Industry Analysis: Semiconductor Industry

Equity Research Division - March 2024

Report Description

This report's objective is to provide a contextual framework for the upcoming equity valuations which will include an analysis of companies operating within the semiconductor industry.

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- 2nm chips are expected to provide a 25% increase in power efficiency and 12% performance improvement compared to the latest technology
- 4.7 Industry Herfindahl Hirschman Index
- The semiconductor supply chain, is evolving rapidly as the demand for advanced electronics continues to surge

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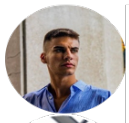
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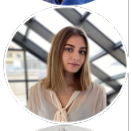
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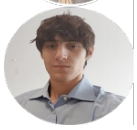
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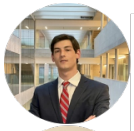
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Market Leaders

- Nvidia (United States)
- ASML (Netherlands)
- TSMC (Taiwan)
- Cadence (United States)
- Samsung (South Korea)
- Intel (United States)

Industry Overview

The semiconductor industry, an integral pillar of the digital age, traces its origins to the advent of the transistor in the mid-20th century. It has since become synonymous with innovation, enabling the creation and advancement of nearly all modern electronics. From the outset, pioneer firms like Fairchild Semiconductor and Texas Instruments laid the groundwork for what would become a relentless pursuit of miniaturization and performance, culminating in the complex integrated circuits that are now ubiquitous across industries.

The industry's trajectory took a dramatic turn towards exponential growth with the advent of personal computing in the late 20th century, further accelerated by the internet boom and the proliferation of mobile technology in the early 21st century. Companies such as Qualcomm and NVIDIA emerged as key players, driving innovation in communication and graphics processing, respectively. The semiconductor market, once confined to specific sectors, now permeated virtually all facets of technology—from consumer electronics to automotive and industrial applications.

Integrated Circuits, the largest segment, is projected to hit a market volume of US$500.70bn by 2024 (Statista), encompasses a broad spectrum of devices including Analog, Logic, Memory, and Micro Integrated Circuits. This segment alone epitomizes the sector's remarkable growth, driven by demand for smarter, more efficient technology. The Optoelectronics market captures semiconductors linked to light, playing a pivotal role in advancements from energy-efficient lighting to high-speed data transmission. Sensors & Actuators, meanwhile, are the industry's interface with the physical world, translating environmental variables into actionable electronic signals.

Currently, the semiconductor market is valued at an estimated US$613.10bn, with expectations to burgeon to US$736.40bn by 2027, reflecting a CAGR of 6.30% from 2024-2027. This growth trajectory is punctuated by the industry's adaptability and innovation, particularly in leading markets such as China, which alone is anticipated to generate US$198.90bn in 2024.

In examining macroeconomic trends, the semiconductor industry's strategic importance is magnified by its role in the global supply chain and its influence on geopolitical dynamics. As a cornerstone of modern manufacturing and technology, semiconductors have become a focus for national policies and international trade agreements. The industry's cyclical nature, marked by periods of rapid growth followed by cooling demand, mirrors broader economic pulses, yet the overall trajectory remains decidedly upward.

Looking to the future, the semiconductor industry is poised for sustained expansion. Innovations in artificial intelligence, the Internet of Things (IoT), and the rollout of 5G networks are set to fuel demand for increasingly sophisticated semiconductors. Key players like Samsung, Intel, and Qualcomm are at the forefront of this evolution, steering the industry toward new horizons of capability and connectivity.

Despite its complexities and the challenges posed by an evolving technological landscape, the semiconductor market continues to thrive. It is an industry defined by its relentless push for progress, constantly redefining the limits of what is possible in the digital world. As it enters the next phase of growth, the semiconductor industry stands ready to cement its role as the foundational element of all things electronic, charting a course for technological innovation well into the future.

