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Autonomous Driving SoC Research Report, 2024

July 2024

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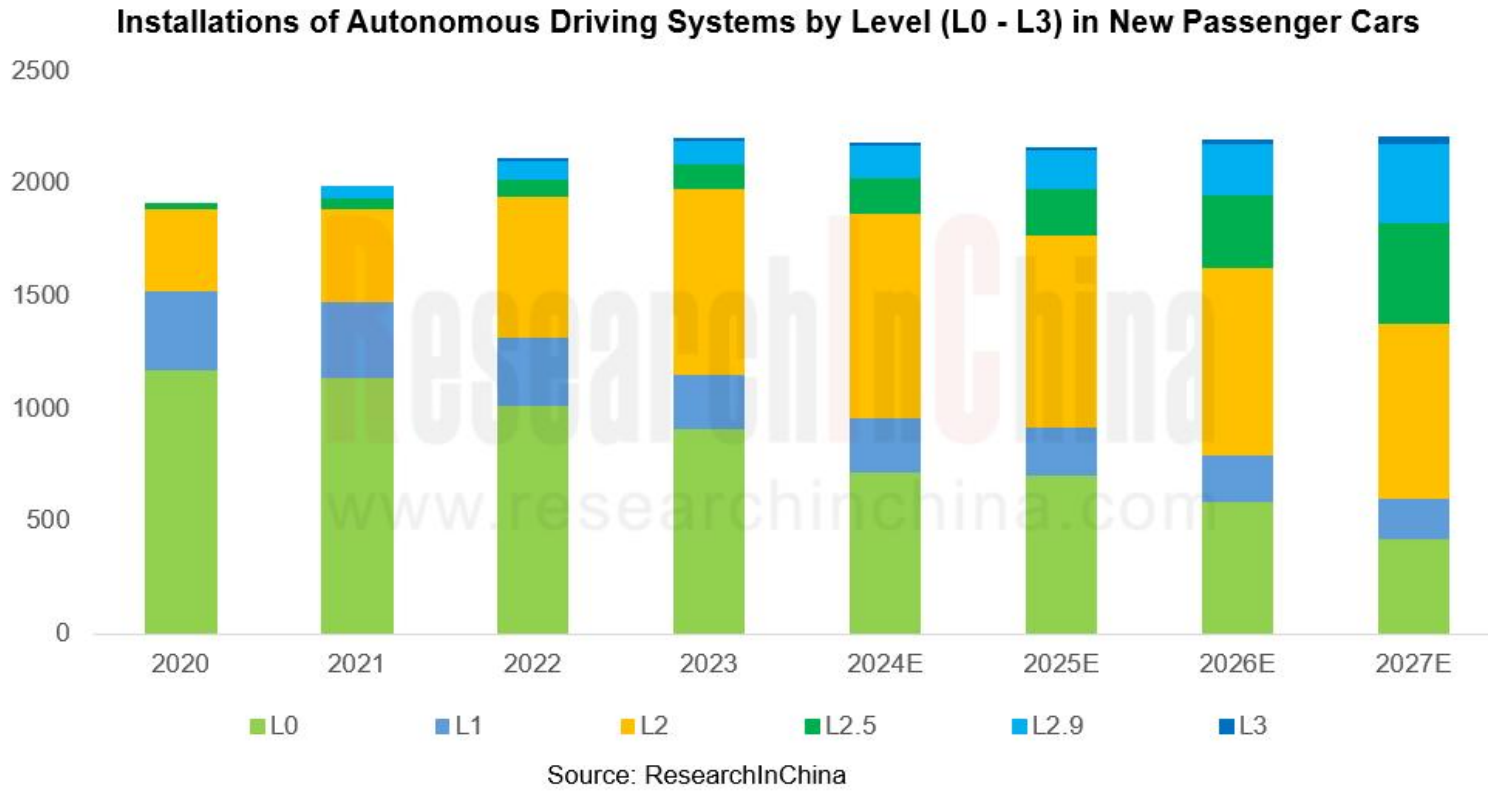
Autonomous driving SoC research: for passenger cars in the price range of RMB100,000-200,000, a range of 50-100T high-compute SoCs will be mass-produced.

According to ResearchInChina's statistical analysis of its database, in 2023 the penetration rate of L2+ NOA (including L2.5 highway NOA and L2.9 urban NOA, with hardware pre-embedded) in new cars in China stood at 9.67%, of which the penetration rate of L2.9 was 4.88%.

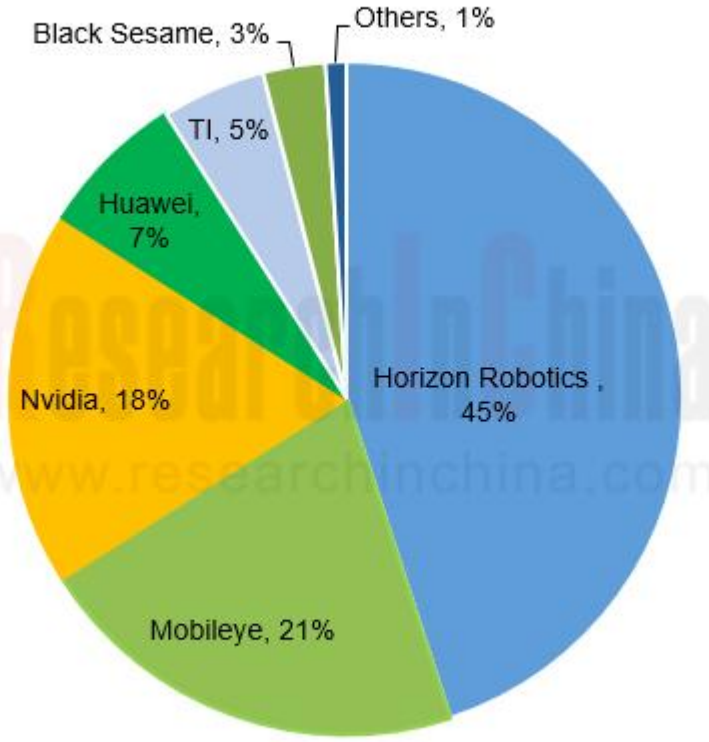


Note: The statistics of above installations is based on the number of insured new passenger cars (hardware pre-embedded, without regard to the optional) and the configurations of supported autonomous driving functions by level.

