** and a **power supply unit**. PS5 uses a heat pipe. The Sony developers convince that the combination of copper heat pipes and heatsinks is just as effective. as a vapor champer. Below the heatsink is the PS5's boot-shaped 350-watt enclosed power supply—which is more than enough for the tested 200W draw at full load.

1.5 System Functions

1.5.1 Main Custom Chip

1.5.1.1 CPU: x86-64-AMD Ryzen™ Zen 2

Zen 2 is a **computer processor microarchitecture** by Advanced Micro Devices, Inc (**AMD**). It upgrades it fabrication process from 14nm of successor Zen to **TSMC 7nm MOSFET node**. The microarchitecture powers the third generation of Ryzen processors, such as Ryzen 3000 for desktop chip. Video game consoles like Xbox Series X\S, PS5, and Steam Deck use this microarchitecture as well.

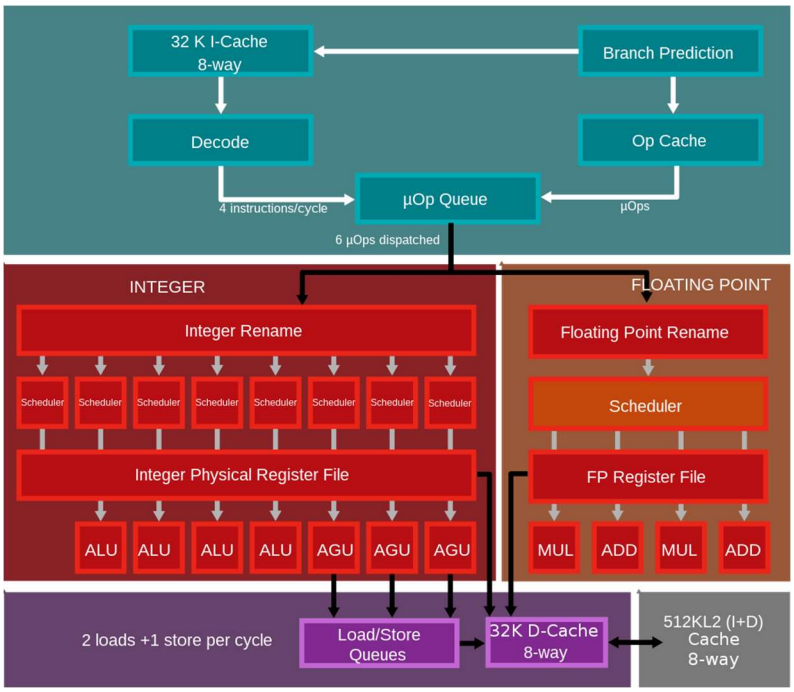

Figure 13: the processor core of Zen2,
image source: https://en.wikipedia.org/wiki/Zen_(first_generation)

Zen 2 has 2 simultaneous multithreading per core (SMT), 4 ALUs, and 3 AGUs. Zen2 upgrades its two floating point units. It supports AVX2 instruction and upgrade to 256 bitwide. It also has **larger micro-operation** cache with 4k instructions to support decoding. With the larger cache, decoding micro-ops once and putting them into a cache speeds things up and makes the processor more efficient. The 7nm fabrication process make it possible to increase 1.5 times instruction per cycle (IPC) and decrease the silicon area by almost half.

Figure 14: CCX of Zen2,
image source: https://benchlife.info/amd-ryzen-5000-cpu-zen-3-architeture-review/

Especially, Zen2 has a fundamental building block called **Core Complex (CCX)**, which consists of 4 cores and associate to 16MB L3 caches (**Game cache**). Each CCX connects by **Infinity Fabric**.

1.5.1.2 GPU: AMD Radeon™ RDNA 2

RDNA 2 is a **graphics processing unit microarchitecture** and accompanying instruction set architecture developed by AMD. It is manufactured and fabricated with **TSMC's N7 FinFET graphics chips**. It was specially designed for efficient high-performance gaming. Video game consoles like Xbox Series X\S, PS5, and Steam Deck as well use this microarchitecture.

