Industry Surveys

Semiconductors & Semiconductor Equipment

OCTOBER 2022

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CHARTS & FIGURES

NEW THEMES

What's Changed: CFRA observes a slight pause in growth for the wafer fabrication equipment segment – a market that we previously estimated to reach $100 billion in revenue in 2022. This can be attributed to an overall cyclical downturn for the semi industry. More on Key Industry Drivers starting pages 8.

What's Changed: The future is AI…for chip startups, that is. Demand for huge computing power has created opportunities for smaller chip companies that focus on making specialized chips for AI – head to page 26 for details.

EXECUTIVE SUMMARY

We have a neutral fundamental outlook for the semiconductors & semiconductor equipment sub-industry over the next 12 months. After coping with significant capacity constraints over the last two years, we believe that a combination of capacity expansion and slowing demand across a host of consumer-driven end-markets have better aligned the supply/demand landscape. We do think some constraints remain for a number of trailing edge chips (*e.g.,* microcontrollers, power management), specifically within the automotive and industrial markets, but the bigger issue is now excess inventory that could provide downward pressure on prices (lead to write-downs) and prolong the downturn longer than we anticipate.

Semiconductor Industry to Witness a Cyclical Trough in the First Half of 2023

History says 2023 may see industry revenue decline after projected growth of 9% in 2022 and 26% in 2021. We believe the industry is in the midst of a consumer-led downturn that will likely trickle into areas like data centers, automotive, and industrials in the coming quarters before bottoming in the first or second quarter of 2023. We expect revenue to decline at least 3% in 2023, which would mark the first industry revenue decline since 2019. We note that the industry hasn't seen four consecutive years of growth in two decades, and we don't see 2023 bucking the trend given macro challenges and lower expected consumer spending ahead. That said, the lower outlook will ratchet down capital spending plans and help normalize inventories before we see a recovery in the second half of 2023.

New China Restrictions Pose Additional Headwinds for the Semiconductor Industry

New geopolitical headwinds are clearly providing additional headwinds for the semiconductor industry at a time when the space is coping with a consumer-led cyclical downturn. One of our biggest risks is coming to fruition as the U.S. looks to expand restrictions on advanced chip sales to China to limit the expansion of their local semiconductor manufacturing industry. Importantly, new regulations also cite Chinese chipmakers with advanced manufacturing equipment must get a license from the U.S. Department of Commerce. The greatest risks to our 2023 views (aside from additional regulatory measures) are for leading-edge chipmakers (*e.g.,* NVIDIA, AMD, Marvell, Broadcom) and large equipment vendors (*e.g.,* Applied Materials, KLA, Lam Research) that generate nearly 30% of sales from China. We see the news as a potential positive for Micron Technology/Western Digital, given the impact on China-based YMTC/CXMT.

Mixed Picture for Semiconductor Equipment Industry Given Geopolitical and Macro Uncertainties

We believe foundry customers are sustaining increasingly elevated levels of investment, while memory customers face larger headwinds (softening demand and lower ASPs) and are more likely to cut capex meaningfully. We see chip equipment sales growing by 12% in 2022 after rising approximately 25% in 2021, with a murkier outlook for 2023. Political drivers have also emerged as potential catalysts. With China controlling an increasing amount of supply chain, the U.S. and Europe are both looking to boost their own chip manufacturing presence, which we believe will be done via smaller and less efficient fabs, boosting Wafer Fabrication Equipment (WFE) capital intensity and benefiting equipment suppliers. However, we do note that the U.S. is also restricting an increasing number of equipment into China in an effort to stifle the growth of the region's local semiconductor manufacturing industry, which will likely act as a headwind on near-term expectations.

Asset Prices Compelling as Semiconductor Valuations Trade Near Decade Lows

We believe valuations of semiconductor companies are near their lowest levels in a decade, trading at an average P/E of 12.6x our 2023 views and have fallen more than 45% from 52-week highs. We attribute the compression to inflationary pressures that have helped compress tech valuations while also creating greater macro uncertainties from uncertain consumer spending in 2023. Still, chip stocks trade more than 60% above pandemic lows and sentiment appears to be extremely depressed.

CFRA Industry Snapshot

www.cfraresearch.com

Semiconductors & Semiconductor Equipment

Outlook: Neutral

MARKET CAP BREAKDOWN*

RANK NO.	COMPANY NAME	MARKET CAP ($ Billion)
1	NVIDIA	299.9
2	Broadcom	176.3
3	Texas Instruments	139.5
4	Qualcomm	126.7
5	Intel	106.8
6	AMD	92.4
7	Applied Materials	72.7
8	Analog Devices	66.5
9	Micron Tech	57.7
10	Lam Research	45.0
	Others	320.0

**Data as of October 20, 2022.*
Source: CFRA, S&P Global Market Intelligence.
†Refer to the Comparative Company Analysis section of this survey for other companies in the industry.

ETF FOCUS

ETF	AUM ($M)	Expense Ratio
VGT Vanguard Information Technology	39,143.1	0.10
XLK Technology Select Sector SPDR	36,983.2	0.10
SOXX iShares PHLX Semiconductor	5,854.9	0.40
XSD SPDR S&P Semiconductor	1,018.5	0.35

BY THE NUMBERS

$600 Billion
Projected semiconductor sales in 2023

$110 Billion
Projected 2023 wafer fab equipment spending

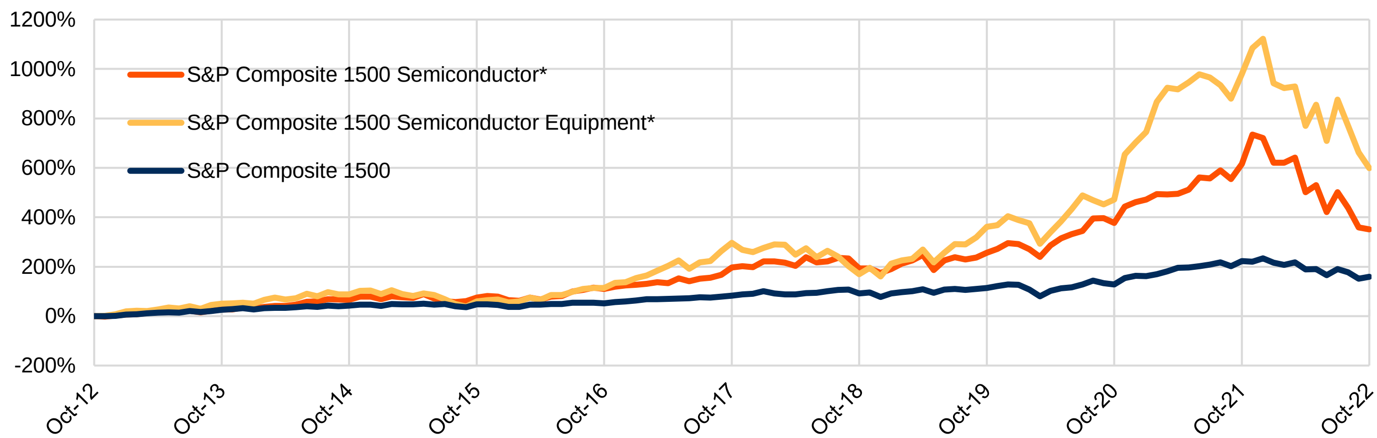
100%
Semiconductor content in data center servers to double in five years

2x
Auto chip growth to double the pace of industry growth through 203

4 Years
Estimated technology lead in semis that U.S. has over China

6%~7%
10-year semiconductor growth CAGR (est. $1 trillion in size by 2030)

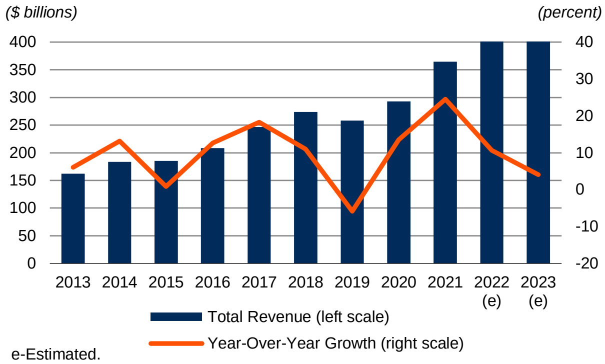
HISTORICAL INDEX PERFORMANCE



*Index launched in February 2011. Data through October 20, 2022.
Source: CFRA, S&P Global Market Intelligence.