Market Share (by Number of Vehicle Model Installed) of L2.5 & L2.9 (with Hardware Pre-embedded) Advanced Intelligent Driving SoCs in China

In 2023, the total sales of new cars supporting L2+ NOA (L2.5&L2.9, with hardware pre-embedded) were around 2.12 million units. Currently, the intelligent driving SoCs installed are led by Tesla FSD, NVIDIA ORIN-X /ORIN-N/Xavier, Horizon Robotics J5/J3, Huawei MDC Ascend 610, TI TDA4VM/ TI TDA4VH, and Black Sesame A1000.

Market Share (by Number of Vehicle Model Installed) of L2.5 & L2.9 (with Hardware Pre-embedded) Advanced Intelligent Driving SoCs in China, 2023



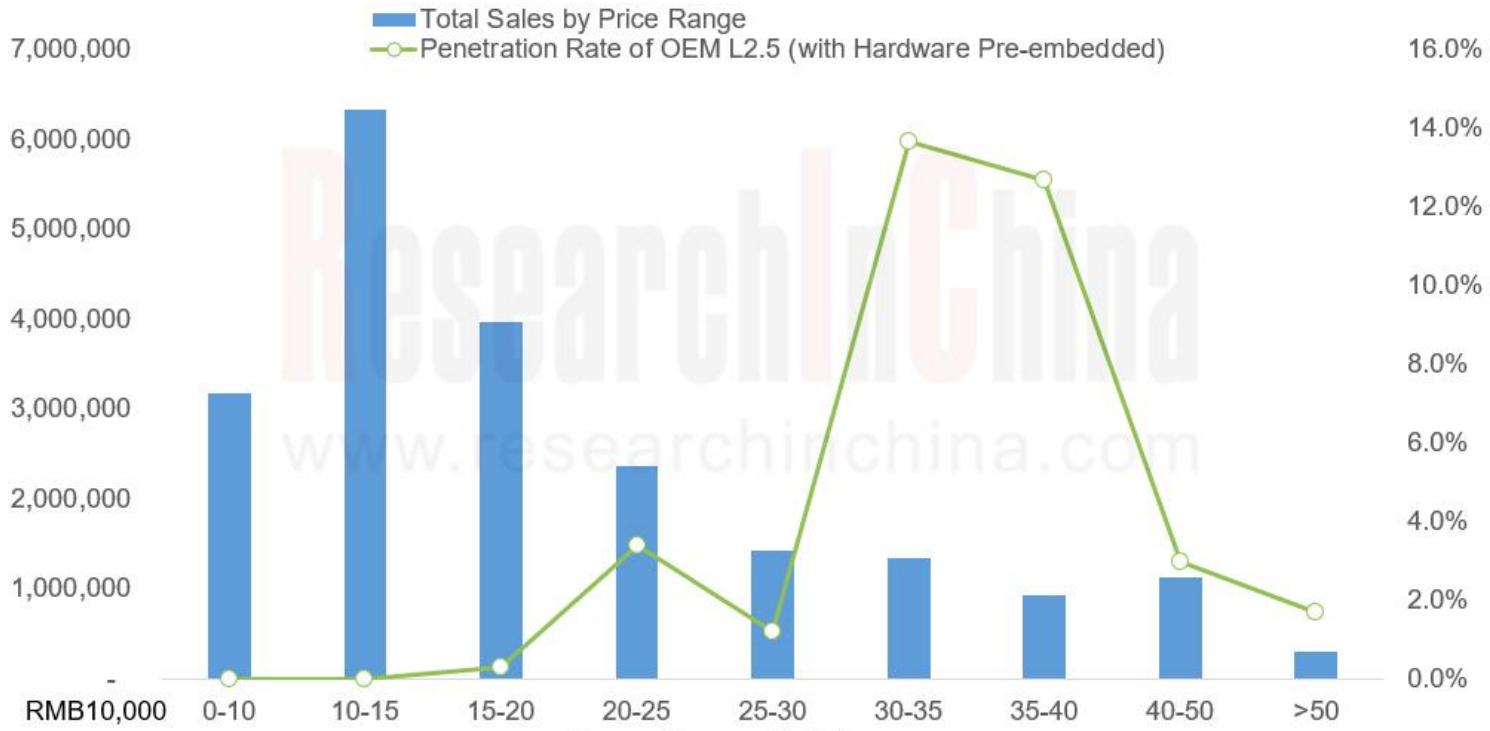
Source: ResearchInChina

50-100T high-compute autonomous driving SoCs will be quickly introduced into passenger cars in the price range of RMB100,000-200,000

50-100T high-compute autonomous driving SoCs will be quickly introduced into passenger cars in the price range of RMB100,000-200,000.

In China, passenger cars priced at RMB100,000-200,000 are still the main sales range. In current stage, the penetration rate of L2+ NOA (L2.5&L2.9, with hardware pre-embedded) in this price range is still very low, mainly due to costs.

