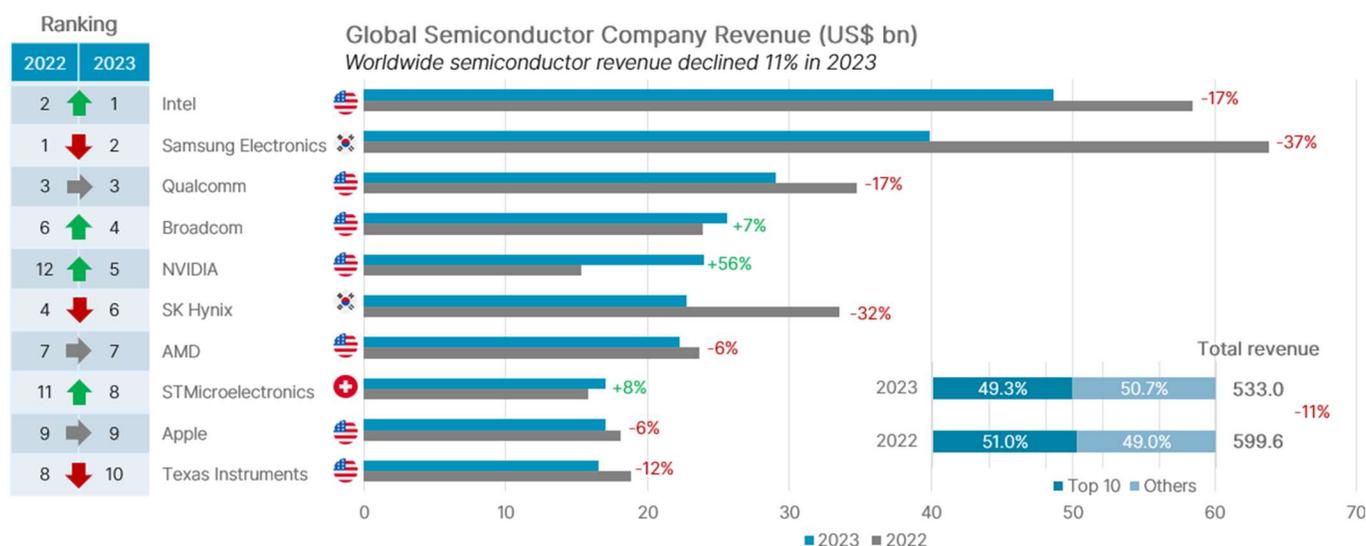


Semiconductors in 2024: Entering a New Era, Propelled by Generative AI

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The cyclical semiconductor industry faced a challenging year in 2023 and saw its seventh downturn since 1990. Global semiconductor revenue¹ amounted to US\$533 billion, representing a decline of 11% compared to 2022. According to Gartner, only three of the top ten semiconductor vendors² posted revenue growth last year, with five experiencing double-digit declines. Intel reclaimed the number one position from Samsung Electronics. The company reported semiconductor revenue of US\$49 billion last year, surpassing Samsung's revenue of US\$40 billion. Driven by its dominant position in the artificial intelligence (AI) chip market, NVIDIA's semiconductor revenue³ grew 56% to US\$24 billion in 2023, propelling the firm into the top five for the first time.⁴



Source: Gartner. As of January 16, 2024. Data compiled by Nasdaq Global Indexes.

Yet, the market is quickly regaining strength as worldwide chip sales increased year-over-year in November 2023 for the first time since August 2022. Global sales in February 2024 were US\$46.2 billion, representing a year-over-year increase of 16%.⁵ According to the Semiconductor Industry Association, the global semiconductor market is

¹ Revenues from non-semiconductor categories, including licensing, royalties and intellectual property, are excluded.

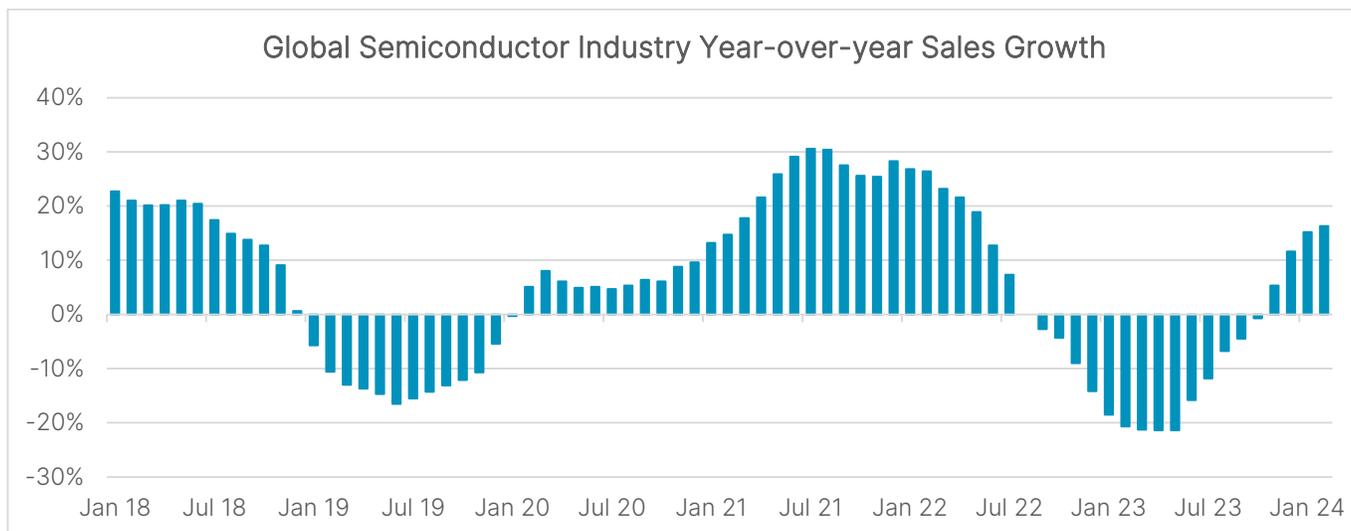
² Only vendors that design and sell semiconductor devices are included. Foundries and equipment vendors are excluded.