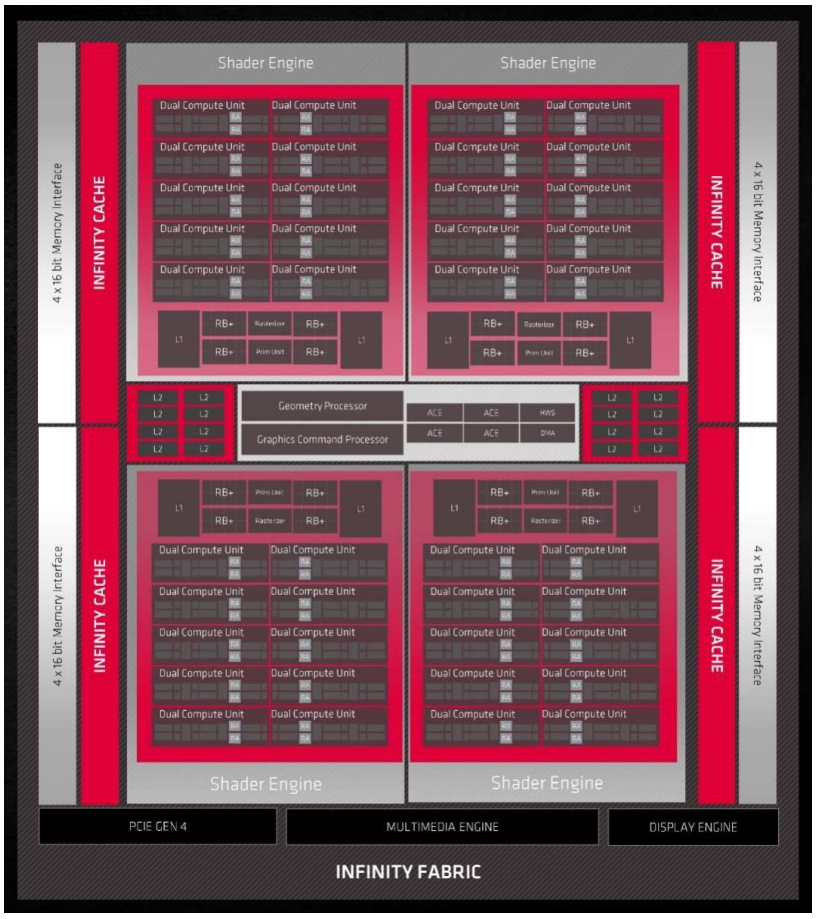

Figure 15: RDNA2 architecture,
image source: https://www.pcworld.com/article/393733/rdna-2-deep-dive-inside-amd-radeon-rx-6000-graphics-cards.html

GDNA2 has Graphics Command Processor (GCP) for handling of asynchronous shaders and 4 Asynchronous Compute Engine (ACE) serving computing purposes. It has geometry processor contains a Geometry Assembler, a **Tesselator**, and a Vertex Assembler. The Tesselator is capable of doing tessellation in hardware as defined by Direct3D 11 and OpenGL 4.5.

RDNA2 has 36 Dual Compute Unit (CU). Each CU combines 64 shader processors with 4 texture mapping units (TMUs) and 2 L1 cache with 1MB capacity. RDNA2 supports real-time, hardware accelerated raytracing. It has **ray accelerator** in CU as well for **bounding volume hierarchy (BVH)** traversal. Like the Game Cache in Zen2, RDNA2 has 128MB L3 cache called **Infinite Cache** for gaming efficiency. The large cache make GPU don't need to request data to PS5 memory considering that part of the gaming data will recompute for subsequent frames. By this way, it safes time and space, so Infinite Cache more fast and energy-efficient.