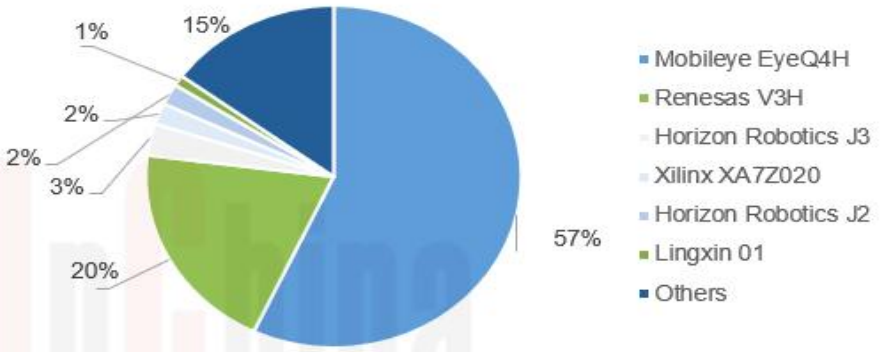
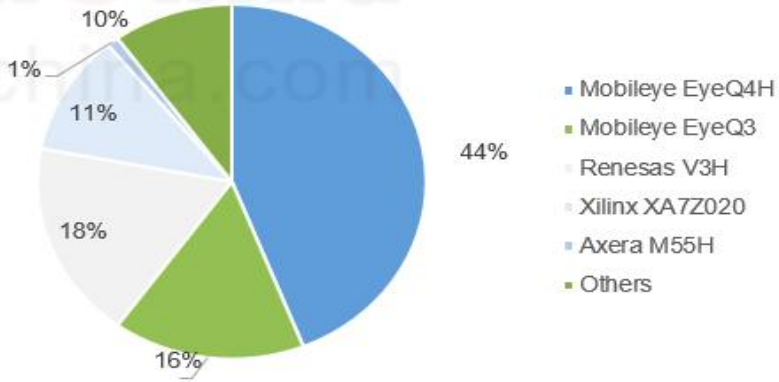
Sales Structure of Passenger Cars with L2.5 Autonomous Driving (with Hardware Pre-embedded) by Price Range in China, 2023



Source: ResearchInChina

The installation of L2.5 autonomous driving is also increasing rapidly

Passenger cars in the price range of RMB100,000-200,000 are still mainly configured with entry-level L2 autonomous driving at this stage, but the installation of L2.5 autonomous driving is also increasing rapidly.

Price Range (RMB10,000)	Time	Total Sales by Price Range	L2 Sales	L2.5 Sales	L2.9 Sales	Share of Vendors
15-20	Jan-Apr 2024	1,183,999	799,425	13,391	637	
	Full Year 2023	3,976,619	2,227,235	11,636	0	

Source: ResearchInChina

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Qualcomm autonomous driving SoC -SA8650/SA8620

Qualcomm SA8650 targets passenger cars in the price range of RMB100,000-200,000. According to Qualcomm's consistent product thinking, cost-effective and rich ecosystems are its main product direction.

SA8650 boasts CPU compute of 230kDMIPs, comparable to the top-end Orin. Orin has multiple versions, and only the top-end Orin-X features CPU compute of 230kDMIPs. It is supposed that SA8650 is composed of 4 Cortex-X3 large cores and 4 A55 small cores. Limited by costs, Chinese chips cost less in CPU, with 8 A55 cores at most and general computing power of 26kDMIPs. CPU costs much more than AI, and must have advanced processes. X3 must correspond to 4nm. Orin uses 12 A78AE cores, all large cores, to be on par with SA8650.

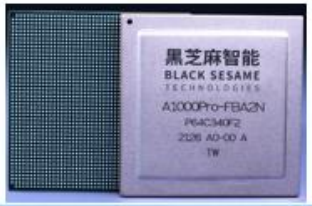
SA8650 has AI compute of 100TOPS, higher than the main competitor NVIDIA ORIN-N, and also has strong graphics output capabilities and supports up to 4 screens. SA8650 can correspond to 12 cameras, namely, 8 8MP cameras and 4 4MP cameras. The power consumption of SA8650 is about 25-40W. If it exceeds 25W, it will be best to use a water cooling design. Currently, the design scheme of SA8650 is water cooling.

Qualcomm has not provided chips individually since the fourth generation. All of its chips are sold in the form of modules. A module is composed of a SoC, 4 power management ICs, and 2-4 LPDDR DRAMs.

By one estimate, Qualcomm SA8650 module includes one SA8650 SoC, four PMM850U power management ICs, two Micron LPDDR5 DRAMs, and one Micron UFSs. The model of Micron LPDDR5 is MT62F3G32D8DV-026 AAT:B, codenamed D8DHD, with 8 die in package, 12GB per die, and the speed of 7500Mb/s. The capacity of one UFS may be 256GB, or it may be three LPDDR5 DRAMs. There is also another chip, which may be a PCIe interface or a temperature protection chip.

Comparison between Some 80-150T High-compute Autonomous Driving SoCs





SoC	NVIDIA ORIN-N	Qualcomm SA8650P	Horizon Robotics J6E /J6M	Horizon Robotics J5	Black Sesame A1000Pro
Process	8nm	4nm	7nm	16nm	16nm
Transistors	17 billion	-	-	-	-
CPU	137KDMIPS	230KDMIPS	100~137KDMIPS	25/30KDMIPS	60KDMIPS
GPU	1.1-2.2TFLOPS	1.1-1.3TFLOPS	-	-	60GFLOPS
NPU	72TOPS	100TOPS	80~128TOPS	96/128TOPS	106TOPS
ISP	1.6Gpix/s	-	-	-	-
Access to Cameras	-	12-channel HD cameras	-	16-channel HD cameras (supporting 4x4 MIPI)	16-channel HD cameras
Safety Island	ASIL-D	ASIL-D	ASIL-D	ASIL-B (D)	ASIL-B (D)
SOP	2023	2024	2024	2022	2023
Features	• ASIL -D functional safety level • Low-level solution	• Aimed at the RMB150,000 - 250,000 passenger car market • SA8650P supports 4 screens, 12 cameras (8 8MP cameras and 4 4MP cameras), and can run Transformer model • Support urban NOA, AVP	• Cost-effective NOA (J6E) • High-performance NOA (J6M)	• Power consumption ratio: 4.8 TOPS/W	• Internally integrate two core IPs self-developed by Black Sesame Technologies, namely, NeuralIQ image signal processor (ISP) and DynamAI neural network (NN) accelerator, both of which meet automotive-grade standards.

Source: ResearchInChina

The second-generation Ride (SA8650P, SA8620P) has been accepted by quite a few European and American OEMs

The first-generation Qualcomm Ride (SA8540P) had few responders, but the second-generation Ride (SA8650P, SA8620P) has been accepted by quite a few European and American OEMs, including BMW, Mercedes-Benz, Audi, Porsche and Stellantis. It has also been accepted by many mainstream Tier1s such as Valeo, Continental Automotive, Bosch and Veoneer.