Market Trends

Market Drivers

Given the pervasive use of semiconductors across various sectors, governments worldwide are taking proactive measures to ensure chip sovereignty. Recognizing the semiconductor industry's significance for national security and economic competitiveness, these initiatives aim to bolster domestic semiconductor production capabilities.

- USA: On August 9 2022, President Joe Biden signed into law the "CHIPS and Science Act of 2022". The act directs $52.7 billions over five years to support domestic semiconductor manufacturing, including 13.2 billion to support R&D and workforce development and $39 billions of financial incentives for building, expanding, and equipping domestic fabrication facilities. Additionally, $6 of the $39 billion will provide guarantees to support a $75 billion direct loan and loan guarantee program. Moreover, Under the CHIPS Act, taxpaying entities are eligible to receive a 25 percent advanced manufacturing investment tax credit for investments in semiconductor manufacturing and processing equipment, an outlay the Congressional Budget Office estimates will cost $24 billion over five years.

- EU: On 25 July 2023, the EU council gave final approval to the EU Chips Act. The program should mobilize 43 billion in public and private investment (€3.3 billion from the EU budget), with the objective of doubling the EU's global market share in semiconductors, from 10% to at least 20% by 2030. The EU anticipates a further €15bn in public and private investment for semiconductor-related R&D on top of the CHIPS Act amount, coming from existing programs (e.g., Horizon Europe, Digital Europe) and separate support announced on a country level by member states. Major chip manufacturers, both European and international, have already committed to R&D and fabrication expansion plans in Europe, with a view to accessing these and similar funds.

- Asia-Pacific: Japan has pursued its own drive to establish semiconductor production facilities, with 2022's Economic Security Promotion Act outlining a framework for combined public and private financing of ¥10 trillion ($66 billion) over 10 years. According to a report released by the U.S. Department of Commerce, China had provided the Chinese semiconductor industry with an estimated $150 billion in subsidies in the last decade as it seeks semiconductor self-sufficiency. As a result, China's semiconductor industry is making gradual progress, despite US export controls.
  On 15 January 2024, The South Korean government announced a detailed plan involving 622 trillion won ($471 billion) in investment from the private sector between 2024 and 2047 to be directed towards the creation of the world's largest chip manufacturing cluster.

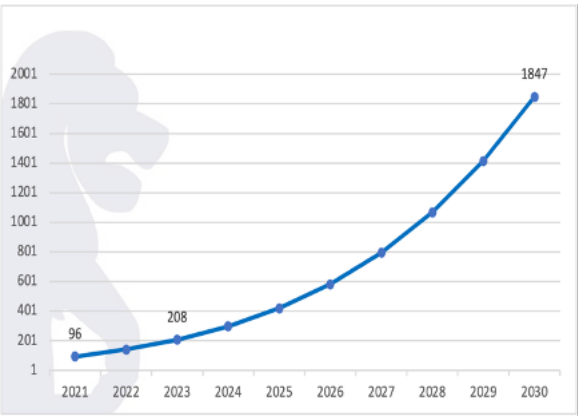
The semiconductor sector is also experiencing a swift expansion as semiconductors are becoming the fundamental components of contemporary technology.

- Artificial Intelligence: The rising demand for AI-based applications across different industries will create new growth opportunities for semiconductor manufacturers and suppliers. AI will also bring improvements in semiconductor manufacturing, by speeding up the process, increasing chip performance, reducing production costs, and increasing output.

- Increased connectivity and consumer electronics: The increasing adoption of Internet of Things (IoT) devices and the demand for connected, feature-rich consumer electronic devices such as smartphones, tablets, laptops, smart TVs, and wearable technology are driving the need for advanced semiconductor components. This trend is fueling growth in the semiconductor sector as chips enable connectivity, data analysis, real-time communication between devices, and power the fundamental components of contemporary technology.

Furthermore, advancements in technology are driving enhanced efficiency in semiconductor manufacturing, thereby catalyzing industry expansion. Anticipated to enter production from late 2024 to early 2025, 2nm chips are expected to provide a 25% increase in power efficiency and 12% performance improvement compared to the latest technology (3nm chips).