1.5.1.3 Raytracing Technology: Bounding Volume hierarchy (BVM)

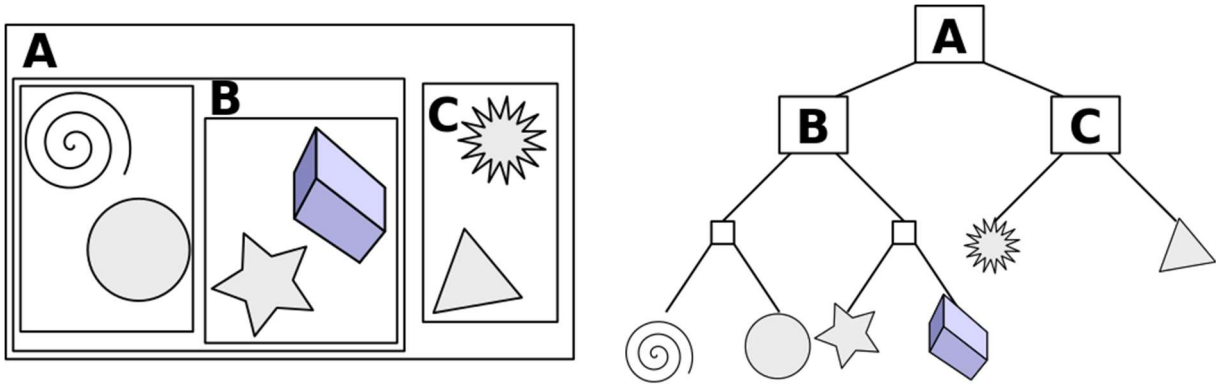

Figure 16: an example of BVH, image source: https://en.wikipedia.org/wiki/Bounding_volume_hierarchy

BVH is a **tree structure** on a set of geometric objects. All geometric objects, that form the leaf nodes of the tree, are wrapped in bounding volumes. These nodes are then grouped as small sets and enclosed within larger bounding volumes. These, in turn, are also grouped and enclosed within other larger bounding volumes in a recursive fashion, eventually resulting in a tree structure with a single bounding volume at the top of the tree.

Bounding volume hierarchies are used to support several operations on sets of geometric objects efficiently, such as in collision detection and ray tracing. With such a hierarchy in place, during ray tracing, children volumes do not have to be examined if their parent volumes are not intersected.

1.5.1.4 AMD SmartShift Technology

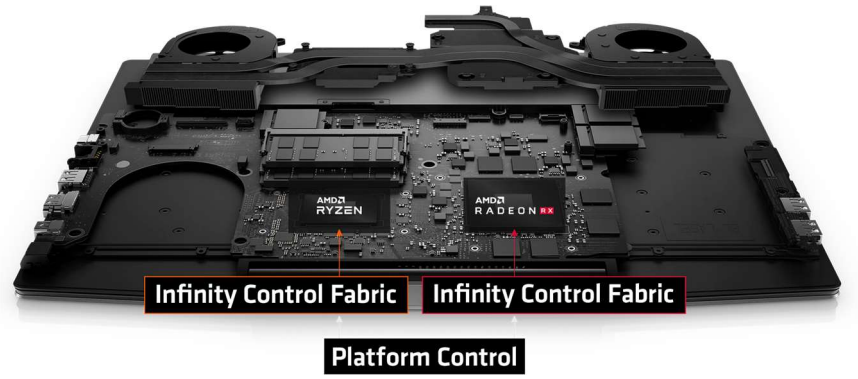

Figure 17: AMD SmartShift technology, image source: https://www.amd.com/en/technologies/smartshift

SmartShift was originally a technology for laptop to help boost performance for gaming, video editing, 3D rendering, content creation and productivity. It features a hardware boosting interface between processor and graphics with machine learning algorithms to automatically boost performance where workloads demand it. This interface links the common Infinity Control Fabric blocks together so that the CPU and GPU react quickly to different workloads. Any work that relies on the combination of a CPU and discrete GPU will benefit.

1.5.1.5 Custom I/O Unit

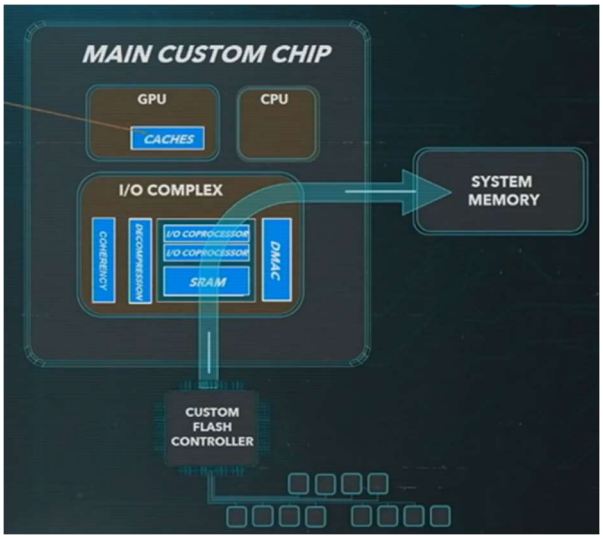

Figure 18: PS5 main custom chip architecture, image source: https://youtu.be/ph8LyNIT9sg