Among Chinese Tier1s, Desay SV, Joyson Electronic, EnjoyMove Technology, Haomo.ai, and Baidu have all been developing based on SA8650 for nearly a year; Hangsheng Electronics, Zongmu Technology, Autolink, MEGA, PATEO, and Freetech are introducing SA8650. A large number of OEMs are already interested in it.

Some Tier 1 Suppliers'Autonomous Driving Solutions Based on Qualcomm SA8650/SA8620

Some Tier 1 Suppliers' Autonomous Driving Solutions Based on Qualcomm SA8650/SA8620

Tier1	SoC	NPU Compute	DCU	Performance and Configuration of Integration Solution	BOM of Integration Solution	SOP Layout
Zhuoyu Technology (DJI Automotive)	Qualcomm SA8650P	100 TOPS	Chenghang Platform (OEM by Desay SV)	✓ Map-free urban NOA (L2.9), 10V1R (front-view trinocular), no LiDAR ✓ Highway NOA (L2.5), 7V1R (front-view stereo), no LiDAR	✓ Hardware BOM: 7,000 yuan (without LiDAR)	✓ Magotan D9, Volkswagen Tiguan L Pro (2024 SOP) ✓ BYD (2025 SOP) ✓ FAW Hongqi (2025 SOP) ✓ Dongfeng Nammi (2025 SOP)
	Qualcomm SA8775P	72 TOPS	Cross-domain Integration Platform	-	-	✓ 2025 SOP
Haomo.ai	Qualcomm SA8650P	100 TOPS	Haomo HP570 (Flex)	✓ Map-free urban NOA (L2.9)	✓ Hardware BOM: 8,000 yuan (LiDAR optional)	-
	Qualcomm SA8620P	36 TOPS	Haomo HP370 (Flex)	✓ Highway NOA (L2.5), realizing highway NOA, urban memory driving, teaching-free home-zone parking assist, intelligent obstacle avoidance, etc.	✓ Hardware BOM: 5,000 yuan (without LiDAR)	-
Momenta	Qualcomm SA8650P	100 TOPS	OEM by Desay SV	✓ Map-free urban NOA (L2.9)	✓ Hardware BOM: 7,000 yuan (LiDAR expandable)	✓ Toyota: Overseas models (2025-26 SOP)
	Qualcomm SA8620P	36 TOPS		✓ Highway NOA (L2.5), 7V3R or 7V1R solution	✓ Hardware BOM: 5,000 yuan (without LiDAR)	-

Source: ResearchInChina

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Advanced Version of DJI Chengxing Platform

Advanced Version of DJI Chengxing Platform

Based on Qualcomm Snapdragon Ride (SA8650P) and without relying on HD maps and LiDAR, it enables point-to-point NOA on urban roads and expressways, and cross-floor home-zone parking assist.

The 7V+100TOPS (Qualcomm SA8650P) version of Chengxing Platform solution enables advanced intelligent driving functions like urban NOA, which is inseparable from DJI's expertise in stereo vision, omnidirectional fisheye perception, and high-performance optimization. In addition, on the 100TOPS domain controller, DJI's latest achievements in stereo OCC, road topology model, prediction and planning model, end-to-end model optimization and so forth are also deployed.

Based on the 7V sensor configuration, it can be expanded to a 10V configuration, further enhancing the ability to cope with individual urban scenarios (such as ultra-wide and ultra-long intersections).

Momenta signed an agreement with Qualcomm

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Mainly based on NVIDIA ORIN solution, Momenta’s advanced intelligent driving has already been designated by OEMs like SAIC, BYD, GAC and GM, and has begun to be delivered.

On April 22, 2024, Qualcomm and Momenta officially announced power-efficient and scalable architecture of SA8620P (36TOPS) and SA8650P (100TOPS) to enable ADAS and AD functions ranging from Highway Navigation Pilot (HNP) and Urban Navigation Pilot (UNP).

* Chip: SA8620P (36TOPS), SA8650P (100TOPS)
* Perception configuration: 7V3R/7V1R
* Functions: Highway Navigation Pilot (HNP, highway NOA), Memory Navigation Pilot (MNP, urban commute NOA), Learned Parking Navigation Pilot (LPNP), and Parking Navigation Pilot (PNP)
* arget customers: The solution is aimed at mainstream passenger cars pried at RMB100,000 to 200,000, with the entry-level coming with highway NOA as standard, without the need to pay extra optional fees. It is known that Momenta's Qualcomm-based platform has been mass-produced and applied by the two OEMs Toyota and GM.

Black Sesame Autonomous Driving SoC - A1000 Series

On July 17, 2024, Dongfeng eπ 007 offered significant upgrades in intelligent driving functions, including advanced intelligent driving functions such as highway NOA and Long-range Automated Parking Assist (LAPA), as well as a number of practical functions and experience optimizations, for intelligent driving models.

The high-configuration model of Dongfeng eπ 007 packs Black Sesame Huashan? A1000 automotive high-performance autonomous driving chip, which fully supports L2+ advanced intelligent driving assistance. Dongfeng eπ 007 can easily cope with daily intelligent driving needs after OTA updates. Huashan A1000 allows eπ 007 to be equipped with a driving-parking integrated high-compute intelligent driving system. The highway NOA enables full-course path planning, and can automatically complete tasks of following, automatic lane change, and on-ramp and off-ramp on urban expressways and highways.

A single Black Sesame A1000 SoC can support complete driving and parking functions, providing OEMs with high-performance and cost-effective driving-parking integrated autonomous driving solutions. At present, Huashan-2 A1000 is in full mass production and has been adopted by multiple leading Chinese OEMs including FAW, Dongfeng, Geely and JAC, with production models including Lynk & Co 08, Hycan V09, Lynk & Co 07, Dongfeng eπ 007 and Dongfeng eπ 008.