Figure 1. Artificial intelligence (AI) market size worldwide in 2021 with a forecast until 2030, $Billions



Source: Statista

Market Restraints

The semiconductors industry demands substantial capital investments, particularly for research and development (R&D) and infrastructure. Establishing a semiconductor fabrication facility can entail costs exceeding USD 10 billion, with an average construction period of three years. Moreover, the industry bears significant fixed expenses attributed to skilled labor wages and machinery costs, rendering it vulnerable to imbalances between supply and demand.

Specialized talent in areas such as engineering, design, and manufacturing is crucial within the semiconductor industry. However, the current rate of workforce expansion is inadequate to match the industry's growth trajectory. According to estimates by the Semiconductor Industry Association, the U.S. alone is projected to experience a shortfall of 67,000 workers by 2030, encompassing roles such as technicians, computer scientists, and engineers.

Opportunities

The expanding range of applications, coupled with increased efficiency and shrinking size of chips is expected to create new opportunities for the semiconductor industry.

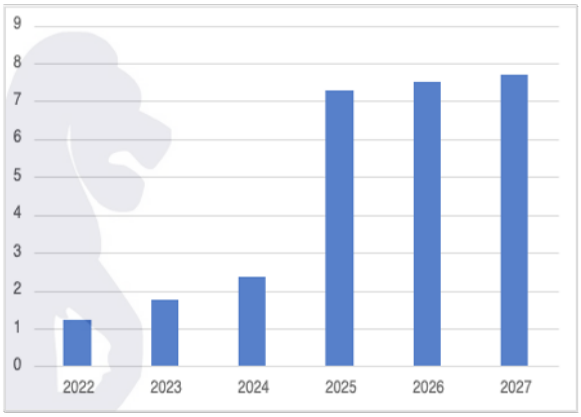
- Automotive manufacturing: the rise of electric vehicles (EVs) is opening up significant prospects for the electronics and semiconductor industries, with these components playing crucial roles in EV technology. Furthermore, the integration of advanced driver assistance systems, including features like blind spot detection, autonomous driving capabilities, and internet-driven functionalities, is creating fresh avenues for chip companies to explore and capitalize upon.

- AI chips: the rapid development and adoption of artificial intelligence (AI) technologies are driving demand for AI application-specific integrated circuits (ASICs). These chips are optimized for AI workloads, including machine learning, neural networks, and natural language processing, and are crucial for enabling AI-powered applications across various industries.

- 5G: the move to 5G is expected to cause increased demand for new devices. Both rising volumes, and the increased complexity of a 5G device, mean that there is extra demand from electronics manufacturers for semiconductors. Industry participants note that a 5G smartphone has 20-50% more semiconductor content compared to a 4G smartphone.

- Cloud/data centers: The increasing demand for cloud computing and data storage services presents opportunities for semiconductor companies to supply high-performance chips for data centers. As data center operators expand their infrastructure to meet growing demand, there is a need for advanced processors, memory chips, and networking components.

Figure 2. Number of 5G subscriptions, Global, Millions



Source: Ericsson

Challenges

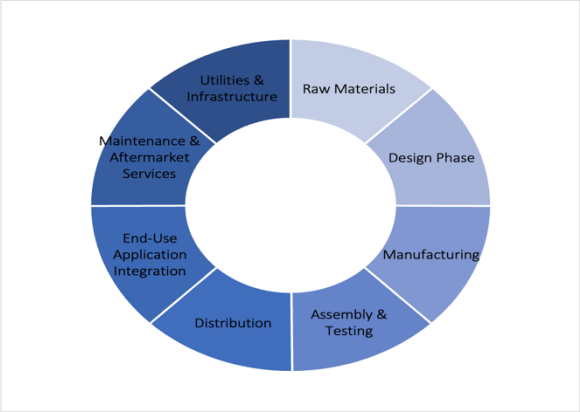
The industry is continuously striving for miniaturization, seen as the primary catalyst for its advancements and expansion. Moore's Law, which suggests that the number of transistors (a miniature semiconductor that regulates current flow) on a chip double roughly every two years, underscores the need for continual innovation while maintaining quality control, improving yield, and speeding up time-to-market. Achieving this delicate balance requires pushing the physical limits of transistor size reduction while also ensuring cost-effectiveness and reliability in production processes.