The final part of PS5 main custom chip is the custom I/O unit. It has DMA controller, 2 I/O coprocessors, SRAM, and coherency engines. It upgrades its data compression library to zlib to Oodle Kraken. Oodle Kraken is specifically designed for games by Epic Games. It is the lossless data compression, which gets very high compression ratios and is also very fast to decode. Kraken is uniquely well suited to compress game content and keep up with the speed requirements of the fast SSD without ever being the bottleneck. PS5 uses it to reduce game file sizes by as much as 60% and increase performance and efficiency of the whole storage subsystem.

1.5.1.6 Custom SSD

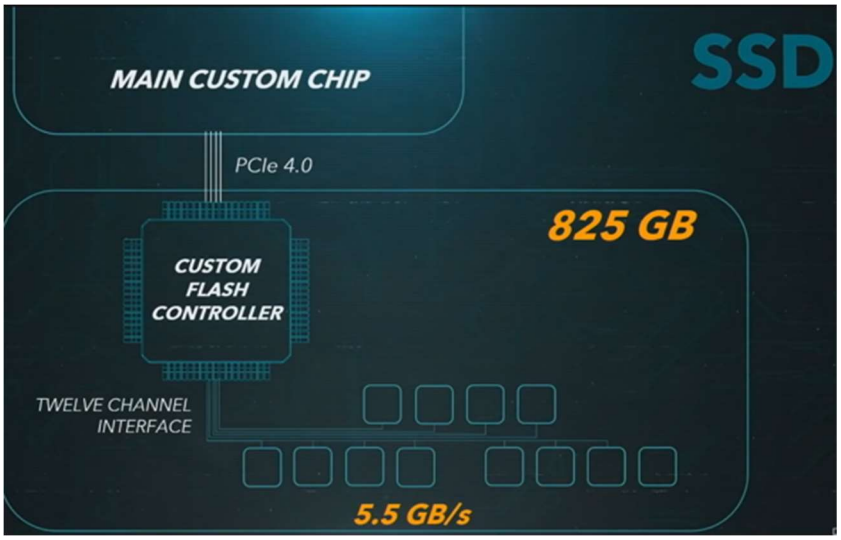

Figure 19: the structure of PS5 custom SSD, image source: https://youtu.be/ph8LyNIT9sg

PS5 custom SSD includes 4 lane PCIe4.0 with 7GB/s, 12 flash channels with 5.5GB/s transfer speed, and 6 data priority tiers. The process of loading data stream includes decompression, coherency, mapping, file I/O, check-in and load management. Sony claims that with their custom SSD loading time will increase 100 times performance. With this custom SSD, games in PS5 don't need load screens and long patch to cover up the loading time anymore.

1.5.1.7 Expansion Storage: M.2. NVME SSD

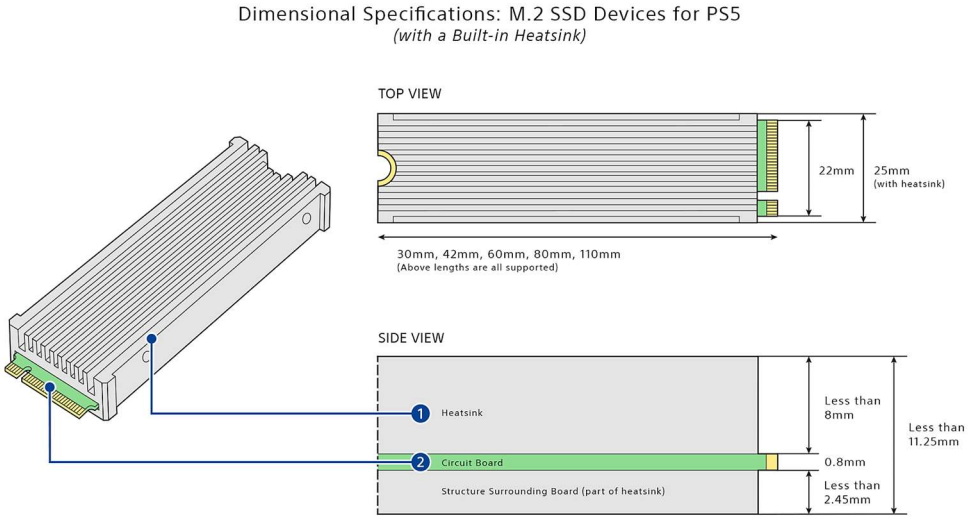

Figure 20: M.2 SSD devices for PS5,
image source: https://www.playstation.com/zh-hant-tw/support/hardware/ps5-install-m2-ssd/

M.2 are suitable for smaller devices such as tablet and notebooks. Computer bus interfaces provided through the M.2 connector are PCIe 4.0, Serial ATA 3.0, and USB 3.0.