The best choice for driving-parking integration solutions - Black Sesame A1000

Single chip supports driving-parking integration

Complete all automotive certifications

High performance

Support L2+/L3 Autonomous Driving

NPU AI Hardware Compute 58TOPS (INT8)

Automotive Dual Channel 64 bit LPDDR4

A1000

CPU Logic Compute 32K DMIPS

5-Core High Performance Visual DSP

8-Core High Performance CPU

16CH HD Camera Inputs

ISP Can Process Per Second 1.2 Gigapixels

3D Panoramic Rendering

Convolution Layer Average 80%MAC Array Utilization

NOA

5V5R

Source: Black Sesame Technologies

Single-chip cockpit-driving cross-domain integration is becoming the focus of the market

Single-chip cockpit-driving cross-domain integration is becoming the focus of the market.

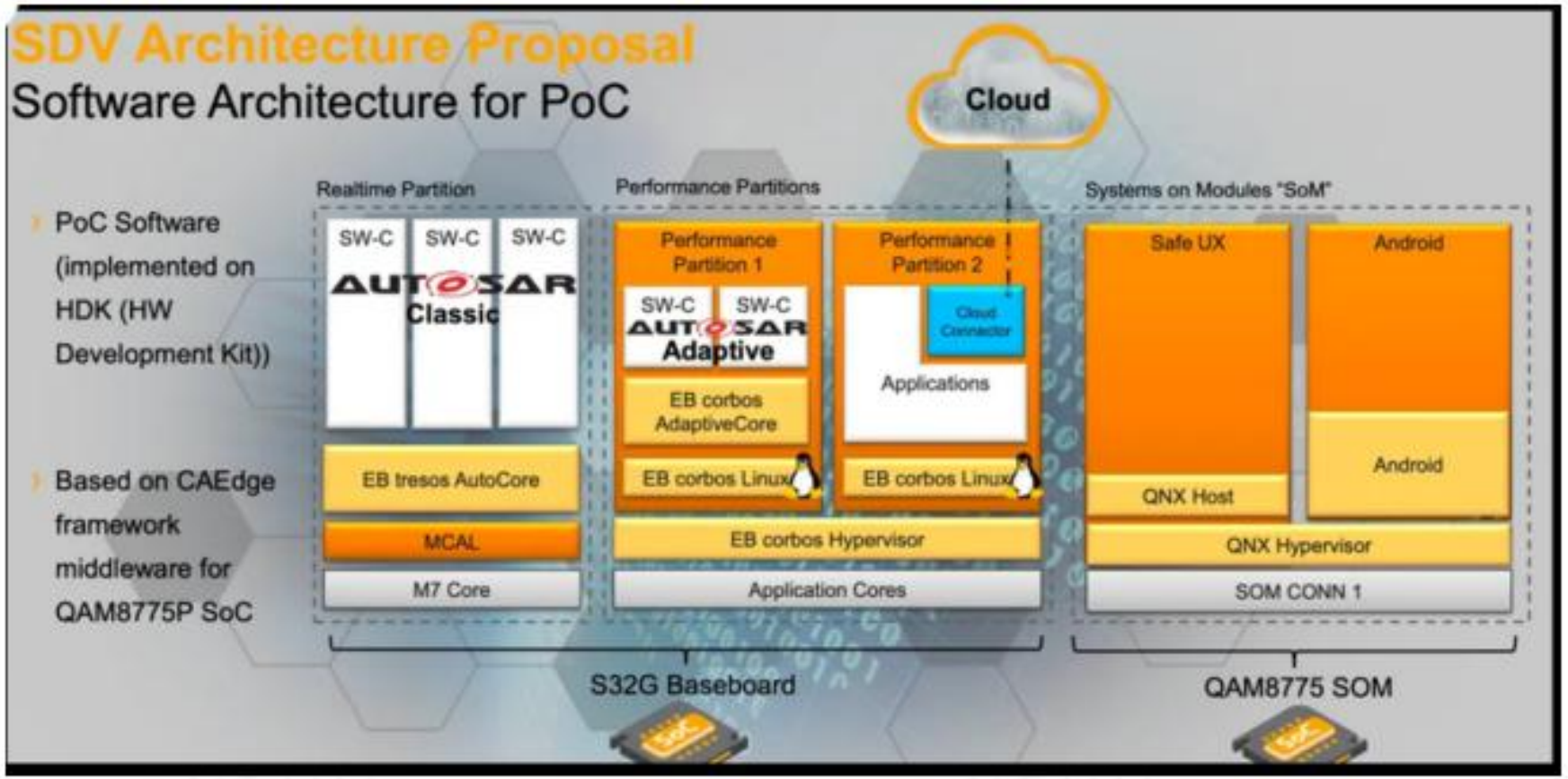
As EEA tends to be centralized, the integration of intelligent driving domain and cockpit domain has become a trend.

* NVIDIA, Qualcomm, SemiDrive and Black Sesame Technologies among others were the first to release cockpit-driving integration chips; the likes of Baidu, iMotion, Bosch, ZF, Desay SV, Hangsheng Electronics and Z-ONE have also announced single-chip cockpit-driving integration domain control products and system solutions;

* It is expected that during 2024-2025, single-chip cockpit-driving cross-domain integration solutions will be massively installed in vehicles.

Currently the industry has launched SoC products for cross-domain integration, such as Qualcomm 8775, Black Sesame C1296, SemiDrive X9CC, and NVIDIA Thor. Tier1s are developing system solutions based on these chips.

Continental has implemented software-defined vehicle architecture based on Qualcomm 8775. It adopts SoC+MCU architecture, with Qualcomm 8775 SoC and NXP S32G MCU. Continental builds a software system based on its CAEdge software framework to enable vehicle-cloud integrated cockpit-driving integration solutions.