Regulation of materials also represents a crucial challenge for chip makers, which are very reliant upon many applications of materials and chemical substances falling under the definition of per- and poly-fluor alkylated substances (PFAS). PFAS are known as 'forever chemicals' as they are extremely persistent in our environment and bodies. New regulations affecting PFAS are being discussed in the US and Europe and could come into effect as early as 2025. Forbidding their use could render manufacturing of such products impossible, and hence the transition to safe alternative materials is now a pressing issue for the industry.

Supply Chain Analysis

The semiconductor supply chain, a marvel of modern logistics and engineering, is evolving rapidly as the demand for advanced electronics continues to surge. This trend is steadfast, indicating a future rich with opportunity for entities spanning from raw material suppliers to end-user manufacturers. Navigating this demand requires companies to constantly refine their supply chain processes, ensuring timely and cost-effective delivery of semiconductor components essential for everything from consumer electronics to critical national infrastructure.

Figure 3. Supply Chain Stages



Source: Minerva Investment Management Society

Sourcing requirements for semiconductors necessitate a sophisticated network of suppliers capable of providing high-purity silicon for wafers, as well as an array of metals and chemicals essential for the fabrication process. These suppliers must possess not only the raw materials but also the specialized knowledge and processes to support the highly technical manufacturing of semiconductor devices.

The semiconductor supply chain encompasses several critical stages:

- Raw Material Sourcing: Key materials such as silicon, metals like copper and aluminum, and various specialty gases are sourced globally. Companies such as Shin-Etsu, Sumco, and GlobalWafers are instrumental in supplying high-quality silicon wafers, while specialty gases and chemicals are provided by firms like Linde and Air Products. In the raw material stage can also be counted the photolitography process, a procedure in which ASML is the global leader.

- Design Phase: Engineers must devise and assemble a collection of interconnected circuit elements to perform a specific function. Engineers receive a request containing requirements for what function or task the chip must complete. They then create the logic/circuit design which contains memories, processing units, sensors, and other technical building blocks necessary for the circuit to function. Engineers will then complete the physical design and layout on the chip and test the prototype to ensure it can carry out the required functions. Once verified, the chip design can be sent out to manufacturers for mass production. Four out of the top five global

electronic design automation (EDA) and semiconductor intellectual property (IP) companies are headquartered in the U.S. Leading U.S. semiconductor design firms include Qualcomm, Intel, Broadcom, and AMD.

- Manufacturing: This stage involves intricate processes to create semiconductor devices on silicon wafers. Major semiconductor fabrication companies, also known as foundries, like TSMC, lead this highly specialized segment.

- Assembly and Testing: After fabrication, semiconductors are assembled and tested by companies that specialize in packaging and quality assurance. ASE Technology Holding and Amkor are two of the leading service providers in this domain.

- Distribution: Completed semiconductor products are distributed through a global network of logistics providers and distributors, ensuring delivery to manufacturers of all sizes, across all industries.

- End-Use Application Integration: Finally, semiconductors are integrated into a vast array of end-user applications by manufacturers in sectors ranging from automotive to consumer electronics and industrial machinery.

- Maintenance and Aftermarket Services: Post-integration, semiconductor devices may require updates, maintenance, or replacements, which are serviced by a combination of original manufacturers and specialized repair firms.

- The semiconductor manufacturing process is energy-intensive, relying on utilities for consistent and reliable power supply, making them a key component of the supply chain ecosystem.