FINANCIAL METRICS

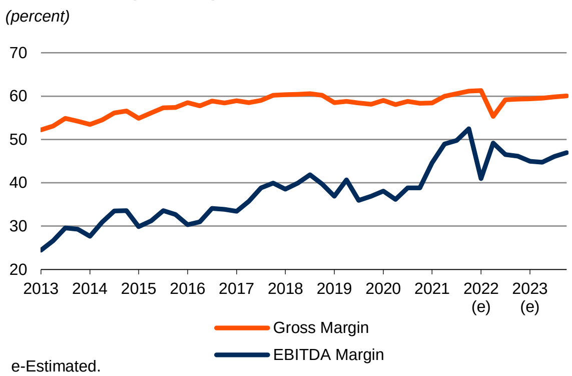
Revenue Growth



e-Estimated.
Source: CFRA, S&P Global Market Intelligence.

- CFRA expects revenue to grow year-over-year by 10.7% in 2022 and 4.1% in 2023, compared to a 24.5% growth in 2021. Demand and supply constraints are likely to peak in the second half of 2022 as the industry is in the midst of a cyclical correction that will likely last until the first quarter of 2023.
- The current downturn is mainly driven by consumer weakness (*e.g.,* PCs and smartphones) but will trickle across data centers, auto, and industrial.

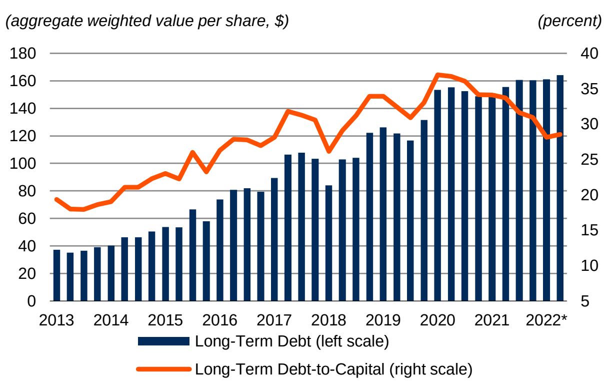
Operating Margins



e-Estimated.
Source: CFRA, S&P Global Market Intelligence.

- CFRA expects margins to remain elevated in the low-60% range in 2023. However, the near-term outlook is unfavorable as we believe the industry would enter a down cycle caused by a contraction in consumer demand (*e.g.,* smartphones, laptops). However, this is expected to stabilize and improve in the longer term.
- We expect organic growth to continue to be a key theme in the longer term. CFRA expects tight cost controls and synergies from acquisitions to aid stable to slightly wider margins in the coming years.

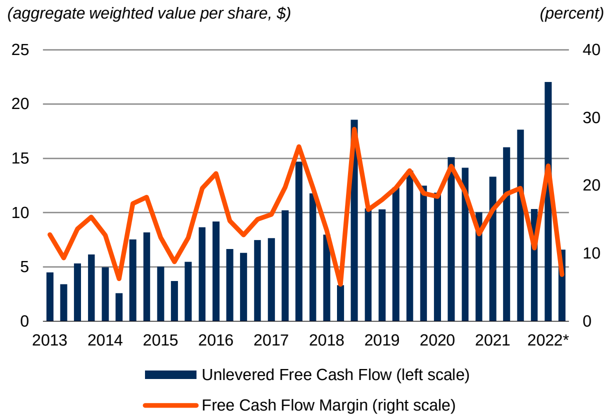
Debt Profile



*Data through Q2 2022
Source: CFRA, S&P Global Market Intelligence.

- Long-term debt-to-capital has dropped from late 2020 till early 2022 due to two large M&A deals, where AMD acquired Xilinx and ADI acquired Maxim. Both were large equity deals; given they were all equity, it naturally reduces the emphasis on debt from a total capital perspective. In addition, Intel's elevated investments toward expanding its foundry business are also increasing debt levels. At the same time, CFRA expects companies in this industry to reduce debt due to the rising interest rate environment. Yet, the bigger chipmakers will continue to fund investments in next generation technology nodes.
- Despite the higher debt levels, balance sheets across the industry will likely remain healthy and be more than capable of navigating the current challenging period, in our view.

Free Cash Flow

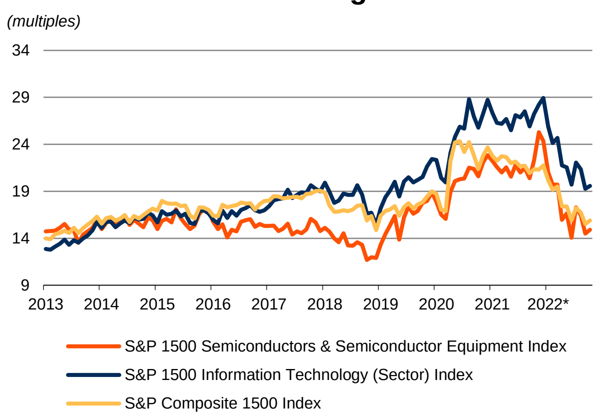


*Data as of Q2 2022
Source: CFRA, S&P Global Market Intelligence.

◆ Free cash flow in 2022 and 2023 is expected to suffer due to weaker demand as well as higher capital spending. While some companies may refrain from share repurchases in the current economic climate, we expect all major chipmakers to sustain dividend payments.

◆ In the intermediate term, foundry providers are likely to sustain investments despite unfavorable market conditions and customer demand dropping suddenly since the start of the year due to the severe impact of rising global inflation.

Forward Price-to-Earnings Ratio



*Data through October 19, 2022.
Source: CFRA, S&P Global Market Intelligence

◆ The industry forward price-to-earnings (P/E) ratio is expected to stabilize as growth is expected to normalize by end-2022, reflecting the belief that consumer demand will pick up in 2023. As of October 19, 2022, the industry forward P/E stood at 14.9x, vs. 19.5x for the S&P 1500 Technology Sector and 15.8x for the S&P 1500 Index.

◆ Forward P/E for this industry dropped from its peak in November 2021 as geopolitical tensions rose, coupled with rising global inflation levels. CFRA believes compression in multiples since 2021 makes sense as the cycle gets longer in the tooth. Nonetheless, the content growth story across the chip space in a post-pandemic environment should allow multiples to be sustained at higher levels than prior cycles.