³ Only revenue attributable to the production of NVIDIA's own designed semiconductor devices, such as graphics processing units (GPUs) and application processors, are included. Revenues from the sale of assembled products to end-users, software and services are excluded.

⁴ <https://www.gartner.com/en/newsroom/press-releases/2024-01-16-gartner-says-worldwide-semiconductor-revenue-declined-11-percent-in-2023>

⁵ <https://www.semiconductors.org/global-semiconductor-sales-increase-16-3-year-to-year-in-february>

expected to witness double-digit growth in 2024.⁶ Gartner also forecasts that global semiconductor revenue will grow 17% in 2024 to US\$624 billion.⁷



Source: Semiconductor Industry Association. As of April 3, 2024.

AI continues to play a pivotal role in bolstering 2024 outlook

Generative AI refers to algorithms that can generate new content, such as text, images, code, simulations, and videos. Generative AI models use neural networks to identify the patterns and structures within existing data to create original content. Given its ability to understand and use natural language for a variety of tasks, many work activities that involve communication, documentation, and supervision have the potential to be automated by generative AI. Demand for generative AI is increasing across many industries, such as healthcare, financial services, legal and the public sector. More than 80% of enterprises will use generative AI in their business by 2026, according to a forecast by Gartner, up from less than 5% in 2023.⁸ The research firm anticipates that by 2025, over 30% of new drugs and materials will be discovered systematically using generative AI techniques, and 30% of outbound marketing messages from large organizations will be generated synthetically. 60% of the design effort for new websites and mobile apps is expected to be automated by generative AI by 2026.⁹

AMD expects the market for data center AI chips to grow to approximately US\$400 billion by 2027.¹⁰ In the pre-AI era, data centers relied primarily on central processing units (CPUs). The landscape has transformed with the advent of AI, and data centers now require GPUs to provide parallel computing power, which executes tasks simultaneously with greater efficiency.

Firms that have benefited from AI continued to record substantial semiconductor revenue increases. NVIDIA holds 85% of the 2023 overall market for GPUs¹¹, which have become vital to AI by providing the computing power for machine learning. According to Omdia, the firm sold nearly half a million H100 and A100 GPUs in the third quarter of last year. Meta Platforms is building a massive computing infrastructure to support its

⁶ <https://www.semiconductors.org/global-semiconductor-sales-decrease-8-2-in-2023-market-rebounds-late-in-year/>

⁷ <https://www.gartner.com/en/newsroom/press-releases/2023-12-04-gartner-forecasts-worldwide-semiconductor-revenue-to-grow-17-percent-in-2024>

⁸ <https://www.gartner.com/en/newsroom/press-releases/2023-10-11-gartner-says-more-than-80-percent-of-enterprises-will-have-used-generative-ai-apis-or-deployed-generative-ai-enabled-applications-by-2026>

⁹ <https://www.gartner.com/en/topics/generative-ai>

¹⁰ <https://www.reuters.com/technology/amd-forecasts-45-billion-ai-chip-market-this-year-2023-12-06/>

¹¹ Include desktop PC, mobile PC, workstation and server GPUs. Source: International Data Corporation.

future AI roadmap and plans to acquire 350,000 H100 chips by the end of this year.¹² The demand for these products is overwhelming, and the lead time for H100 GPUs ranges from two to three months.¹³ The introduction of its newest GPU platform "Blackwell" may help extend the firm's technology leadership advantage for years to come. The B200 GPU shows strong performance gains over the prior generation H100, with 2.5 times training improvement and 5 times inference improvement. While the new products will be available later this year, NVIDIA expects Blackwell to be adopted by the world's major technology firms, including Amazon, Google, Meta, Microsoft, OpenAI, and Oracle.¹⁴ While the firm is perhaps the biggest beneficiary of the AI enthusiasm thus far, NVIDIA is more than just a chip supplier. The firm helps clients meet their front- and back-end technology needs as they deploy AI capabilities. It has built different libraries and tools that serve as foundation models, enabling its clients to create bespoke ChatGPT equivalents for their industry or company.

As NVIDIA continues basking in the limelight for its AI-ready GPUs, AMD has strategically positioned AI as a critical driver for its growth in 2024. With the launch of its MI300 series, AMD is poised to intensify competition with NVIDIA's flagship AI processors. Microsoft, Meta, Oracle, and other cloud providers stated that they will adopt AMD's Instinct MI300X chip. Such endorsement indicates that technology firms are exploring alternatives to NVIDIA's expensive GPUs, which have been critical for developing and deploying AI programs. AMD expects to generate sales of over US\$3.5 billion from the MI300 series this year, up from the previous projection of US\$2 billion.¹⁵ The chip designer has recently introduced a new series of semiconductors tailored for AI-enabled business laptops and desktops¹⁶ as the firm aims to expand its share of the lucrative AI PC market. AI-enabled PCs refer to machines with advanced chips capable of running large language models and applications powered by AI directly on the device, instead of in the cloud. Gartner projects shipments of AI PCs to represent 22% of all PCs this year.¹⁷

The growing adoption of generative AI also indicates remarkable growth prospects for the high bandwidth memory (HBM) market. With half of the global HBM market in 2022¹⁸, SK Hynix has benefited from the strong demand for this niche technology. It is vital for building generative AI systems as it offers faster data transfer and lower power consumption than conventional DRAM. HBM chips use stacking technology to enhance the bandwidth and performance of GPUs. They are expected to account for 15% of industry-wide DRAM sales this year, demonstrating a remarkable increase from the 8% market share in 2023.¹⁹ SK Hynix's sales of HBM3 chips increased by more than fivefold in 2023 from a year earlier. While it has started mass production of the next-generation HBM3E since March 2024²⁰, SK Hynix is also developing the HBM4 chip, which is expected to double processing speeds. As the world's second-biggest memory chipmaker, the firm overtook LG Energy as South Korea's second-largest company by market capitalization at the end of 2023. Micron has also started mass production of its HBM semiconductors and expects "several hundred million" dollars of revenue will be generated from these products in fiscal 2024. While its HBM is sold out for 2024, the majority of its 2025 supply has already been allocated. The firm also noted that its HBM3E product, which consumes 30% less power than its competitors' offerings, will be used by NVIDIA's H200 Tensor Core GPUs. The firm's capital expenditures (CapEx) for FY 2024 are expected to reach up to US\$8.0 billion, primarily supporting