Source: Continental

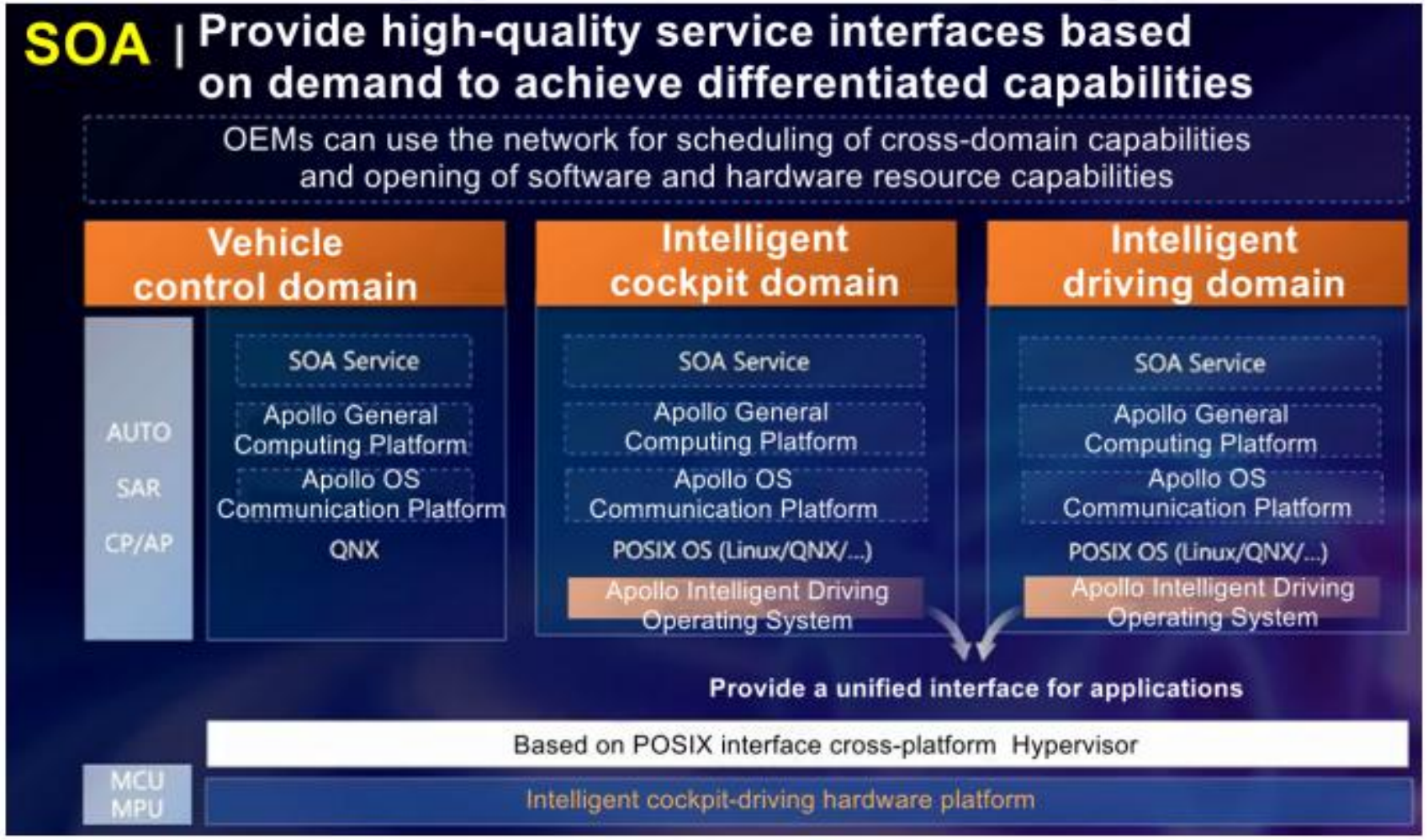
Baidu is also developing Apollo Robo-Cabin

Baidu is also developing Apollo Robo-Cabin, a cockpit-driving integrated computing platform based on a SOC to enable both basic intelligent driving functions such as AEB and LCC and cockpit capabilities. It adopts a cockpit-driving partition isolation design that isolates hardware, communication links and resource scheduling to ensure the independence of business, communication and operation.

In the future, the ultimate goal of this chip-software integrated solution is to realize the urban commuting + automated parking 2.0 and intelligent cockpit capabilities in terms of intelligent driving functions. Of course, seen from Baidu's layout plan for intelligent driving solutions, the underlying computing chip should at least be a medium-compute chip by then. The current mainstream 8295 is still a bit overstretched.

In the cockpit-driving integrated intelligent driving mode, based on its own OS SOA, Baidu Apollo provides complete open architecture with atomic AI capabilities, realizing multi-modal integration and creating human-machine cooperative intelligent driving, and full-vehicle intelligent experience of the intelligent cockpit. Baidu Apollo has deployed intelligent driving products, for example, all-scenario AVP, driving-parking integrated highway pilot product ANP2, and three-domain integrated urban NOA product ANP3.

SOA provides high-quality service interfaces based on Demand to achieve differentiated capabilities