Valuation

FORWARD PRICE-TO-EARNINGS RATIO *(as of October 6, 2022)*	2022*	2023*
Semiconductors	12.6	13.0
Semiconductor Equipment	12.5	12.5
S&P 500 Information Technology	20.9	19.2
S&P 500	16.9	15.7

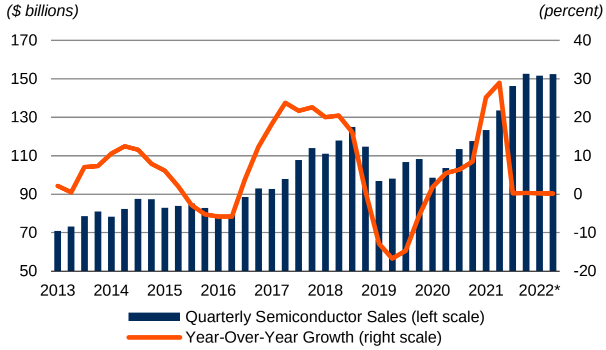
*Estimated.
Source: CFRA, S&P Global Market Intelligence.

◆ Our analysis, based on an equal-weighted basket of the 20 largest semiconductor stocks within CFRA's STARS coverage (including only those that trade on U.S. exchanges), notes that valuations remain below the projected broader S&P 500 Information Technology Sector Index and the S&P 500 Index.

◆ We see industry growth of about 9% in 2022 and a 3% decline in 2023, following a 28% increase in 2021 (using 2021 revenue as the base year). The bigger issues pressuring the valuations are excess inventory and slowing consumer demand, which we expect to persist well into 2023.

KEY INDUSTRY DRIVERS

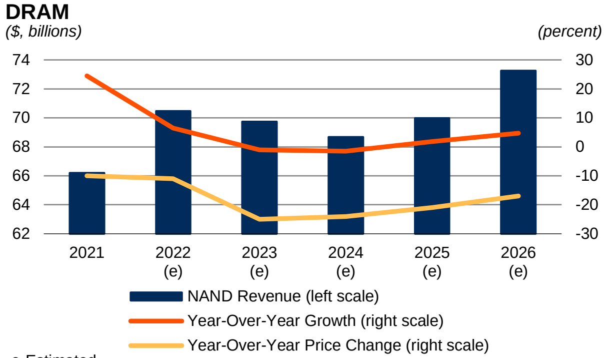
Semiconductor Sales



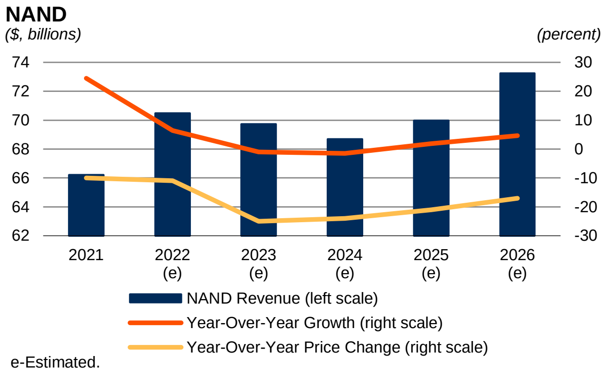
Source: Semiconductor Industry Association.

- Semiconductor sales came in at $152.5 billion in the second quarter of 2022, increasing 13.3% from the prior-year period and 0.5% compared to the first quarter, according to the World Semiconductor Trade Statistics. After coping with significant capacity constraints over the last two years, we believe that a combination of capacity expansion and slowing demand across a host of consumer-driven end markets have aligned the supply and demand landscape.
- For 2023, our base case assumes revenue to be flat after growing a little over 9% in 2022 after our outlook for a 20%-plus rise for 2021 came true (up about 28% last year). CFRA thinks the industry is amid a cyclical correction within the chip space (we see troughing for the first half of 2023), and the semiconductor industry will witness a super cycle over the next decade as content growth per device across a host of markets accelerates, driven by the emergence of greater AI capabilities.

Memory Chip Sales



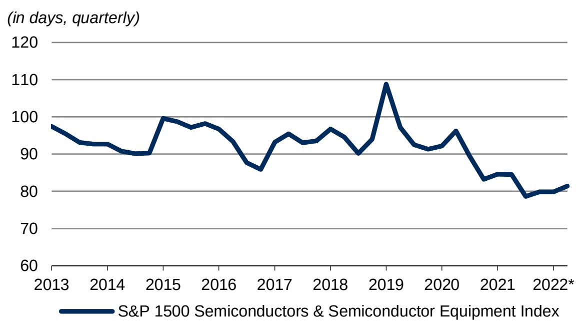
e-Estimated.
Source: IDC.



e-Estimated.
Source: IDC.

- IDC expects revenue for DRAM to increase 2.6% in 2022 and decrease by 0.2% in 2023, compared with 42.7% jump 2021. CFRA believes the memory market is rolling over, led by sharply declining average selling prices for both DRAM and NAND in the second half of 2022. We believe the previous consolidation in the memory space will allow customers to better sustain a healthy long-term industry landscape and create more predictable cyclical corrections moving forward.
- IDC forecasts the NAND market will grow 6.5% in 2022 and decrease 1.1% in 2023. Like the DRAM forecast, the NAND market will also experience similar effects to the DRAM market. IDC expects supply pressure will be controlled even during the down cycle period as chip makers will plan new fabs in the down cycle. Notable new fabs to be built by Kioxia, Samsung, SK Hynix, and Micron.
- As of the second quarter of 2022, Samsung, SK Hynix, and Micron held 94.7% of the DRAM market share. During the same period, Samsung, SK Hynix, and Kioxia held 71.9% of the NAND market share.

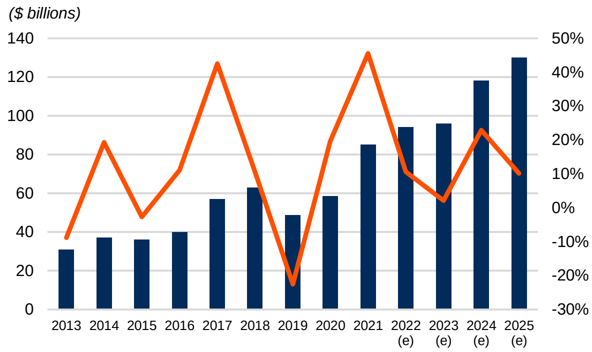
Average Inventory Days Outstanding



*Data as of Q2 2022
Source: CFRA, S&P Global Market Intelligence.

- Due to the cyclical nature of the industry, inventories will likely be the most volatile during periods of end-demand uncertainty, as chipmakers prefer to keep inventories lean during those periods. We saw an extreme case of this scenario in 2009 when inventories appeared too high entering the year, but by year-end inventories could not keep up with demand.
- In the second quarter of 2022, average inventory days outstanding stood at 81.4, lower than the five-year historical average of 90.1 and the prior-year quarter of 84.5. Given the trajectory of the pandemic and geopolitical tensions, inventories have been building for consumer-driven products, but we expect slowing end-demand to lead to further inventory days outstanding growth for the industry before peaking the in the first half of 2023.

Wafer Fabrication Equipment (WFE)



e-Estimate
Source: CFRA, SEMI.

