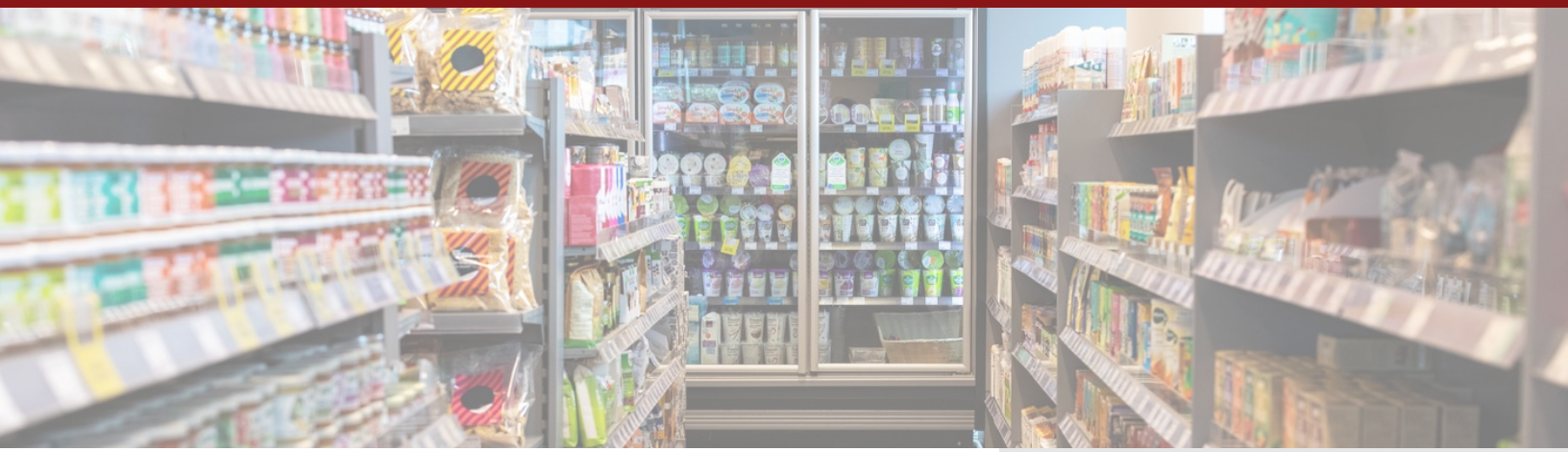

Semiconductor Industry Primer

Driving Force of Electronics

This industry primer discusses a leading driver of the Information Technology Industry, the Semiconductor sub-industry.

The Semiconductor sub-industry is known to be the driving force of all electronics. Virtually all forms of electronics involve semiconductor applications—everything from computers, communication devices, Industrial automation, to modern cars. With the increase of R&D investment, the semiconductor industry has seen tremendous development. Today, semiconductors are a staple in modern electronics and are embedded in everything we use.

This primer covers the general sector highlighting its history, key-value chains, terminology, and unit economics. Moreover, it dives deeper into key trends of the industry including macro and microeconomic developments that impact the sectors' future. Lastly, it highlights some key actors within the industry, investment opportunities, and recent news stories.

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Sector Overview

Demand exceeding supply is a significant consequence of the pandemic in 2021, resulting in the global semiconductor shortage and adversely affecting a large variety of end-users. Virtually all forms of electronics involve semiconductor applications—everything from computers (32.3%), communication devices (31.2%), Industrial automation (12%), to modern cars (11.4%). The global semiconductor industry is expected to grow at a moderate rate of 8.8% in 2022, with industry sales reaching $601.5 billion. Growth will be driven by increased digitization due to COVID-19 and the record levels of investment in manufacturing and R&D.