¹² https://www.instagram.com/reel/C2QARHJR1sZ/?utm_source=ig_embed&ig_rid=a80e276d-7f38-4892-9c30-eb1581dec62a

¹³ <https://www.tomshardware.com/pc-components/gpus/nvidias-h100-ai-gpu-shortages-ease-as-lead-times-drop-from-up-to-four-months-to-8-12-weeks>

¹⁴ <https://nvidianews.nvidia.com/news/nvidia-blackwell-platform-arrives-to-power-a-new-era-of-computing>

¹⁵ <https://ir.amd.com/news-events/press-releases/detail/1180/amd-reports-fourth-quarter-and-full-year-2023-financial>

¹⁶ <https://ir.amd.com/news-events/press-releases/detail/1190/amd-expands-commercial-ai-pc-portfolio-to-deliver>

¹⁷ <https://www.gartner.com/en/newsroom/press-releases/2024-02-07-gartner-predicts-worldwide-shipments-of-ai-pcs-and-genai-smartphones-to-total-295-million-units-in-2024>

¹⁸ <https://www.ft.com/content/8f65a241-414b-4661-8923-78f6b9941b65>

¹⁹ <https://www.reuters.com/technology/sk-hynix-swings-q4-profit-strong-ai-chip-demand-2024-01-24/>

²⁰ <https://news.skhynix.com/sk-hynix-begins-volume-production-of-industry-first-hbm3e>

their HBM3E production ramp.²¹ It is reported that SK Hynix and Micron each received an advance payment of approximately US\$540 million to US\$770 million from NVIDIA to ensure a stable supply of HBM chips.²²

TSMC, the world's largest contract chipmaker, expects its revenue to grow by up to 25% this year on robust demand for AI semiconductors, and its management believes that server AI processors²³ could account for more than 20% of its revenue by 2028.²⁴ Some of the firm's biggest semiconductor clients, including prominent names like NVIDIA and AMD, have reoriented their growth strategy around AI to fuel the demand for their chips. TSMC has invested in advanced packaging technology for more than ten years, which is critical for producing AI semiconductors. Advanced packaging entails integrating multiple chips in the same package and interlocking them to function harmoniously as a unified entity. NVIDIA's H100 chip is a commercialized example of advanced packaging, leveraging the power of TSMC's CoWoS (chip-on-wafer-on-substrate) technology.²⁵ The firm will invest US\$2.9 billion to construct an advanced chip plant in Taiwan to expand its advanced packaging capabilities.²⁶

The rise of autonomous driving

Before exploring how autonomous vehicles will also contribute to semiconductor demand growth, it is crucial to clarify the levels of autonomy as defined by the Society of Automotive Engineers (SAE). The SAE's six levels of driving automation can be divided into two broad categories: driver support systems from Level 0 to Level 2 (shown in blue below) and automated driving systems from Level 3 to Level 5 (shown in green below). While most major automotive original equipment manufacturers (OEMs) have mastered their technologies for Level 2 autonomy, the transition from Level 2 to Level 3 – which involves hands-off and eyes-off as the critical step up – is the most significant leap on the spectrum. In June 2023, Mercedes-Benz became the first automaker to obtain US state approval to deploy SAE Level 3 conditionally driving vehicles in California.²⁷ Undoubtedly, more and more carmakers will follow in Mercedes-Benz's footsteps and pursue Level 3 autonomy.

²¹ <https://investors.micron.com/static-files/c531bd08-22cd-4d6b-9540-f8aa72459716>

²² <https://www.blackridgeresearch.com/news-releases/sk-hynix-and-micron-receive-advance-payment-from-nvidia-for-hbm-supply>

²³ TSMC categorizes server AI processors as those performing training and inference functions, including GPUs, AI accelerators and CPUs.

²⁴ https://investor.tsmc.com/chinese/encrypt/files/encrypt_file/reports/2024-04/34ff75e23e53246302ce3a8d90d0423c57c6b120/TSMC%201Q24%20Transcript.pdf

²⁵ <https://www.forbes.com/sites/tiriasresearch/2022/03/22/nvidias-gtc-shows-the-company-has-not-slowed-down-chip-development/?sh=3f8e045e1653>

²⁶ <https://www.cnbc.com/2023/07/25/tsmc-to-invest-2point9-billion-in-advanced-chip-packaging-plant-in-taiwan.html>

²⁷ <https://www.dmv.ca.gov/portal/news-and-media/california-dmv-approves-mercedes-benz-automated-driving-system-for-certain-highways-and-conditions/>

SAE Levels of Driving Automation

| | SAE LEVEL 0™ | SAE LEVEL 1™ | SAE LEVEL 2™ | SAE LEVEL 3™ | SAE LEVEL 4™ | SAE LEVEL 5™ |
|--|--|--------------|--------------|---|--|--------------|
| What does the human in the driver's seat have to do? | You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering | | | You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat” | | |
| | You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety | | | When the feature requests, you must drive | These automated driving features will not require you to take over driving | |

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| | These are driver support features | | | These are automated driving features | | |
|----------------------------|---|--|--|---|--|---|
| What do these features do? | These features are limited to providing warnings and momentary assistance | These features provide steering OR brake/acceleration support to the driver | These features provide steering AND brake/acceleration support to the driver | These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met | This feature can drive the vehicle under all conditions | |
| Example Features | <ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning | <ul style="list-style-type: none"> • lane centering OR • adaptive cruise control | <ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time | <ul style="list-style-type: none"> • traffic jam chauffeur | <ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed | <ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions |

Source: SAE International

McKinsey estimates that autonomous driving could generate between US\$300 billion and US\$400 billion in the passenger car market by 2035.²⁸ Autonomous vehicles rely on sensors in different parts of the car to generate and maintain a map of their surroundings. The number of more sophisticated sensor chips increases drastically with higher levels of driving autonomy. Level 3 autonomous driving carries an average of 8 sensor chips, while the number of sensors required for Level 5 autonomous driving approaches an average of 20.²⁹