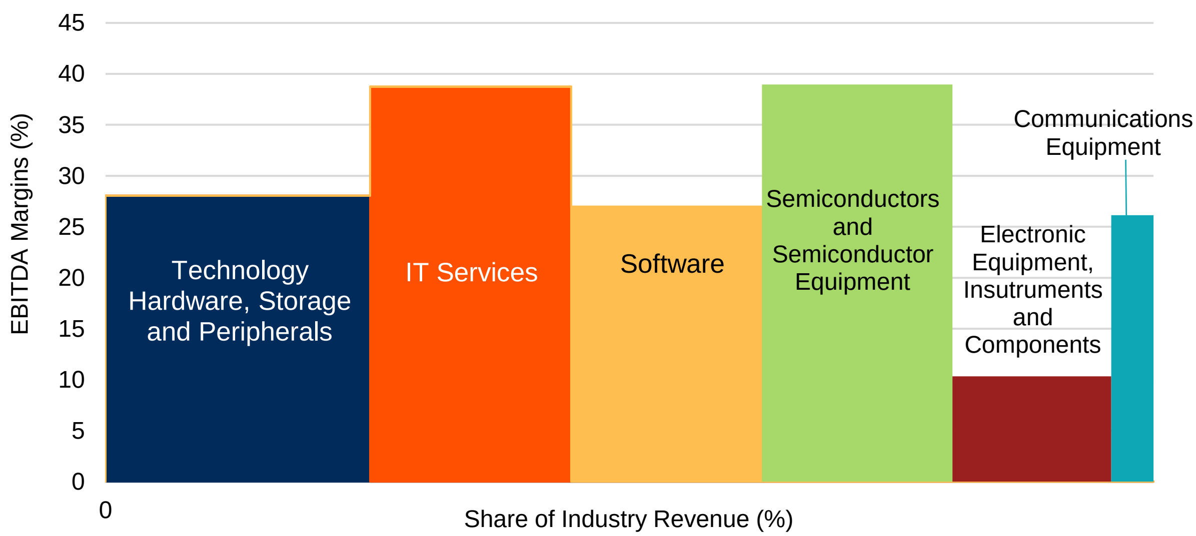
- CFRA observes the cyclical downturn in the overall semiconductor industry to slightly pause the growth trajectory of the WFE market but still believes there will be growth in 2022 and 2023. 2022's WFE market, on a purely demand driven basis, is well over $100 billion. The market is currently operating at a mid-$90 billion run rate for WFE.
- Our $94 billion forecast is based on the current revenue run rate; our original $100 billion target was contingent on an incremental improvement in the supply chain in the fourth quarter of 2022, but we view this as offset by export control restrictions for selling equipment into China. Any unmet demand in 2022 will be pushed out to 2023, supporting our continued growth forecast as we expect the WFE market to reach $100 billion in 2023.
- In addition, the prioritization of countries to diversify the semiconductor supply chain away from the Asia-Pacific region is aiding our outlook for a sustainably higher WFE market. Higher average selling prices for equipment used in EUV lithography machines and next-gen High-NA systems that go into R&D in 2023 and high-volume manufacturing (HMV) also attributed to our WFE outlook.

INDUSTRY TRENDS

The Semiconductors & Semiconductor Equipment industry comprises semiconductor manufacturers and equipment suppliers. Both tend to be driven by similar end-market characteristics and are highly cyclical. However, semiconductor makers are more unit-driven, while equipment producers are naturally more capital-driven.

Profit Pools

PROFIT SHARE MAP OF INFORMATION TECHNOLOGY SECTOR, 2022*



*Companies within the S&P Composite 1500 Index as of October 8, 2022.
Source: CFRA, Company Reports.

The Semiconductors and Semiconductor Equipment industry is the second largest industry (in terms of total revenue) in the Information Technology sector and is ranked second in terms of EBITDA margins. We would like to highlight that our analysis above is based only on constituents of the S&P Composite 1500 Index.

The Semiconductors sub-industry represented 79% of industry revenues, while semiconductor equipment companies made up the remaining 21% in the first half of 2022. We note that Intel and Qualcomm were the biggest players within the Semiconductors sub-industry, representing 21% and 14% of estimated total sub-industry revenues. Applied Materials and Lam Research are the market leaders within the semiconductor equipment space, representing 31% and 22% of estimated sub-industry revenues.

PROFIT SHARE MAP OF SEMICONDUCTORS AND SEMICONDUCTOR EQUIPMENT INDUSTRY, 2022*

*Companies within the S&P Composite 1500 Index as of October 8, 2022.
Source: CFRA, Company Reports.

Competitive Environment

Revenue advances have slowed over recent decades, and even as barriers to entry rise, competitors are facing increasingly brutal competition, rapid technological changes, and falling product prices. Chipmakers are trying to achieve faster growth through market share gains, product cycles, and penetration in end markets that are just now starting to employ semiconductors in products.

We believe the semiconductor space remains in a multi-year period of consolidation. We think the major reasons for additional chip M&As remain intact. One reason we are seeing consolidation in the space is the benefits from scale within an industry largely dependent on volume and inorganic growth. In addition, chipmakers are taking advantage of easier access to capital within both the equity and debt markets as well as stable China relations at the moment. Semiconductor producers managed to decrease the cost of products by continually shrinking transistor sizes, increasing wafer sizes, and improving throughput. Successful companies have been able to experience longevity by realigning their business models for maturing growth.

Porter's Five Forces

Porter's five forces, which provide a framework for industry analysis, were formulated by Michael E. Porter of Harvard Business School in 1979. Below we describe the five parameters on which an industry can be analyzed, and how these apply to the Semiconductors & Semiconductor Equipment industry.

◆ **Threat of new competition (Low).** In the Semiconductors & Semiconductor Equipment industry, high startup costs and the significant capital investments needed for the creation and development of technology to compete against existing players create huge barriers for a new player to enter. In the microprocessor arena, for example, Intel Corp.'s dominance raises significant barriers to entry for competing firms. For a company such as Advanced Micro Devices Inc. (AMD) to challenge Intel successfully, not only must it develop compelling technologies, but it must also offer distinct price advantages in order to wrest market share from the monolithic chipmaker. Consequently, Intel's presence makes it difficult both to achieve and to maintain success in the microprocessor arena.

◆ **Threat of substitute (Low).** Currently, there are no substitutes for semiconductor chips.

◆ **Bargaining power of customers (High).** Buyers have the advantage when it comes to purchasing, since they purchase in large volumes. In addition, chips are not sold to individual consumers, but rather to original equipment manufacturers (OEMs) and original design manufacturers (ODMs), which constitute a strong buyer influence. Intel and its competitors face a number of segment-specific challenges. The microprocessor segment primarily serves manufacturers of corporate- and consumer-focused computing devices, so chipmakers in this segment are sensitive to demand for computer hardware. In contrast, the markets for analog chips, digital signal processors (DSPs), logic devices, and memory are much more fragmented, with many players vying for market share.

◆ **Bargaining power of suppliers (Low).** The supplier market is characterized by a high number of suppliers and dominated by a small number of players. These factors allow semiconductor firms to apply pricing pressures on their suppliers, since many suppliers may have a particular semiconductor firm as their largest client. Hence, supplier power is low in the industry, and suppliers have to cater to the ever-evolving demands of their semiconductor clients.