The M.2 specification supports NVMe as the logical device interface for M.2 PCIe SSDs, while the support for AHCI ensures software-level backward compatibility with

legacy SATA devices and legacy operating systems. Used for PCIe SSDs and interfaced through the NVMe driver, as a high-performance and scalable host controller interface designed and optimized especially for interfacing with PCIe SSDs. NVMe has been designed from the ground up, capitalizing on the low latency and enhanced parallelism of PCI Express SSDs, and complementing the parallelism of contemporary CPUs, platforms and applications.

1.5.1.8 TIM: Liquid Metal

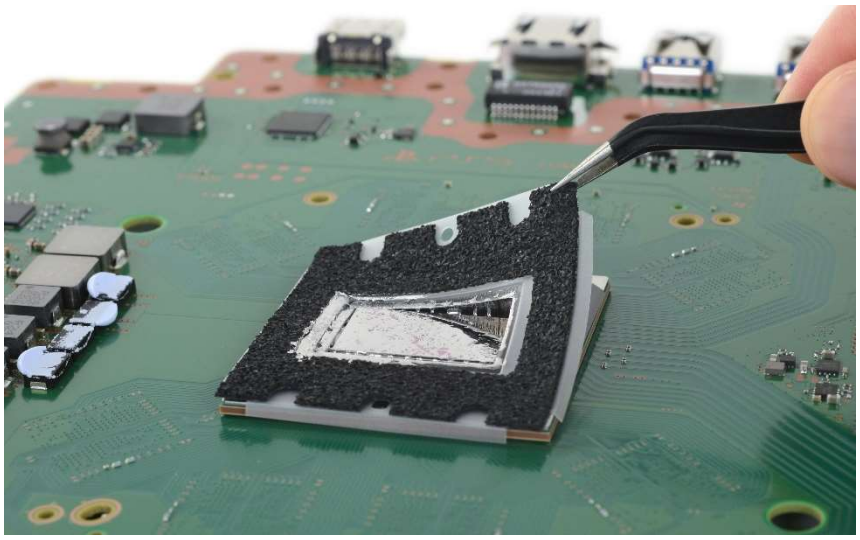

Figure 21: Liquid Metal on the main custom chip,
image source: https://www.ifixit.com/Teardown/PlayStation+5+Teardown/138280

Thermal Interface Material (TIM) transfer heat from the chip to the heatsink. Typically, developers use paste-style TIM, while PS5 developers use liquid metal. Liquid metal is a metal or a metal alloy which is liquid at or near room temperature. It has thermal conductivity far superior to ordinary non-metallic liquids, allowing to efficiently transfer energy. PS5 developers use insulting sheet as a corral to prevent from electronically conductivity. By this way, liquid metal won't conduct to other chips and cause short out.

2 Industrial Analysis

2.1 Industrial Chain

2.1.1 Competitive Analysis

2.1.1.1 Xbox Series X\S

Figure 22: Xbox Series X, image source: https://www.xbox.com/zh-TW/consoles/xbox-series-x

The Xbox Series X/S are home video game consoles developed by Microsoft. Along with Sony's PlayStation 5, the Xbox Series X/S consoles are part of the ninth generation of video game consoles. The target audience of Xbox was also for players playing at home, so it is the direct competitor of PS5. Moreover, its hardware specification is similar to PS5. It uses Ryzen Zen 2 CPU and Radeon RDNA 2 GPU as well. Last but no least, it has the same price like PS5.

The competition between PS and Xbox was used to the one between their platform exclusivity games. When its eighth generation of video console, Xbox has *Gears of War*, *Halo*, and *Titanfall*, while PS4 has numerous best-selling games such as *God of War*, *Marvel's Spider-Man*, *The Last of Us*, and *Bloodborne*. However, the platform exclusivity has slightly influence on the sales of ninth generation consoles, since their supply shortage issue.