Automakers often turn to NVIDIA for their high-power and high-speed computing needs in semi-autonomous driving technologies. NVIDIA recently announced that Chinese automakers Li Auto, Great Wall Motor, ZEEKR, and Xiaomi will use their DRIVE technology to power automated driving.³⁰ BYD, the world’s largest electric vehicle maker, already uses NVIDIA’s DRIVE centralized compute platform in its electric vehicles.³¹

NXP Semiconductors is one of the leaders in the automotive radar market, with 56% of its 2023 revenue derived from the automotive end-market.³² In November 2023, NXP Semiconductors unveiled the Trimension NCJ29D6, a fully integrated automotive single-chip ultra-wideband family that combines precise and secure real-time localization with short-range radar. The solution addresses multiple use cases with a single system, including secure car access, intrusion alert, child presence detection, and gesture recognition.³³

²⁸ <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected>

²⁹ <https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/consumer-business/deloitte-cn-cb-automotive-semiconductors-strategic-en.pdf>

³⁰ <https://nvidianews.nvidia.com/news/wave-of-ev-makers-choose-nvidia-drive-for-automated-driving>

³¹ <https://nvidianews.nvidia.com/news/byd-worlds-largest-ev-maker-partners-with-nvidia-for-mainstream-software-defined-vehicles-built-on-nvidia-drive>

³² <https://investors.nxp.com/static-files/f7456590-dc42-4291-b78c-85bac9e3073c>

³³ <https://www.nxp.com/company/about-nxp/nxp-introduces-the-next-generation-of-automotive-ultra-wideband-ics-combining-secure-ranging-and-short-range-radar:NW-NXP-COMBINING-SECURE-RANGING-SHORT-RANGE-RADAR>

At CES 2024, Texas Instruments unveiled the industry's first single-chip radar sensor designed for satellite architectures, enabling more accurate advanced driver assistance systems (ADAS) decision-making. It is also the first sensor with launch-on-package (LOP) technology, which helps reduce the sensor size by up to 30% and extend the sensor range beyond 200m.³⁴

The future of mobility becomes increasingly electric

According to market research firm Rho Motion, global sales of battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs) rose 31% in 2023, reaching 13.6 million units in total. BEV sales grew 50% in the US and Canada, and increased 27% and 15% in Europe and China, respectively.³⁵ The pace of electric vehicle adoption will vary across regions, with Europe and China set to lead the way among major auto markets, followed by the US.

The worldwide shift towards electric vehicles is set to accelerate as the cost of batteries, which constitutes up to 40% of the production cost of a typical electric vehicle, continues to decline rapidly. Goldman Sachs expects battery prices to fall to US\$99 per kilowatt hour (kWh) of storage capacity by 2025, reflecting a 40% decrease from 2022.³⁶ Automakers are making substantial ongoing investments in electrifying their vehicle fleets, with over US\$500 billion worth of investments by 2025 announced by OEMs.³⁷ BMW expects full-electric models to account for at least 20% of total sales by 2024 and 50% well ahead of 2030.³⁸ Toyota is targeting annual global sales of 1.5 million battery-powered vehicles by 2026.³⁹

Electric vehicles boast a substantially higher semiconductor content, reaching as much as US\$1,500 in high-end electric cars, in contrast to a mere US\$500 in regular internal combustion engine (ICE) cars.⁴⁰ Wolfspeed is a crucial supplier of specialized chips for electric vehicles. It produces over 60% of the world's silicon carbide (SiC) and committed US\$6.5 billion in CapEx through 2027 to expand its production capacity.⁴¹ SiC semiconductor-based power devices can operate at higher voltage, switching frequency, and temperature compared to their silicon-based counterparts.⁴² These benefits directly impact two crucial factors that drive mass adoption of electric vehicles: increased driving range and reduced charging time. The SiC device market is expected to reach US\$11 billion to US\$14 billion in 2030, growing at a CAGR of 26% between 2022 and 2030.⁴³ ON Semiconductor completed the expansion of its SiC fabrication facility in South Korea in October 2023, which will be able to manufacture over one million 200mm SiC wafers annually at full capacity.⁴⁴ It is also considering investing US\$2 billion in boosting the production of SiC chips.⁴⁵

³⁴ <https://news.ti.com/ti-debuts-new-automotive-chips-at-ces-enabling-automakers-to-create-smarter-safer-vehicles>

³⁵ <https://www.reuters.com/business/autos-transportation/global-electric-car-sales-rose-31-2023-rho-motion-2024-01-11/>

³⁶ <https://www.goldmansachs.com/intelligence/pages/electric-vehicle-battery-prices-falling.html>

³⁷ <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/automotive-powertrain-suppliers-face-a-rapidly-electrifying-future>

³⁸ <https://europe.autonews.com/automakers/after-doubling-sales-full-electric-bmw-and-mini-cars-last-year-automaker-expects-demand>

³⁹ <https://www.reuters.com/business/autos-transportation/toyota-plans-expand-battery-ev-line-up-europe-6-models-by-2026-2023-12-04/>

⁴⁰ <https://www.robeco.com/en-int/insights/2023/09/empowering-the-drive-the-silent-revolution-of-ev-semiconductors>

⁴¹ <https://www.wolfspeed.com/company/about/manufacturing-leadership/>

⁴² https://web.archive.org/web/20180604134619id_/http://tpea.cpss.org.cn/uploads/soft/170214/1_1511396481.pdf

⁴³ <https://www.mckinsey.com/industries/semiconductors/our-insights/new-silicon-carbide-prospects-emerge-as-market-adapts-to-ev-expansion>

⁴⁴ <https://www.onsemi.com/company/news-media/press-announcements/en/onsemi-completes-expansion-of-silicon-carbide-production-facility-in-bucheon-south-korea>

⁴⁵ <https://www.reuters.com/technology/semiconductor-mulls-2-blm-investment-electric-vehicle-chip-production-2023-05-16/>

Governments are providing incentives to bolster domestic semiconductor capabilities

As governments worldwide provide incentives to fortify domestic supply chains, bolster technological advancements, and mitigate geopolitical risks, the already intense global competition to secure chips is poised to intensify further.