◆ **Intensity of competitive rivalry (Medium/High).** Although rivalry in the Semiconductors & Semiconductor Equipment industry is high, each sub-industry may have only a few big players. For example, the major players in the Semiconductors sub-industry are Intel, Qualcomm, Texas Instruments, AMD, NVIDIA, and SoftBank Group Corp.'s ARM Holdings. These firms differentiate themselves on various parameters: chip performance (speed, reliability, and features), power consumption, life expectancy, and total cost of ownership across the various segments.

CFRA Top Semiconductor Risks for 2022

We highlight our top 8 risks for semiconductor investors/fundamentals, with geopolitical uncertainty, supply constraints, and sustainability of cyclical trends being among our biggest concerns. Nonetheless, we believe the chip industry remains in a decade-long secular bull market.

CFRA'S SCORE ON TOP SEMICONDUCTOR RISKS FOR 2022

Risks	Risk Impact
Future Taiwan Attack by China	10
Prolonged Ukraine/Russia tensions – new supply constraints	9
China, China, China	9
Slower Economic Growth/ Europe-led recession	7
Diminishing Pricing Power	6
Shortening Lead Times/ Channel Rebuild	5
Further Inflationary Pressures	3
Rising Interest Rate	2

Risk Impact scales from 1-10; 10 being of greatest risk and 1 being the least.
Source: CFRA.

For a further in-depth take on CFRA's top semiconductor risks for 2022, please refer to the thematic research titled "*Semiconductors: Compressing Valuations and Mounting Risks – Now What*?" by Angelo Zino, published March 16, 2022, on MarketScope Advisor.

The Semiconductors Sub-Industry

CFRA thinks the best way to assess the current opportunities and challenges in the Semiconductors sub-industry is to take all the growth trends and relate them to end markets. It is important to look at the end markets that use semiconductor components in order to get a better understanding of the demand environment. We will discuss key trends driving the semiconductors market – artificial intelligence (AI), 5G, and automobiles – followed by a discussion of the major end markets. In terms of size, the four general categories are computing, communications (wireless and wireline), consumer, and industrial (including automotive, military, and aerospace).

LARGEST SEMICONDUCTOR COMPANIES
(excluding pure-play foundries, ranked by 2021 semiconductor revenues, in $ billions)

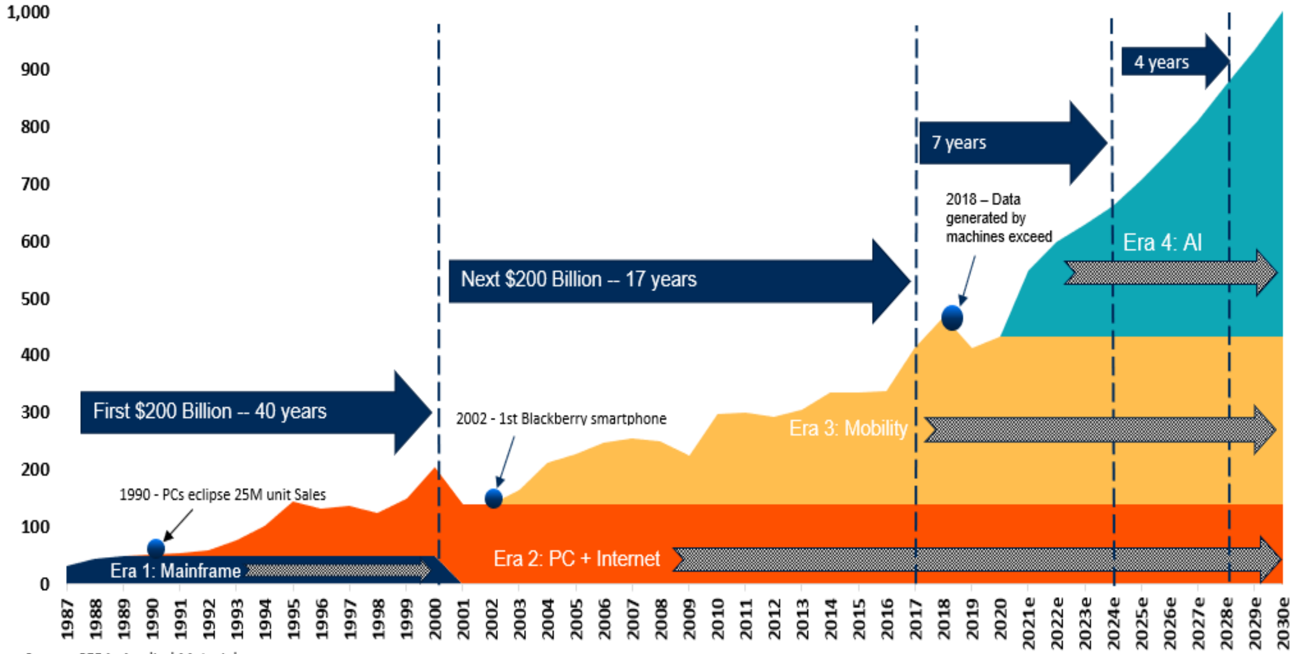
RANK	COMPANY	COUNTRY	REVENUES		PERCENT CHANGE
			2020	2021	
1	Samsung	South Korea	61.9	82.0	32.6
2	Intel	United States	76.3	76.7	0.5
3	SK Hynix	South Korea	26.1	37.4	43.3
4	Micron	United States	22.5	30.0	33.3
5	Qualcomm	United States	19.4	29.3	51.0
6	NVIDIA	United States	14.7	23.2	57.8
7	Broadcom	United States	17.7	21.0	18.6
8	MediaTek	Taiwan	11.0	17.7	60.9
9	Texas Instruments	United States	13.6	17.3	27.2
10	AMD	United States	9.7	16.4	69.1

Source: CFRA, company filings, IC Insights.

Semiconductor Super Cycle Driven by Content Growth

CFRA expects AI to support robust growth in the semiconductor industry over the next decade. The chip industry has seen a number of transformative changes over the last several decades (*e.g.,* PCs/internet age started in the 1990s and the shift to mobility in the early/mid-2000s), and each has supported an acceleration of growth for the space. We believe that the industry is now in the very early phases of the biggest disruptive trend that it will ever experience – AI. The chart below depicts the opportunity across the different "eras" from a historical context and where we see industry revenue heading over the next decade. We currently forecast semiconductor growth of about 10.7% in 2022 after growing about 24.5% in 2021. Thereafter, we see a compound annualized growth rate of at least 6%-7% through 2030. This will not likely be reached in a straight manner, as we think current industry supply constraints and demand across a host of end-markets are unsustainable. Our long-term bullish view on semiconductors and AI largely reflects the semiconductor content per unit growth that will be achieved in core markets, coupled with the need for more chips across new markets as everything around us gets much smarter. We think an important inflection to support the AI theme occurred in 2018, which was the first year where global data generated by machines exceeded that of humans. While machine learning capabilities have dominated AI-related investments until now, greater insight/advancement on inferencing is driving substantial progress towards redefining industries like automotive, retail, and banking.