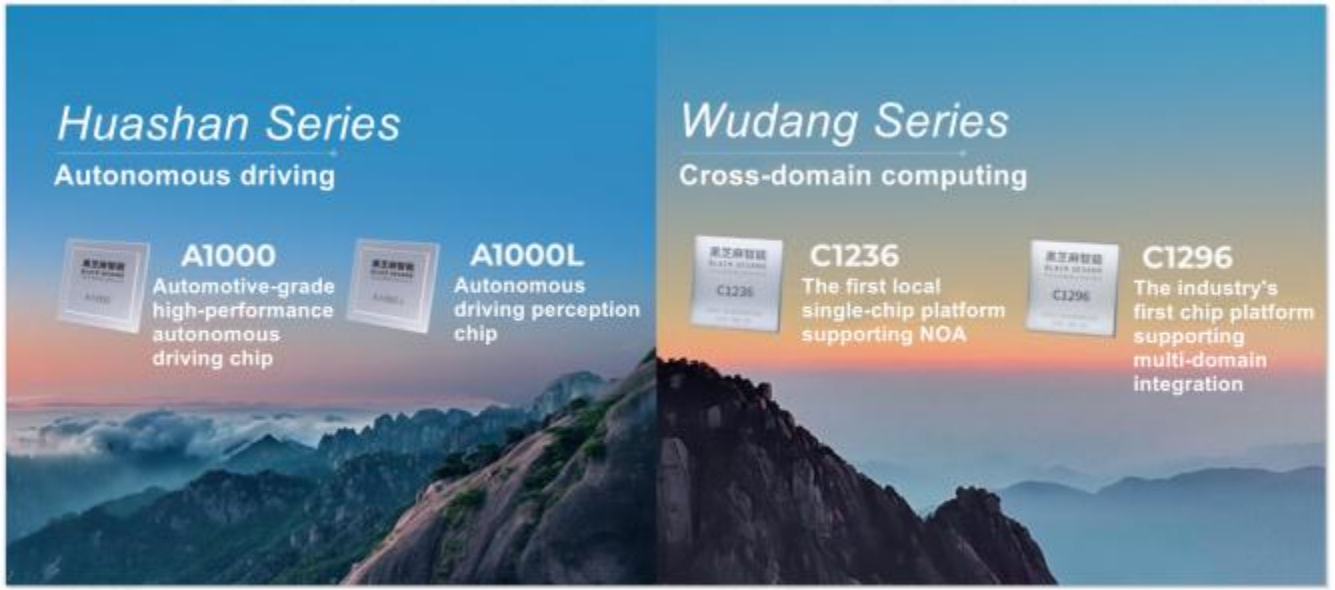


Source: Baidu

Black Sesame Technologies exhibited the mass-produced chips in the Wudang series, C1236 and C1296

At Auto China 2024, Black Sesame Technologies exhibited the mass-produced chips in the Wudang series, C1236 and C1296. A single C1236 integrates sensor access for NOA domain control, algorithm acceleration, line-speed data forwarding, 4K display, etc. Black Sesame Technologies and FAW Hongqi jointly launched a single-chip intelligent vehicle control project based on the C1200 family. The new cooperative solution is based on the C1200 family and will cover intelligent driving, vehicle data exchange and control functions.

Black Sesame Technologies officially announced CoreFusion, a C1296-based cockpit-driving integrated software open platform jointly created with Nesinext.



Source: Black Sesame Technologies

Will SoCs self-developed by OEMs become mainstream?

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Background of OEMs strengthening independent development of SoCs

Cost control: The unit price of the mainstream ORIN-X SoC is at least USD250, that is, more than USD500 for two. The price of Thor is at least USD500 per unit. OEMs develop SoCs in house, hoping to achieve cockpit-driving integration with a single chip and replace the current NVIDIA ORIN + Qualcomm 8295 combination to cut down costs. Typical examples include NIO NX9031, and Xpeng and NVIDIA's customized 750T version of Thor. However self-developed SoCs need to achieve scale effect, and with shipments of at least 1 million units, they will be cost-effective.

Independent and controllable: in the context of US sanctions, relying on only Orin, Thor or Qualcomm 8295/8255 brings a bigger supply chain risk. OEMs prefer to introduce more domestic alternatives into high-level autonomous driving. A typical example is SiEngine, which is supported by Geely and has developed AD1000 intelligent driving SoC and SE1000 cockpit SoC.

Product customization and AI-oriented development: the SoC designs of NVIDIA, Qualcomm and other companies are oriented to general needs. IP, circuit design, tool chain and other links all target the general needs of customers, resulting in high complexity in chip design. Yet OEMs can design chips just based on their own needs and do not need to open them to the outside world, so the chip design is less complex, and highly integrated with their own intelligent driving algorithms, and even cloud AI chips. Typical examples include Tesla FSD and cloud Dojo chips. Li Auto is also self-developing intelligent driving SoCs and cloud AI chips, and plans to tape out in 2024 and start production as early as 2026.

Challenges faced by OEMs in self-developing SoCs

Challenges faced by OEMs in self-developing SoCs

-In the current market environment, it is quite challenging for OEMs to independently develop chips. On the one hand, they have to compete with professional chip design companies in development speed, product definition capabilities, human resources and management capabilities; on the other hand, it is difficult for a single OEM to purchase tens of millions of chips, so whether they can make continuous investments is a huge challenge.