Semiconductors are made out of Silicon, Gallium Arsenide, Silicon Carbide, or Silicon-Germanium. A semiconductor has four electrons in its outer ring and conducts electricity under specific circumstances. The term has come to refer to all devices made of semiconducting material, including integrated circuits (chips), transistors, and diodes. Integrated circuits are the most widely used semiconductors today. Semiconductors are often categorized into three buckets: logic chips (41% of industry revenue) that are used to control the operation, memory chips (26% of industry revenue) that store information, and discrete, analog, and other chips (DAO) (32% of industry revenue) that transmit, receive, and transform information.

History:

The origins of semiconductors date back to 1821 when the German physicist Thomas Johann Seebeck first discovered the thermoelectric effect of semiconducting metals. A century later in 1947, Bardeen and Brattain at Bell Laboratories in the US made a major push for the industry through discovering the point-contact transistor. The industry took off following this invention. In 1957, the industry was well over 100 million dollars. Semiconductor technologies continue to advance. In 1964, David Talbert and Robert Widlar at Fairchild invented the first widely used analog integrated circuit. In 1978, John Birkner developed the first programmable array logic (PAL) device, which implemented logic functions in digital circuits.

During the 1980-90s, the U.S. semiconductor industry lost a significant share of the global market to Japan. In the early 1980s, U.S. firms supplied 75 percent of the $2 billion global semiconductor market, and the 10 largest equipment producers were all located in the United States.

In 1990, Japanese firms supplied 73 percent of the $9.2 billion semiconductor market, increasing from 21 percent in 1980. U.S. firms supplied only 13 percent of the market, and no U.S. firm was among the 10 largest suppliers. Due to intense competition from Japanese firms as well as the effect of illegal dumping, Japan briefly overtook the U.S. industry. However, over the next decade, the U.S. semiconductor industry began to rebound, and by 1997 it had regained its dominant position with a market share of around 50%, a position the U.S. still holds today.

With the increase of R&D investment, the semiconductor industry has seen tremendous development. In 2000, the large-scale integrated circuit system was formally put into production. As the development of integrated circuits gear towards high performance and multifunction, its application fields are also expanding. Today, semiconductors are a staple in modern electronics and are embedded in everything we use.

Types of semiconductors

There are two main types of semiconductors that exist: Logic chips and memory chips. Logic chips process information to complete a certain task. In other words, they serve as the brains of electronic devices. The main examples of logic chips are Central Processing Units (CPUs), Graphical Processing Units (GPUs), and Neural Processing Units (NPUs). Next, memory chips store information. The main type of memory chip is Dynamic Random Access Memory (DRAM), a chip that only saves data when the electronic device is on.

Chip production

Chip production is very complex and detailed; however, we can break it into three main steps: Wafer manufacturing, actual chip manufacturing (front-end process), and assembly & packaging (back-end process). Wafer manufacturing consists of growing pure silicon into a block of mono-crystalline cylindrical ingots up to 300mm and slicing them into approximately 400 wafers (0.75mm thick each). Actual chip manufacturing, or the front-end process, consists of producing transistors directly onto blank wafers, thereby creating multiple chips. Finally, the back-end processing consists of interconnecting the various semiconductor devices and testing the device. Currently, this entire process takes approximately 3 months from start to finish.

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Sector Overview

Key terms

Integrated device manufacturers: Companies who design and manufacture their chips

Fabless: Companies who design their chips and outsource manufacturing to foundries (the name comes from the lack of a fab)

Foundries: Companies that manufacture pre-designed chips

Fab: State-of-the-art chip factory (costs anywhere from $18-$27B to build)

Wafer: Single round silicon disk where multiple dies are made

Die: A chip on a wafer

Transistors: Gates regulating the flow of electrons through the microchip

Integrated circuit: A singular semiconductor chip that is designed and integrated with many other discrete semiconductor components such as resistors, capacitors, inductors, and diodes)

Nanometers: The measurement unit used in chip production. The current state of the art chips measure 5nm

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Key Trends

The Rise of Artificial Intelligence/Machine Learning in Manufacturing

Manufacturing is the semiconductor industry's largest cost driver, artificial intelligence and machine learning can deliver the most value in the manufacturing process by reducing costs, improving throughput rates, and increasing yields, in total experts estimate manufacturing costs can be decreased by a maximum of 17%. Additionally, artificial intelligence and machine learning will help semiconductors companies to achieve greater accuracy through metrology readings, tool-sensor data which allows for machine-learning models to capture nonlinear relationships between process time and outcomes. With these machine-learning models, optimal process times can be optimized and implemented on a per-wafer or per-batch basis.