HISTORICAL REVENUE LANDSCAPE OF THE SEMICONDUCTOR INDUSTRY (1987-2030e)
($, in billions)



Source:CFRA, Applied Materials

Semiconductor content per unit will explode across key markets. In the chart below, we highlight some of the most important markets in terms of future growth for the semiconductor industry and the sharp rise in silicon content growth that will be seen over the next five years. The largest semiconductor end-market, smartphones, will see content per unit growing at an annualized pace of 13% over the next five years for high-end devices, driven by the ongoing adoption of 5G, more advanced application processors, and a modest uptick in memory content. On the Datacenter Server side, semiconductor content is seen growing at a more pronounced 19% compound annualized pace through 2025, with sales growth for accelerators (*e.g.,* GPUs and FPGAs) far outpacing that of CPUs as an increasing amount of customer capex shifts towards those high-performance chips that can better serve the AI needs of cloud service providers. Notable memory growth will be seen in the data center, reflecting an explosion of data growth occurring. On the automotive side, we see annual content growth of 10%-11% over the next five years, primarily driven by the shift to hybrid/full electric vehicles as well as autonomous vehicles in time. We would highlight that this growth only reflects the silicon increase in a car, and in actuality, the revenue potential is significantly higher when factoring in the hardware and software opportunities for these companies. In terms of the smart home, the dollar content will more than double over the next five years but from a much lower price point than other market segments, given the vast number of different types of products that chips go into that have relatively low semiconductor content (*e.g.,* smart bulbs, doorbells, smart speakers, etc.). Nonetheless, the potential growth remains impressive from both a content and unit perspective for the segment. In the coming sections, we go a bit deeper into each of these markets.

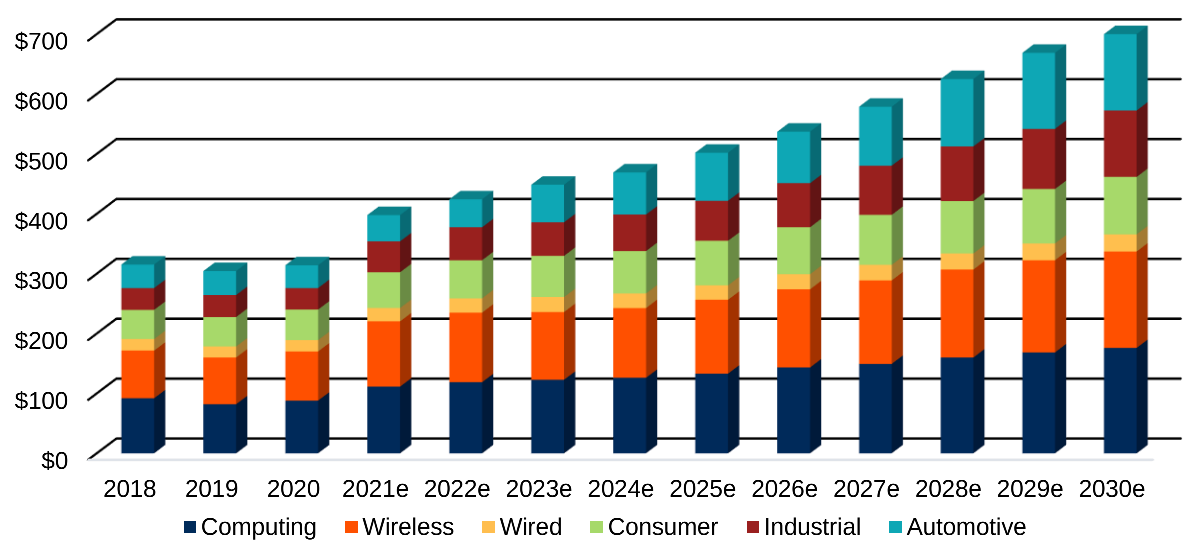
SEMICONDUCTOR CONTENT OUTLOOK FOR SELECT END-MARKETS

Semi Content Per Unit	2015	2020	2025e
High End Smartphone	$100	$170	$275
Auto (Global Average)	$310	$460	$690
Datacenter Server (CPU + Accelerator)	$1,620	$2,810	$5,600
Smart Home (Global Average)	$2	$4	$9

Source: CFRA, Applied Materials.

Rising memory demand, higher investments by cloud providers, and healthy spending for next-generation mobiles are among many factors that will continue to drive semiconductor orders, in our view. In the coming years, we see higher communications spending, continued growth in consumer electronics, an uptick in the automotive market, and growth in military and industrial end-markets. CFRA expects the computing end-market to be stable with periods of lumpiness. The next chart shows projections by CFRA on semiconductor sales by end-use categories from 2018 to 2030.

SEMICONDUCTOR DEMAND DRIVERS
(projected semiconductor sales by end-use categories)



e-Estimate
Source: IDC, CFRA.

End-Markets Feel the Pain from Supply Constraints

The major theme during recent supply constraints has been on matching issues, with the availability of advanced chips (3nm and below) improving, but chips at mature technology nodes remain highly constrained. The greatest constraints are being realized within the automotive and industrial markets, partly because these segments rely more heavily on more mature semiconductor components. However, when it comes to capital spending plans, foundries typically invest in expanding capacity for advanced technology nodes to pave the way for the manufacturing of next generation products, which offers the greatest return on investment. Some of the biggest constraints being seen are for power management integrated circuits (PMICs), microprocessors, image sensors, high voltage, and a variety of analog components, among other areas. For instance, TSMC has announced plans for a capex budget of $40 billion for 2022 on top of $30 billion in 2021. 70% to 80% of 2022 capex is expected to be spent on developing advanced node technologies, which include 2nm, 3nm, 5nm, and 7nm nodes.

In terms of the supply constraints, we are not necessarily surprised, given that there is typically a rush of orders from customers after a recession. However, the constraints exiting this recession are far more severe than any we have seen in the last 20 years, largely reflecting the sharp recovery in demand as consumers appear well-positioned to spend. Specifically, the automotive space was caught flat-footed as demand was already weak entering the pandemic (auto sales fell in 2019 and 2020) and digested inventories amid the downturn while factories were shut down. As demand recovered in the second half of 2020, the entire industry rushed to place orders (double ordering likely taking place as well). However, with demand already booming in other end-markets and automotive historically not being a key area of growth for chipmakers (about 10% of sales), these customers were put on the back burner.