The current semiconductor supply chain is characterized by a level of complexity and specificity unmatched in other industries. With lead times that can extend up to several months due to the intricate manufacturing and testing processes, the industry faces unique challenges, especially in the context of recent global chip shortages. Unlike the more mature automotive supply chain, which benefits from regional supplier networks and just-in-time delivery, the semiconductor supply chain demands careful coordination across continents and a keen eye on geopolitical and market forces. It is an industry where precision, foresight, and adaptability are not just virtues but necessities for success.

Competitive Landscape

Global Semiconductors Market Overview

On a regional basis, Europe was the only regional market that experienced annual growth in 2023, with sales there increasing 4.0%. Annual sales into all other regional markets decreased in 2023:

Japan (-3.1%), the Americas (-5.2%), Asia-Pacific/All Other (-10.1%), and China (-14.0%).

The global outlook on the semiconductor industry underlines that the prominence of the industry will accelerate in the coming years, and developing countries need to have long-term, strategic objectives to be resilient to shocks and facilitate access to chips for their domestic industries. For instance, some developing countries such as Indonesia and Turkey have been negatively affected by the global chip shortage and the automotive production facilities in these countries had to cut their production capacity due to lack of access to chips.

Asia Pacific is the largest regional semiconductor market, and China is the largest single-country market, which accounted for 55 percent of the Asia Pacific market and 31 percent of the total global market.

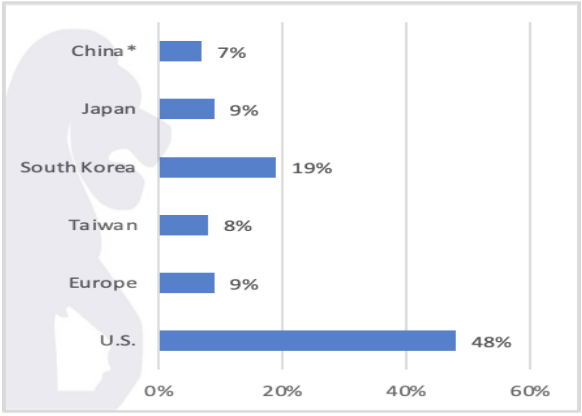
Geographical differences up now have depended on several factors:

R&D Investment: U.S. semiconductor industry's R&D spending as a percent of sales is unsurpassed by any other country's semiconductor industry, whose percentage is close to 19% and represents more than double the percentages of other nations such as South Korea, Japan and China.

- **Regulatory Environment**: Each country has its own regulatory environment that can impact the semiconductor industry, including export controls, intellectual property protection, and government subsidies, plus trade tensions between countries, such as those between the U.S. and China, can also have significant implications for the semiconductor industry.

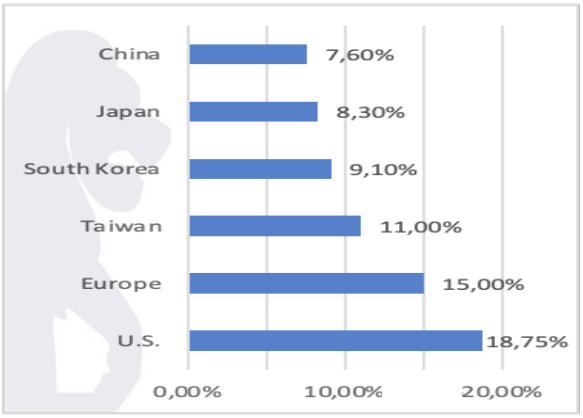
- **Manufacturing Centers**: Taiwan, South Korea, China, and the United States are key manufacturing centers for semiconductors. Each of these countries has significant semiconductor fabrication facilities (fabs) and assembly and testing facilities. Taiwan, particularly, is home to TSMC (Taiwan Semiconductor Manufacturing Company), one of the world's largest semiconductor foundries.
  South Korea hosts Samsung and SK Hynix, major players in memory chips, while China has been rapidly expanding its semiconductor manufacturing capabilities, with companies like SMIC (Semiconductor Manufacturing International Corporation) making significant strides.
  Emerging economies, including India, Indonesia, and Malaysia, are positioning themselves to seize the opportunities presented by evolving global landscapes.