US – the CHIPS and Science Act

The US enacted the CHIPS and Science Act in August 2022, providing US\$52.7 billion for US semiconductor production, research, and workforce development. Taxpaying entities receive a 25% advanced manufacturing investment tax credit for investments in semiconductor manufacturing and processing equipment — an outlay the Congressional Budget Office estimates will cost US\$24 billion over five years until Jan 1, 2027.

The CHIPS Act's manufacturing incentives have already sparked substantial investments in the US. Companies like Intel, TSMC, and Micron are already taking advantage of the CHIPS Act funding to build new or expanded fabs across the US. Intel will receive up to US\$8.5 billion in direct funding and US\$11 billion in loans from the US government to construct and expand its facilities in Arizona, Ohio, New Mexico, and Oregon.⁴⁶ The US government also plans to award TSMC US\$6.6 billion in grants and as much as US\$5 billion in loans to help the world's top chipmaker build factories in Arizona. The firm announced a new third fab in Arizona that will produce 2 nanometer or more advanced chips, upping total investments in the state to more than US\$65 billion.⁴⁷ Micron Technology is poised to receive US\$6.1 billion in grants and up to US\$7.5 billion in loans from the US government to help build megafabs in New York and Idaho.⁴⁸ On January 4, 2024, the Biden administration announced plans to provide US\$162 million in federal grants to Microchip Technology, an Arizona-based semiconductor company.⁴⁹ The investment will enable Microchip to increase its production of semiconductors that are used in cars, airplanes, appliances, medical devices, and military products. Several new fabs will commence operations this year while discussions regarding additional manufacturing plants are underway.

Prominent Semiconductor Projects in the US after May 2020

| Name of Company | Location | Amount (US\$B) | Announced | Start | Type | Product |
|---------------------|----------------|----------------|-----------|-------|--------------|--------------------|
| Foundries | | | | | | |
| Micron | Clay, NY | 100.0 | Oct 2022 | 2025 | 4 new fabs | DRAM |
| TSMC | Phoenix, AZ | 65.0 | Apr 2024 | 2025 | 3 new fabs | Leading-edge logic |
| Texas Instruments | Sherman, TX | 30.0 | May 2021 | 2025 | 4 new fabs | Analog chips |
| Intel | Chandler, AZ | 20.0 | Mar 2021 | 2024 | 2 new fabs | Leading-edge chips |
| Intel | New Albany, OH | 20.0 | Jan 2022 | 2025 | 2 new fabs | Leading-edge chips |
| Samsung Electronics | Taylor, TX | 17.3 | Nov 2021 | 2024 | 1 new fab | Leading-edge logic |
| Micron | Boise, ID | 15.0 | Sep 2022 | 2025 | 1 new fab | DRAM |
| Texas Instruments | Lehi, UT | 11.0 | Feb 2023 | 2026 | Expansion | Analog chips |
| Equipment | | | | | | |
| Applied Materials | Sunnyvale, CA | 4.0 | May 2023 | 2026 | New facility | R&D Platform |

⁴⁶ <https://www.whitehouse.gov/briefing-room/statements-releases/2024/03/20/fact-sheet-president-biden-announces-up-to-8-5-billion-preliminary-agreement-with-intel-under-the-chips-science-act/>

⁴⁷ <https://www.nist.gov/news-events/news/2024/04/biden-harris-administration-announces-preliminary-terms-tsmc-expanded>

⁴⁸ <https://www.commerce.gov/news/press-releases/2024/04/biden-harris-administration-announces-preliminary-terms-micron-onshore>

⁴⁹ <https://www.commerce.gov/news/press-releases/2024/01/biden-harris-administration-announces-chips-preliminary-terms-microchip>

| Materials | | | | | | |
|------------------|-------------|-----|----------|------|--------------|----------------------|
| GlobalWafers | Sherman, TX | 5.0 | Jun 2022 | 2025 | New facility | 300-mm wafer factory |

Source: Semiconductor Industry Association, company filings, Bloomberg Intelligence. As of April 8, 2024.

Prominent US semiconductor projects include foundries investment above US\$10 bn and equipment and material investments above US\$1 bn.

Europe – European Chips Act

The European Chips Act, entered into force on September 21, 2023, aims to bolster the semiconductor supply of the European Union (EU) while enhancing resilience and technological sovereignty within the region. This legislation, backed by the European Parliament and EU member states, seeks to double Europe's chip production capacity from 10% to 20% of the global market by the end of the decade. EUR43 billion (US\$46.3 billion) of public and private investments will be mobilized and measures will be set to prepare, anticipate and swiftly respond to any future supply chain disruptions.⁵⁰

The German government has made substantial commitments to provide extensive state support to international chipmakers investing in Europe's largest economy. For instance, Intel is set to receive EUR9.9 billion (US\$10.7 billion) in grants for its project, which involves investing over EUR30 billion (US\$32.3 billion) to construct two new factories in Magdeburg.⁵¹ This investment is the largest foreign investment in Germany's postwar history.

South Korea – the K-Chips Act

South Korea's semiconductor industry is the nation's largest source of exports, accounting for 18.9% of total exports in 2022.⁵² In 2022, Samsung Electronics and SK Hynix accounted for approximately half of global market share in NAND flash memory chips and nearly 70% in the DRAM segment globally.⁵³

On March 30, 2023, the South Korean Parliament (National Assembly) passed a tax bill known as the "K-Chips Act" as an amendment to the existing Restriction of Special Taxation Act. The K-Chips Act increases the tax credit from 8% to 15% for large companies investing in manufacturing facilities for "national strategic goods," including semiconductors. Tax breaks for small and medium-sized firms will rise from 16% to 25%.

As Taiwan and Japan aggressively invest in their semiconductor industries, the Korean government unveiled a blueprint anticipating private sector investment of US\$471 billion through 2047. On top of their existing 21 fabs, 13 new chip plants and three research facilities will be built. As part of the two-decade strategy, Samsung Electronics and SK Hynix will construct their state-of-the-art chip plants domestically.⁵⁴

SOX™ – the leading index for the semiconductor industry

Covering the 30 largest US-listed stocks and ADRs of companies primarily involved in the design, distribution, manufacture, and sale of semiconductors, Nasdaq's PHLX Semiconductor™ Index (SOX™) had a very impressive total return in the last 12 months ending April 30, 2024, rising 58% and outperforming the Nasdaq-100® and the S&P Semiconductors Select Industry Index by 25 percentage points and 31 percentage points, respectively.