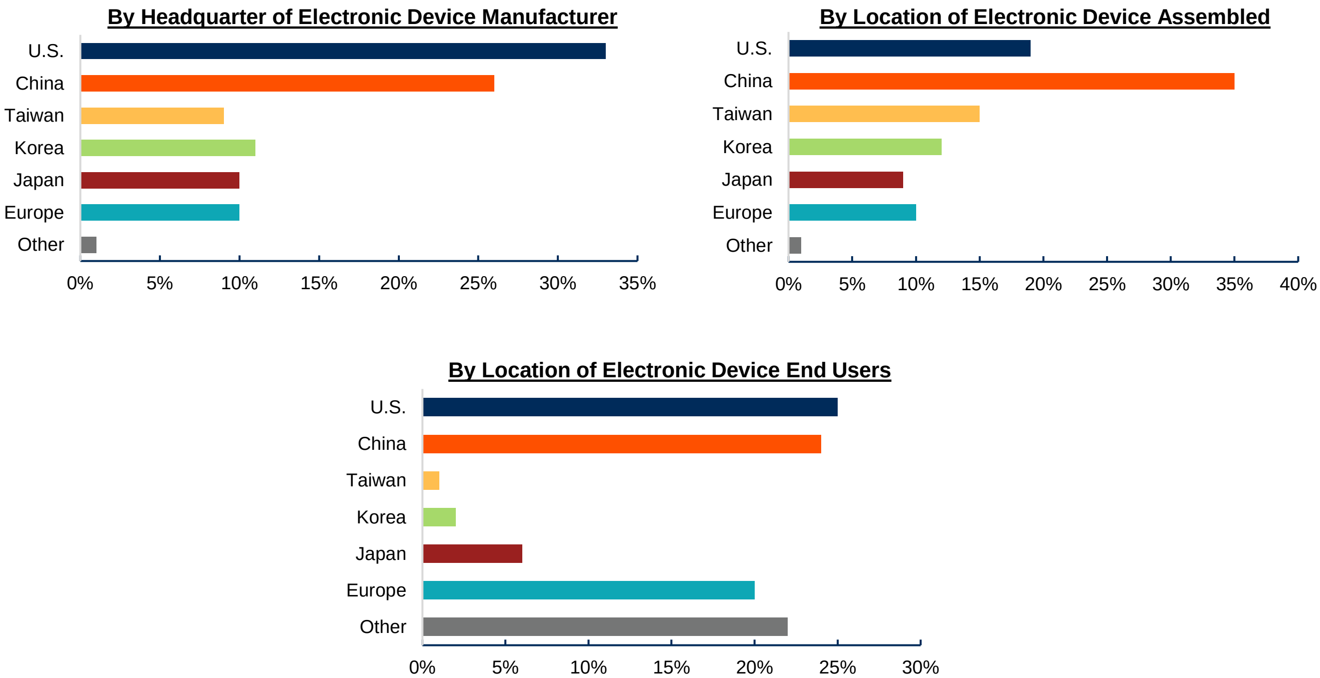
Due to these constraints, whether it be in automotive or other areas, both the Chinese and U.S. governments are looking to build capacity within their home territory to better manage supply chains and prioritize national security. The expansion of smaller fabs across more regions will also benefit equipment providers as these smaller fabs will likely be less efficient in nature, and thus more capacity will be needed to keep up with future chip demand. Nonetheless, time and increased capacity will likely alleviate most of the supply chain pressure points by the end of the fourth quarter of 2022, in CFRA's view.

The biggest customers are getting priority (*e.g.,* Apple, data center players) while more fragmented industries that are not as relevant to the chip industry (*e.g.,* industrials, autos) are being pushed to the backburner. In fact, many chipmakers at the moment are beginning to hold more inventory on hand rather than release it into the channel, so they can better funnel orders to the biggest customers.

China: It's Much More than Just Chips

With the ongoing U.S.-China trade war (getting colder), semiconductors and minerals needed for chip production are becoming the crux of the matter. China's 14th Five-Year Plan is a major issue for policymakers as the region looks for greater self-sufficiency from U.S. chipmakers and while its growing role in the electronics supply chain increases risk. China is the world's largest manufacturing hub, and with a growing population of 1.45 billion people, it is the second-largest final consumption market, nearly matching the U.S., for electronic devices embedded with semiconductors. China's biggest role is with multinational contract electronics manufacturers based in China that import semiconductors. After import, these semiconductors are assembled into tech products to be re-exported or sold in the domestic market for final consumption. In 2021, China imported $432 billion in semiconductors (a 23.6% year-over-year increase), assembled 35% of the world's electronic devices, and consumed one-quarter of all semiconductor-enabled electronics. Access to this market is critical to the success of any competitive chip firm in the foreseeable future.

GLOBAL SEMICONDUCTOR SALES BY GEOGRAPHICAL AREA



Source: CFRA, UN Comtrade; BCG x SIA.

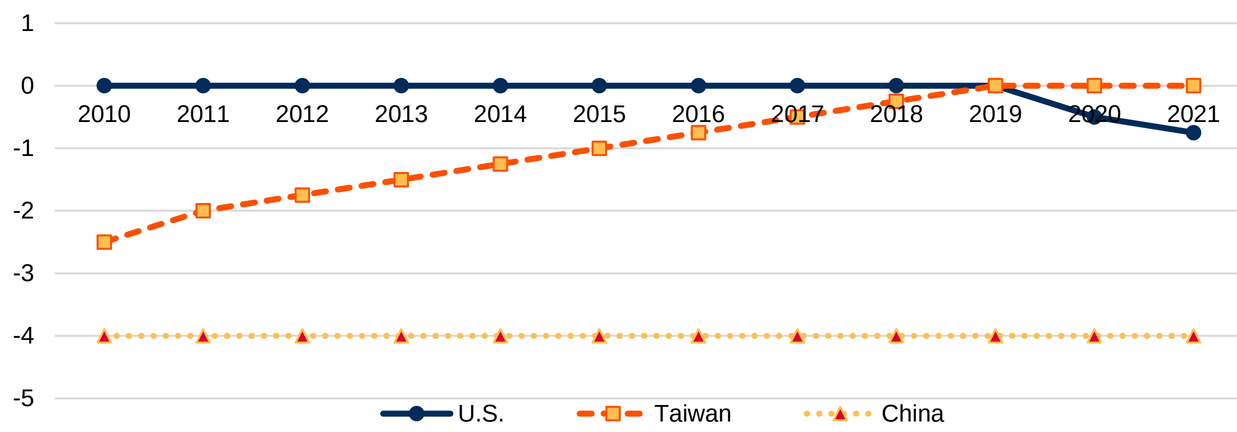
China is creating an uneven playing field to bolster domestic chip production. The Chinese government has been using subsidies and providing easy access to capital, such as through ultra-low interest loans, to help support growth for domestic companies across a host of industries. For instance, at the end of March, the China Finance Ministry said that chipmakers can now import machinery and raw materials tax-free through 2030. This exemption is for China chip producers that manufacture chips below 65nm in width and IC producers that focus on special processes, such as radio frequency. The exemption is for raw materials and equipment that are imported in cases where domestic producers are not able to supply or the performance of domestic products cannot meet demand. Additional Chinese government incentives being used to support domestic chip production include grants, reduced utility rates, other tax breaks/deductions in areas like R&D, and free or discounted land. These incentives provide a significant cost advantage for firms and help insulate them from competitive forces.

A 2020 report by the Boston Consulting Group highlights that the cost of building and operating a fab in China is 37% lower than in the U.S. These exemptions, along with more likely to follow, are intended to allow China to ultimately produce enough chips to help manufacturers like Xiaomi avoid the same fate as Huawei. The Chinese government's help for homegrown integrated circuits did not go unnoticed. In 2021, the output of integrated circuits was 359.4 billion units, representing 33.3% year-over-year growth as published by the Ministry of Industry and Information Technology (MIIT).

CFRA believes that China will be unable to catch U.S. chipmakers on the technology front, given the current ban on Extreme Ultraviolet (EUV) tools from ASML Holding. The Biden administration has made a tactical decision to have the Netherlands restrict sales of ASML's EUV equipment to China, citing national security concerns that were first identified by the Trump administration. While ASML generated about 17% of revenue from China last year and saw sales grow 69%, it was for lithography tools used to manufacture chips at trailing technology nodes. Looking at plans by TSM, Samsung, and INTC, all are committed to utilizing EUVs at 7nm-and-below technology nodes. We believe that the restricted use of ASML's EUVs will keep U.S. chipmakers ahead of emerging China companies for the next five years.