The Proliferation of the Internet of Things (IoT)

The Internet of Things is the next wave of computing devices embedded in everyday objects, enabling them to send and receive data, which includes devices such as wearable devices, smart home devices, and factory equipment. This industry is a major end-market for the semiconductor industry and the global industry is expected to grow at a CAGR of 30.9% to $58.4 billion in 2025.

The Growth of Sustainability Among Chipmakers

A growing concern in the semiconductor industry is the massive growth in demand, which in turn is expected to cause a massive surge in energy consumption and water usage. To counteract this issue, industry leaders are taking proactive steps to develop sustainability programs. These programs include water recycling initiatives, the expansion of diverse water sources, pollution prevention techniques, and shifting cloud workloads to geographics regions with more access to renewable energy.

Secular Tailwinds in PC Gaming and Portable Computers is Expected to Continue

PC/Computer end markets accounted for 11.0% of industry revenue in 2021. This is mainly due to the growth of portable computers over the five years to 2021, the portable computer segment has consumed market share away from the servers and desktop computers segment.

Prior to the period, chips used in laptops were significantly slower than those in desktops due to their more demanding temperature and power control requirements. As desktop processors approached performance ceilings, mobile processors were able to narrow the performance and price gap that kept consumers from buying laptops over desktops. Demand from this market segment increased substantially due to the coronavirus pandemic, as consumers responded to increased spare time while social distancing by increasing their usage of personal electronic devices. Additionally, the largest surgence of PC gaming is expected to register a CAGR of 9.6% from 2022-2027, reaching a value of $314 billion in 2027.

Autonomous Vehicles and Electric Vehicles: The New Era of Transportation

In recent years there has been a major shift from traditional gasoline vehicles to electric vehicles. This has bolstered strong demand for chipmakers as the average electric vehicle requires 2.3x the number of semiconductors required for internal combustion vehicles. This trend is expected to exacerbate the demand for chips in the automobile industry as large automakers began to design and produce electric vehicles.

International competition and lower production costs abroad will continue to exert pressure on domestic manufacturers

Some industry operators will continue to shift manufacturing away from the U.S. to countries where production and labor costs are lower. Moreover, downstream electronics manufacturing is vibrant abroad, and operators have an incentive to be closer to their customer markets. Offshoring trends are countered by new opportunities in higher value-added industry products and the advancement of wide bandgap semiconductors.

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Key Trends

Trends

Innovation in Capabilities Sparking New Growth Opportunities

Original equipment manufacturers (OEMs) of electronic systems and devices increasingly outsource the integration of the semiconductor and software components of their products to suppliers. OEMs have also adopted complete system-level solutions that integrate the functionality of multiple integrated circuits required to operate on a system-on-a-chip, commonly known as a microchip. These shifts benefit semiconductor companies that possess strong system-level expertise, software capabilities, validation and testing capabilities, fully functional reference designs, and knowledge of specific end markets to successfully provide system-wide solutions. Industry operators with these capabilities are prepared to experience strong growth in the future.

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Case Studies

Key Actors

As a whole, semiconductor companies play a significant role in the innovation and development of new technologies and are seen by investors as key investments. Stocks in the sector tend to have highly cyclical characteristics.

As of 2020, the top three largest semiconductor companies that are publicly traded in the U.S. or Canada based on their 12-month trailing (TTM) revenues include Intel Corp. (INTC), Taiwan Semiconductor Manufacturing Co. Ltd. (TSM), and Qualcomm Inc. (QCOM).