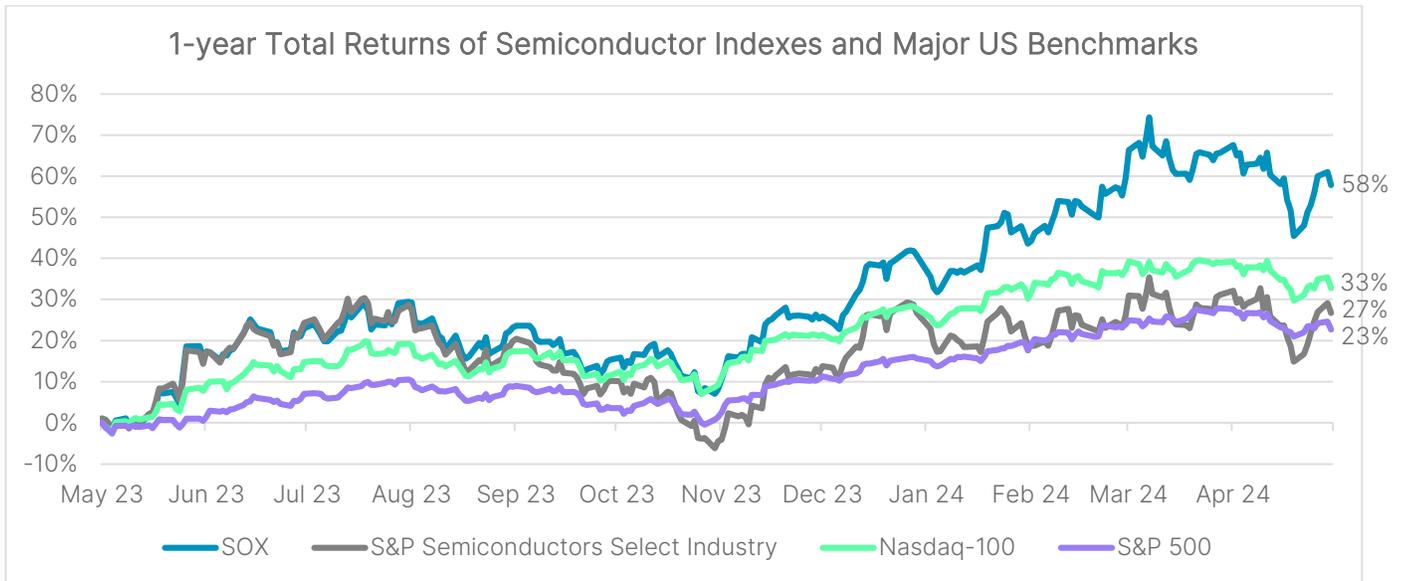
⁵⁰ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en

⁵¹ <https://www.intc.com/news-events/press-releases/detail/1628/intel-german-government-agree-on-increased-scope-for-wafer>

⁵² <https://www.trade.gov/market-intelligence/south-korea-semiconductors>

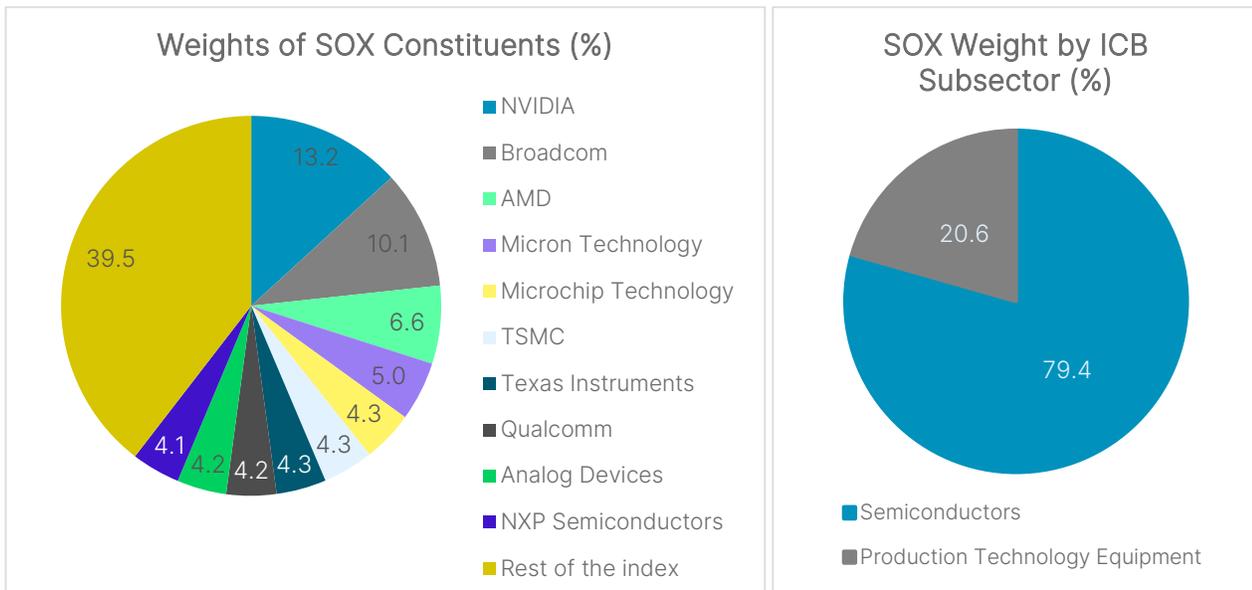
⁵³ <https://www.nbr.org/publication/the-role-of-south-korea-in-the-u-s-semiconductor-supply-chain-strategy/>

⁵⁴ <https://www.bloomberg.com/news/articles/2024-01-15/south-korea-lays-out-470-billion-plan-to-build-chipmaking-hub>