Considering the above reasons, the competition between PS5 and Xbox Series X becomes the battle of faith. Players will buy their preferred brand rather than the hardware performance or platform exclusivity games.

2.1.1.2 Nintendo Switch

Figure 23: Nintendo Switch, image source: https://www.nintendo.tw/hardware/switch/feature/

Nintendo Switch is a hybrid video game console developed by Nintendo and released worldwide in most regions on 2017/3/3. It is a tablet that can either be docked as a home console or as a portable device. The architecture makes it has the largest market share from Xbox and PS nowadays. Fist, it is easy to carry. Players can play as a portable device when commuting, and play as a home console at a static place. Second, Switch has lower price than other consoles. The price of switch is similar to that of some smartphones, which makes people who seldom play games will buy one. In addition, Switch has countless party games, so players can play with friends. Last but not least, it has lots of platform exclusivity games. Nintendo has games, like *Super Mario*, *Zelda*, and *Kirby* series. People who are the fans of these series will buy Nintendo console in order to play these games.

Nintendo Switch still has some drawbacks. Due to it's a hybrid video game, switch has larger mass than ordinary portable consoles. It is too heavy to carry by hand for a long time. Most importantly, all series of Nintendo consoles has low resolution screens and low fps compare to PS and Xbox. Players who get used to high resolution game play will find it frustrates when using Switch.

2.1.2 Sales Comparison

Current	2020	2021	2022	Lifetime
PS5	4,390,029	12,608,953	10,566,324	**27,565,306**
	12.5%	*27.7%*	*30.6%*	*16.8%*
XS	3,036,468	8,231,846	8,419,263	**19,687,577**
	8.6%	*18.1%*	*24.4%*	*12.0%*
	27,758,846	24,748,809	15,555,174	**117,269,529**
	78.9%	*54.3%*	*45.0%*	*71.3%*
Current Total	**35,185,343**	**45,589,608**	**34,540,761**	**164,522,412**
Legacy	**2020**	**2021**	**2022**	**Lifetime**
PS4	8,368,159	2,207,717	449,313	**117,027,310**
	74.0%	*81.8%*	*92.4%*	*69.5%*
	2,934,882	490,779	36,806	**51,278,798**
	26.0%	*18.2%*	*7.6%*	*30.5%*
3DS	469,092	34,395	-	**75,940,755**
	-	-	-	-
Legacy Total	**11,772,133**	**2,732,891**	**486,119**	**244,246,863**
All Total	**46,957,476**	**48,322,499**	**35,026,880**	**408,769,275**

Figure 24: total sales comparison, image source: https://www.vgchartz.com/

We can see the above statistic that PS4 has biggest market share among the eighth generation of consoles, while Switch has largest one this year. I think this is because the rapid changes of marketing. The increase number of Mobile players and PC players makes home console are less popular. Considering this, the portable feature of Switch dominant the console market.

2.2 SWOT

Strength	**Weakness**
• PS4 has the best sales • Best hardware for gaming • Lots of exclusive games • Best game experience	• High Price • Games on PlayStation have higher price • Shortage • Big console size
Opportunities	**Threats**
• People stuck at home since COVID-19 • Play At Home activity • High price of GPU • Support Network connection	• More PC players • Sales of Nintendo Switch • More Mobile players • Less console exclusivity

3 Conclusion

Though there are supply shortage and shrinking market of home console, PS5 is still the good gaming console with high resolution, less loading time and good gaming experience nowadays. Players are recommend to buy one to get best gaming experience.

4 Reference

[1] https://zh.wikipedia.org/zh-tw/PlayStation_5

[2] https://zh.wikipedia.org/zh-tw/%E7%AC%AC%E4%B9%9D%E4%B8%96%E4%BB%A3%E6%B8%B8%E6%88%8F%E6%9C%BA

[3] https://www.playstation.com/zh-hant-tw/ps5/

[4] https://youtu.be/CaAY-jAjm0w

[5] https://youtu.be/Gwat5qIwNjk

[6] https://youtu.be/tcyvHP0L9-s

[7] https://youtu.be/cWMIEgsSgDw

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