Intel Corp is an integrated device manufacturer that specializes in designing and manufacturing motherboard chipsets, network interface controllers, and integrated services. Known for its long-standing partnership with Apple Inc, the company has TTM revenues of $75.7 billion. Taiwan Semiconductor Manufacturing Co. Ltd. is a dedicated independent pure-play semiconductor foundry that only fabricates integrated circuits. With TTM revenues of $37.9 billion, many semiconductor companies outsource the manufacturing of their components to Taiwan Semiconductor. Lastly, Qualcomm is currently one of the world's leading wireless technology innovators and the driving force behind the development, launch, and expansion of 5G. Known for its Snapdragon chipsets found in many mobile devices, the company has TTM revenues of $24.7 billion.

Investment Opportunities

When identifying the best semiconductor companies that are long-term undervalued and are a good buy, there are four common critical factors involved:

1. Sustainable Revenue Growth

Most companies in this sector often struggle to cope with the industry's cyclical nature as if a semiconductor company isn't constantly innovating and finding new outlets, weathering the cycle can be unstable. Therefore, it is highly attractive if a company can constantly innovate and achieve long-term sustainability.

2. Above-average profit margins

With high-profit margins, the company will have a greater ability to reinvest in research and improve operations, essential in this sector. Moreover, it is also a positive indicator that the company is operating efficiently.

3. Attractive returns on invested capital

An attractive ROIC indicates the company is likely strategically innovative and improving operations to increase efficiency.

4. Strong Balance sheet

Since semiconductor manufacturing tends to be expensive, it is important to understand how these companies are able to obtain the necessary financial resources to expand. A strong balance sheet that shows plenty of cash relative to debt means the company is well-positioned to pay interest and principal payments.

Moreover, the two key trends that drive semiconductor stocks include connectivity and mobility (5G mobile networks, self-driving cars) and computing accelerators (GPUs, cryptocurrency miners).

In addition to stocks, individuals can gain exposure to the growth of the sector by investing in semiconductor **exchange-traded funds (ETFs)**. The top two semiconductor ETFs are:

- ***iShares Semiconductor ETF (NASDAQ:SOXX):*** iShares is an ETF composed of 30 chip companies. It has an annual expense ratio of 0.43% and manages over $7.6 billion in *assets.*
- ***VanEck Vectors Semiconductor ETF (NASDAQ:SMH):*** VanEck is a fund that owns 25 stocks of semiconductor chip companies from around the globe. It has an annual expense ratio of 0.35% and manages $6.5 billion in assets.

Although semiconductor stocks can be unpredictable due to the large number of steps involved in manufacturing and dozens of players in the sector, over the long term, as the demand for these chips continues to rise, investing in these stocks and building blocks of technology will likely continue to be profitable.

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Case Studies

Recent News Story

Global Semiconductor Chip Shortage Wreaking Havoc

The global chip shortage has been a consequential issue throughout the past couple of years and is predicted to continue for most of 2022. The sales of devices that use semiconductor chips have soared throughout the pandemics, resulting in semiconductor companies struggling to keep up with demand.

The pandemic is partly to blame, leading to disrupted supply chains alongside increased demand for computers and gadgets due to an increased number of people working from home. Researchers found that the demand for semiconductors was up to 17% higher in 2020 than it was in 2019.

Additionally, existing foundries are already running at capacity, and building more is a long and rigorous process. Analyst Richard Windsor says “It takes about 18 to 24 months for a plant to open after they break ground”. Semiconductor leader Intel has warned that it could take up to two years to catch up to existing demand.

Overall, the global chip shortage has impacted multiple industries, including IT and automotive. Every major chipmaker has experienced shortages, that have constrained the growth of their customers in addition to themselves. Auto manufacturers, in the meantime, have had to temporarily halt production.