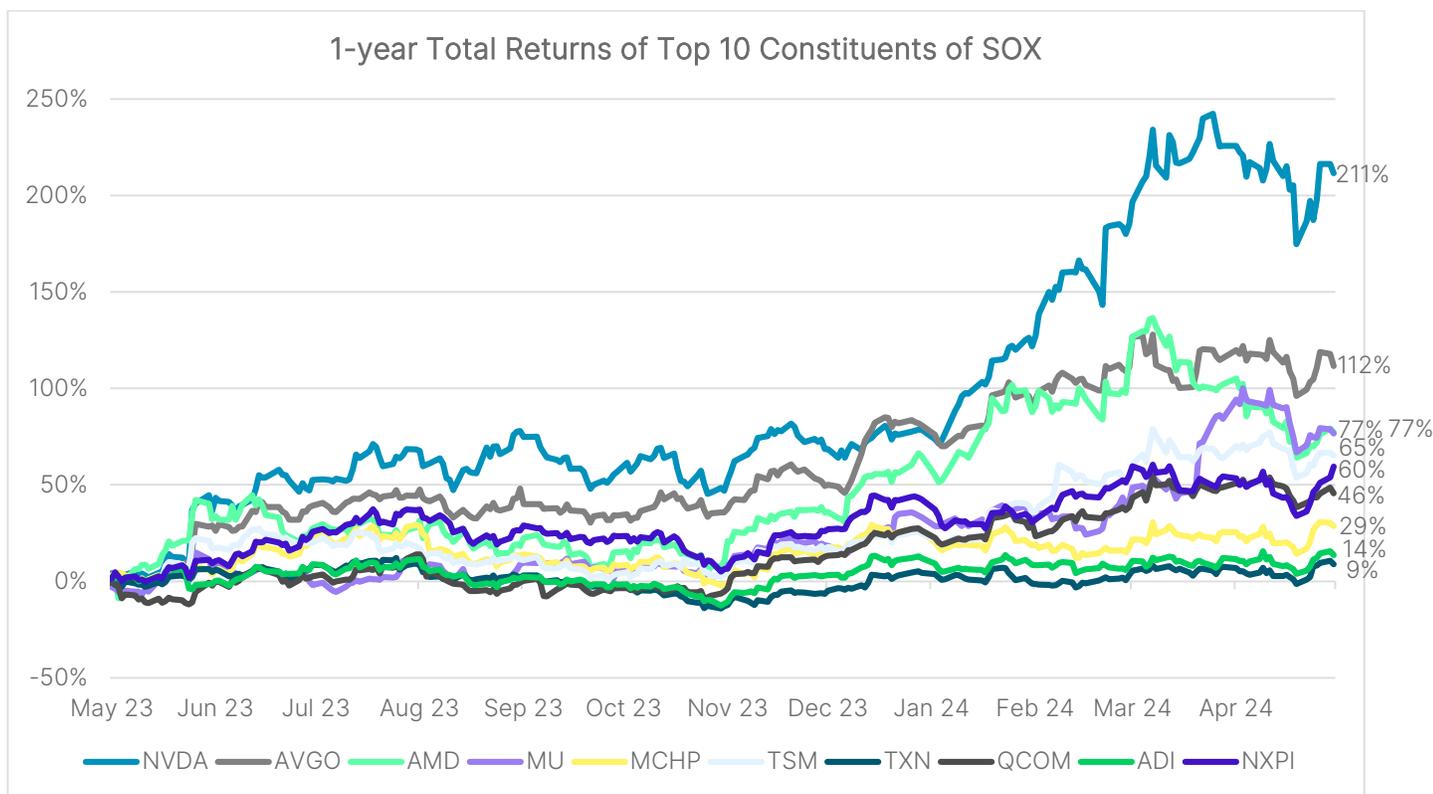
Source: Nasdaq Global Indexes, Bloomberg. As of April 30, 2024.

SOX is modified market capitalization-weighted, with the top three constituents by market capitalization capped at 12%, 10% and 8%, respectively, and the rest capped at 4% during quarterly rebalancing. As of the end of April 2024, the ten largest constituents accounted for 60.5% of the index weight. 79.4% of the index weight is in the Semiconductor Subsector, with the rest in the Production Technology Equipment Subsector, according to the Industry Classification Benchmark (ICB) classification system.



Source: Nasdaq Global Indexes; FactSet. As of April 30, 2024

Two of the top ten SOX constituents have seen their share prices more than double over the last 12 months ending April 30, 2024, averaging a gain of 69.8%. Within the same industry, the performances of these stocks varied significantly. The difference in one-year total returns between the best and worst performing stocks among the top ten constituents (NVIDIA and Texas Instruments) was a staggering 203 percentage points. This demonstrated the importance of diversification, even when investing in a single sector or theme.



Source: Nasdaq Global Indexes, FactSet. As of April 30, 2024.

As the largest constituent with a 13.2% weight in SOX as of the end of April 2024, NVIDIA was the top performer among all constituents with a 211% gain during the last 12 months, and Goldman Sachs recently called it “the most important stock on planet Earth.”⁵⁵ Its valuation passed the US\$2 trillion threshold for the first time in February 2024⁵⁶, after becoming the fifth publicly traded US company to join the trillion-dollar club in May 2023.⁵⁷ Although its share price more than tripled in the last 12 months, its forward P/E ratio tumbled to 35x as of the end of April 2024, compared to 47x one year ago.⁵⁸ While NVIDIA’s net income grew 769% year over year to US\$12.3 billion during the quarter ending January 2024, its Q4 gross margin was 76%, increasing substantially from 63% a year ago.⁵⁹ Most of this impressive performance was driven by the AI boom and the strong demand for its GPUs.

As a technology infrastructure powerhouse with unmatched technology capabilities and scale in the industry, Broadcom is the second-largest constituent with an 10.1% weight in SOX and its shares had a one-year total return of 112% as of the end of April 2024. While NVIDIA’s GPUs have undeniably dominated the AI gold rush since 2023, Broadcom is poised to seize a significant share of the forthcoming wave, particularly in the realms of networking and application-specific integrated circuits (ASICs). The firm’s growth in the semiconductor segment is mainly driven by strong demand for its networking products in AI data centers, as well as custom AI accelerators from hyperscalers. Over the past five years, Broadcom has established itself as a leader in ASIC development, particularly in collaboration with tech giants like Google and Meta. JPMorgan estimates that Google and Meta combined will drive over US\$9 billion in AI ASIC chip revenues for Broadcom this year, a significant increase from US\$3.5 billion last year.