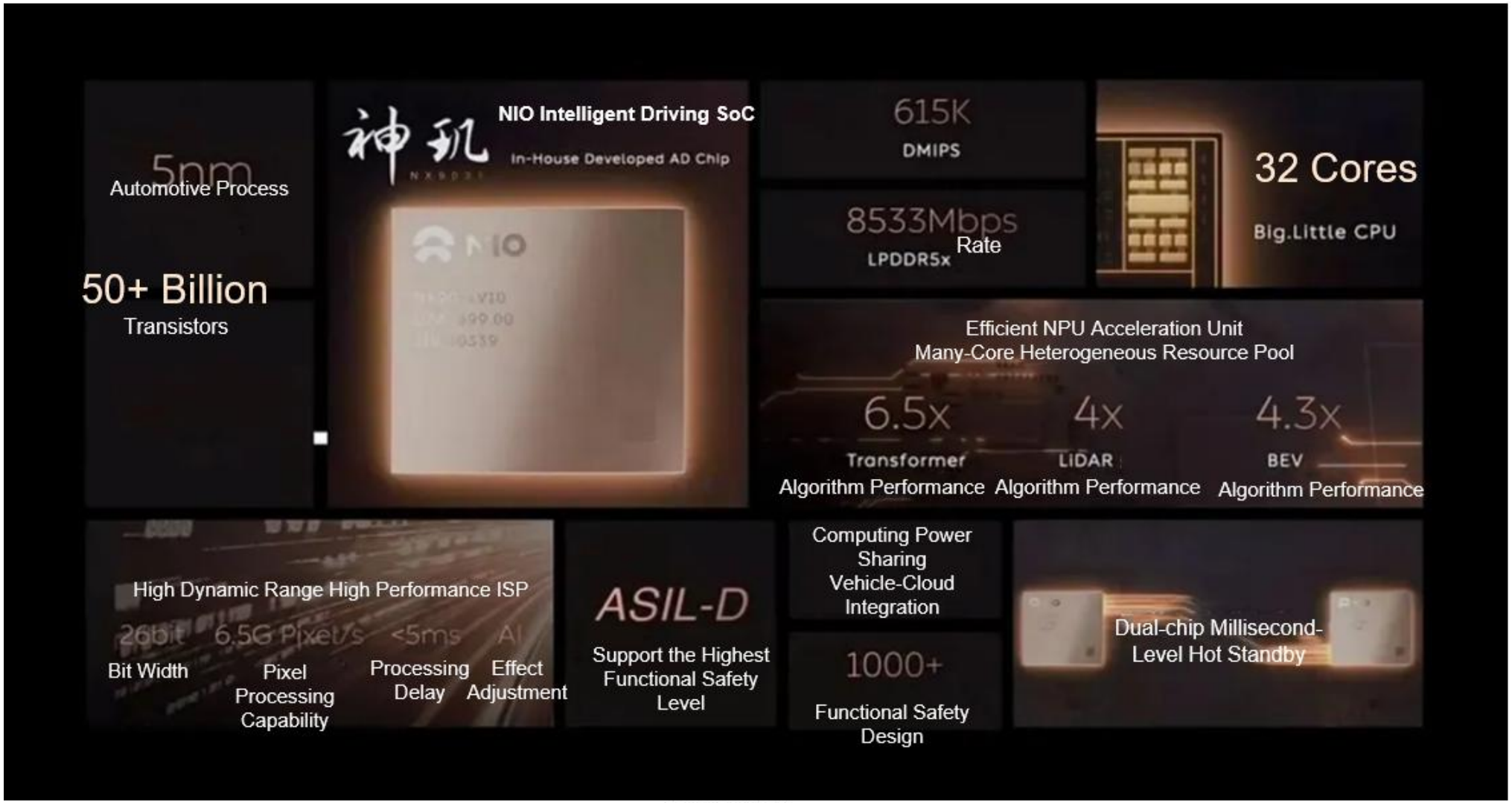
-The annual shipments of an automotive SoC are lower than one million units, making it difficult to support the continuous investments in chip R&D. If OEMs do not have sufficient shipments, it will be difficult for them to recover the costs, and lowering the chip cost of vehicles will be even a false hope.

-Independent chip manufacturing is more suitable for OEMs or OEM alliances with large shipments (SiEngine has developed multiple leading customers like Geely, FAW, Zeekr, and Volvo; Xpeng has chosen to form an alliance with Volkswagen) or OEMs with high unit prices of vehicles (NIO and Li Auto target high-end users).

For OEMs, "chip + operating system" must be developed in pair to bring its performance advantages into full play.

In September 2023, NIO introduced SkyOS, an all-domain vehicle operating system for intelligent electric vehicles. It is the underlying operating system for NIO cars. According to NIO's plan, the full-function mass production of SkyOS will be realized on NT3 platform-based models, which will be equipped with the self-developed intelligent driving SoC Shenji NX9031.

NIO SkyOS



Source: NIO

Shenji NX9031 should be a 5nm cross-domain integration chip mainly for autonomous driving

It is speculated that Shenji NX9031 should be a 5nm cross-domain integration chip mainly for autonomous driving. To save costs, it is expected to be manufactured by Samsung, just like Tesla FSD, as OEM by TSMC is too expensive.

- Transistors: 50+ billion
- CPU, ARM IP, Cortex-A78AE, 32-core CPU configuration, and both large and small core configuration, performance of 615KDMIPS, far higher than NVIDIA ORIN (228KDMIP, 12-core CPU)
- ISP, developed in-house by NIO, high dynamic range; 26 bits (bit width is mainly subject to the dynamic range of ADC, the higher the bit width of ISP the higher the frame rate can be, and the bit width of most ISPs are only 10 or 12 bits); image bandwidth of 6.5GPixel/s, far higher than NVIDIA ORIN (1.85Gpixel/s); processing delay of <5ms
- NPU, the core of intelligent driving SoC, has computing power equivalent to 4 ORIN-X SoCs; the self-developed reasoning acceleration unit NPU (NPU TPP compute, total power performance: <4800) can run various AI algorithms flexibly and efficiently.
- Memory: LPDDR5X, bandwidth of 8533Mbps, performance higher than LPDDR5
- Bus: ARM, NOC bus IP, building a data transmission channel between CPU, BPU, GPU and MCU

* Functional safety: ASIL-D level, just adding an MCU island, generally 2 to 4 Cortex-R52 cores for lockstep

Comparison between NIO Shenji NX9031 and Next-generation Advanced Intelligent Driving SoC Counterparts

Vendor	Autonomous Driving SoC	Process	Transistors	CPU Compute	NPU Compute	ISP Performance	Access to Cameras	DDR Bandwidth Storage	SOP	Counterpart
NIO	NX9031	5nm (Samsung)	50+ billion	615KDMIPS	Equivalent to 4 ORIN-X SoCs	6.5GPixel/s	/	204GB/s LPDDR5X	2025Q2	NVIDIA Thor
SiEngine	Longying AD1000	7nm (TSMC)	35 billion	250KDMIPS	256 TOPS @INT8 Multiple chips can be cascaded to expand the computing power up to 1024 TOPS	4.8GPixel/s	20 channels	204GB/s LPDDR5/4X	2024.10	NVIDIA ORIN-X
Horizon Robotics	J6P	7nm (TSMC)	37 billion	410KDMIPS (Cortex-A78AE)	560 TOPS@INT8	5.3GPixel/s	24 channels	204GB/s LPDDR5X	2025	NVIDIA Thor
NVIDIA	ORIN	7nm (TSMC)	17 billion	228KDMIPS (Cortex-A78AE)	256 TOPS@INT8	1.85GPixel/s	16 channels	204GB/s LPDDR5	2022	/
NVIDIA	Thor	4nm (TSMC)	77 billion	Neoverse V2	500-2000 TOPS@INT8	/	/	/ LPDDR5X/GDDR6	2026	/

Source: ResearchInChina

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