Figure 4. Semiconductor market revenue share based on company headquarters worldwide in 2022, by region
(* 2022 data for China is incomplete, with the market share percentage based on 2021)



Source: Statista

Figure 5. R&D Expenditures as a Percent of Sales



Source: SIA

Competitive Landscape: Semiconductors

The semiconductor industry plays a crucial role in supplying leading-edge chips for everything from smartphones to data centers. As demand for semiconductors continues to grow, there is increasing attention on the competitive dynamics between the major players, which can be listed as below:

- USA: Nvidia, Cadence, Intel, Broadcom, AMD
- Europe: ASML, NXP Semiconductors, Infineon
- Asia-Pacific Region: Samsung, TSMC, SK Hynix
- Japan: Kyocera, Toshiba, Fujitsu

The Herfindahl Hirschman Index (HHI) for this market is estimated at 4.7. This indicates being right in between a highly competitive and a moderately concentrated one. Despite the high concentration ratio, some differentiation exists between the players, mainly because of regional and industry segmentation. Technological trends such as artificial intelligence, 5G connectivity, Internet of Things (IoT), autonomous vehicles, and edge computing are driving demand for specialized semiconductor solutions. Companies that can innovate and deliver products tailored to these applications stand to gain a competitive edge in this rapidly evolving landscape.
In the coming years, the strongest-growing segment is likely to be automotive, where we could see a tripling of demand, fueled by applications such as autonomous driving and e-mobility, while in the wireless segment smartphones could account for the majority of expansion, amid a shift from lower-tier to mid-tier segments in emerging markets and backed by growth in 5G.

China is making significant strides toward developing a robust local ecosystem and is expected to construct a staggering 18 new fabs in 2024. This ambitious expansion plan reflects the Chinese government's unwavering commitment to fostering domestic chip development in response to the ongoing U.S. sanctions.

Europe continues to hold a significant position. ASML, the world leader in lithography systems, is poised to deliver high-numerical–aperture EUV machines to foundry leaders for the development of sub-2-nm technologies. These groundbreaking machines, expected to cost about US$500 million to US$600 million each, will play a crucial role in enabling the fabrication of even smaller and more powerful chips. Despite U.S. sanctions limiting the supply of EUV tools to China, ASML will remain the market leader in advanced lithography machines.

Following is a brief overview of the select players mentioned above:

- Nvidia: It is a designer and developer of graphics processing units, central processing units, and system-on-a-chip units. The company offers its products to gaming, professional visualization, data center, and automotive markets. It also offers solutions for Artificial Intelligence and data science, data center and cloud computing, design and visualization, edge computing, high-performance computing, and self-driving vehicles. It is one of the most significant semiconductor companies in the world. The company has gained massive popularity with the rise of generative AI applications like ChatGPT. The A100 and H100 by NVIDIA are vital for developing and training AI applications.

- Cadence: Known for its computational software that is used to design semiconductors and other highly complex technologies. The growing complexity of semiconductors needed for AI, hyperscale computing, and beyond have transformed Cadence into an invaluable partner for many firms and a key cog in the broader tech and chip ecosystem.

- ASML: develops, produces, markets, sells, and services advanced semiconductor equipment systems for chipmakers. It offers advanced semiconductor equipment systems, including lithography, metrology, and inspection systems. The company also provides extreme ultraviolet lithography systems; and deep ultraviolet lithography systems comprising immersion and dry lithography solutions to manufacture various ranges of semiconductor nodes and technologies. In addition, it offers metrology and inspection systems. Further, the company provides computational lithography solutions, and lithography systems and control software solutions; and refurbishes and upgrades lithography systems, as well as offers customer support and related services.

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