⁵⁵ <https://www.bloomberg.com/news/articles/2024-02-21/goldman-s-rubner-says-nvidia-is-most-important-stock-on-earth>

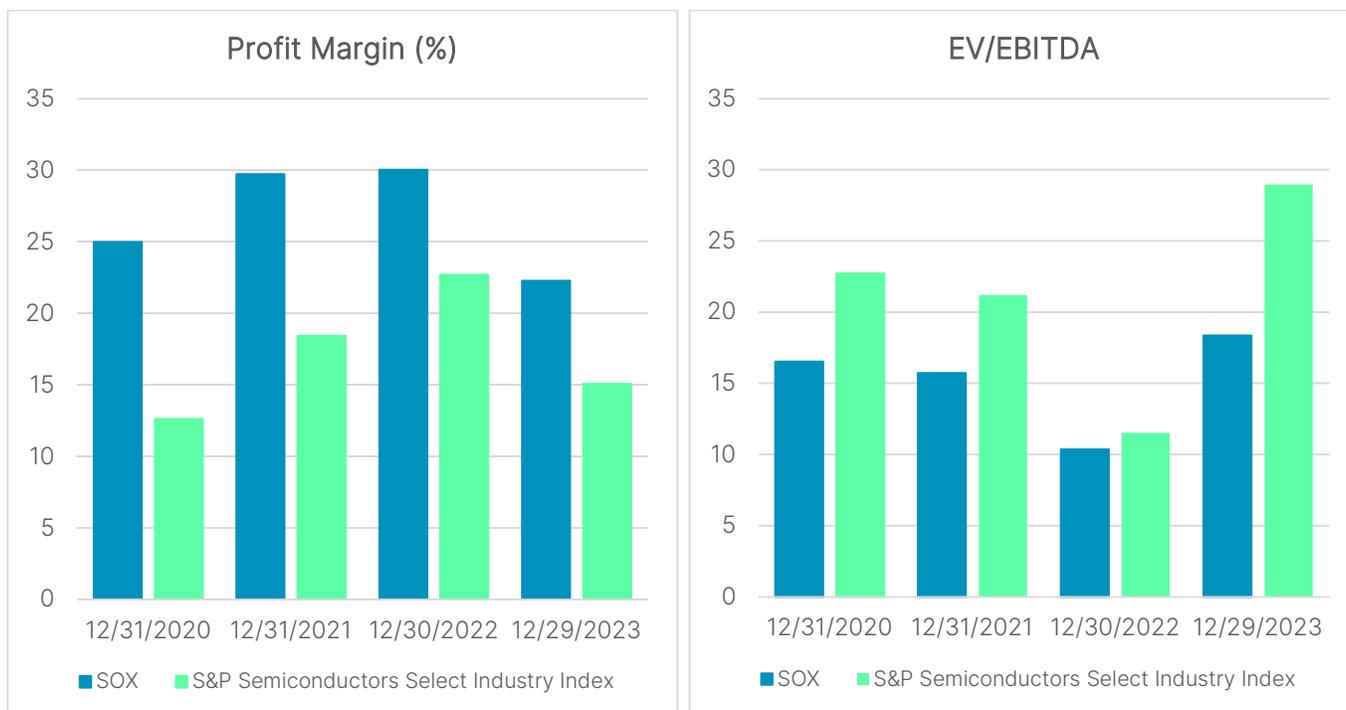
⁵⁶ <https://www.reuters.com/technology/nvidia-hits-2-trillion-valuation-ai-frenzy-grips-wall-street-2024-02-23>

⁵⁷ <https://www.reuters.com/technology/nvidia-sets-eye-1-trillion-market-value-2023-05-30/>

⁵⁸ Bloomberg. As of April 30, 2024.

⁵⁹ <https://investor.nvidia.com/news/press-release-details/2024/NVIDIA-Announces-Financial-Results-for-Fourth-Quarter-and-Fiscal-2024/>

Compared to the equal-weighted S&P Semiconductors Select Industry Index, SOX had a higher index-weighted profit margin in each of the last four years. SOX also had lower trailing twelve-month EV/EBITDA ratios than its S&P counterpart every year since 2020. Semiconductor manufacturing is among the most capital-intensive industries in the world, as the rapid pace of innovation necessitates substantial investments for delivering cutting-edge devices consistently. And while it is still incredibly innovative, it is not a new industry - established players like Intel have been around for more than 50 years, making it far more mature than more recent investment themes such as cloud computing or cybersecurity. A modified market capitalization-weighted approach is thus more appropriate, as larger firms tend to lead the way in research and development spending, which is essential to their competitive position. The outperformance of SOX, as evidenced by superior returns, profit margins, and valuations compared to the S&P index, substantiates its reputation as a compelling benchmark for the semiconductor industry.



Source: Bloomberg. As of December 31, 2023.

Conclusion

The semiconductor industry is navigating through yet another cycle, with a robust recovery in sales expected this year across most of the major players. Recent advancements in generative AI and large language models are fueling an escalating demand for the deployment of high-performance GPU-based servers and accelerator cards in data centers. Automotive is another strong-growing segment for semiconductors, driven by the rise of autonomous driving and electric vehicles. Several major economies, such as the US and Europe, have implemented policies to subsidize local chip production directly. In addition to subsidies, other countries are also offering tax incentives to manufacturers. These incentives provide a substantial financial boost to companies operating in the chipmaking industry, as the business is capital-intensive and demands significant investments in research and development.

Funds tracking SOX include the Invesco PHLX Semiconductor ETF (Nasdaq: SOXQ), the Mirae Asset TIGER US PHLX Semiconductor Sector Nasdaq ETF (South Korea: 381180), the Cathay PHLX Semiconductor ETF (Taiwan: 00830), and the Global X Semiconductor ETF (Japan: 2243). The Mirae Asset TIGER Synth-US PHLX Semiconductor Sector Leverage ETF (South Korea: 423920) tracks SOX with two times leverage.

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