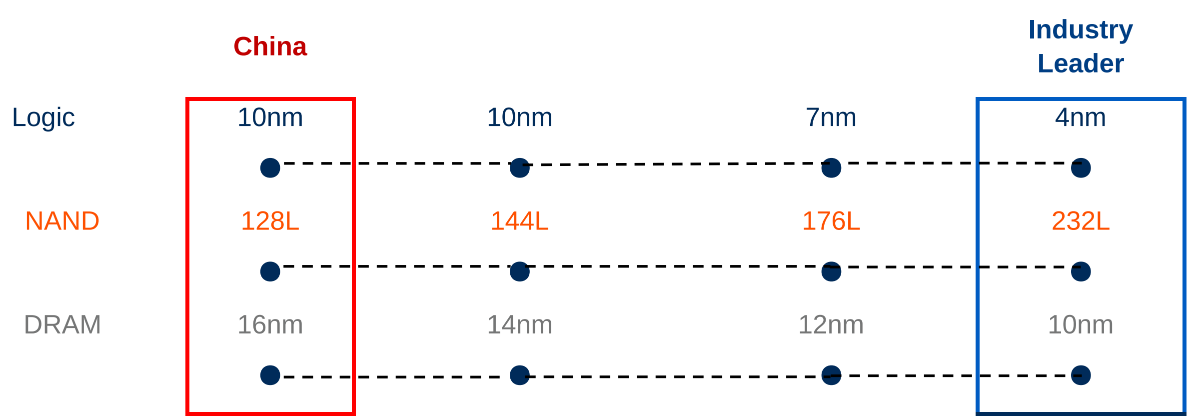
Even if a technology breakthrough is created in China on the EUV side, it will be extremely tough to keep pace with ASML given the company's track record. ASML is unlikely to ever go against the direct orders of the U.S., as the U.S. can restrict the supply of important components needed to make ASML's EUV machines. Given the current state, Huawei has essentially been fully boxed out as it can't purchase U.S. chips and now can't rely on the China semiconductor industry to make the chips it needs, as China can't get its hands on the right equipment. China remains about four years behind industry leaders in manufacturing next generation logic chips.

LOGIC MANUFACTURING POSITION (YEARS BEHIND LEADER)



Source: CFRA and SIA.

CHINA'S TECHNOLOGY POSITION VERSUS INDUSTRY LEADER



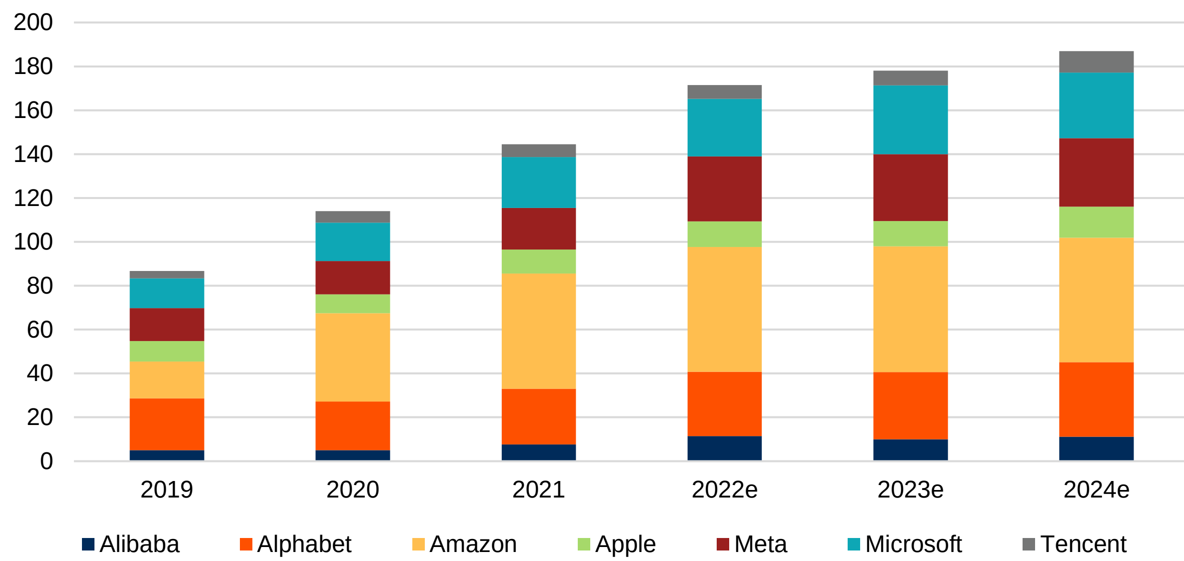
Source: CFRA and SIA.

Data Centers

The most powerful long-term secular opportunity for the semiconductor market, in CFRA's view, resides in the data center. This trend will be propelled by the combination of data creation and the rising need for AI capabilities across a host of end-markets. While IT spending slowed during the pandemic, data growth accelerated, driven by greater online usage by work-from-home employees. This has resulted in rising demand for data to be created via video communication and an increase in the number of downloaded/streamed videos from consumers.

Chipmakers most exposed to the data center benefit from being tied to the strongest/best-capitalized customers on the planet, supporting higher long-term capital spending. Companies most tied to the data center will continue to witness robust demand even in a post-pandemic world given the ongoing shift to the cloud and need for greater AI capabilities. These chipmakers have a more reliable customer base given improving fundamentals amid the pandemic for the Super 8 (see chart below) – Amazon, Microsoft, Facebook, Apple, Alphabet, Alibaba, Baidu, and Tencent. We highlight that data center cycles often see an upcycle of about four to six quarters before taking a breather. We continue to predict that greater dollar investments will be placed on central processing units (CPUs), graphics processing units (GPUs), and application-specific integrated circuits (ASICs), which will benefit the likes of Intel, AMD, NVIDIA, Broadcom, and Marvell Technology the most. We believe growth for accelerated AI servers will grow at a five-year compounded annual growth rate of 20%, much faster than non-accelerated (CPUs), which we see growing at a 5% annual pace.

CAPITAL SPENDING PLANS FROM MAJOR CLOUD PROVIDERS
(in billions, $)



Source: CFRA, S&P Global Market Intelligence.

AMD will be a share taker, while Intel is a share loser in the CPU server space, according to CFRA analysis. As employees work from home, students learn from home, and medical professionals practice telemedicine remotely, demand for communication and collaboration platforms is rising. Videoconferencing tools as well as streaming entertainment services are experiencing huge surges in demand that will likely last on a more permanent basis.

We expect the current work environment (including hybrid and work-from-home) to accelerate transformational initiatives within organizations, helping drive further demand for servers. We expect servers that run on x86 architecture (servers made only by Intel and AMD) to sustain a market share of more than 90% in the foreseeable future given the supreme performance of these servers and the enormous cost it would take for customers to migrate from this technology. Until now, Intel has dominated as it possesses about 80% to 85% of the server market share in numbers. We expect AMD to continue to be a share taker with its next-generation EPYC processors. Separately, in March 2022, NVIDIA announced its first Arm Neoverse – based discrete data center CPU designed for AI infrastructure and high performance computing, providing the highest performance and twice the memory bandwidth and energy efficiency compared to today's leading server chips. CFRA expects Nvidia's offering named Grace CPU Superchip will take share from x86 providers Intel/AMD.

5G Adoption Well Underway

We anticipate rising semiconductor content per device, with radio frequency (RF) chips witnessing the greatest boost. Given the need for higher frequencies required to support 5G, signals won't be able to travel as far. This will mean that more antennas will be required, which will raise the cost of implementation as the network is deployed. As 5G is rolled out, both end-user devices like smartphones and base stations will need to be able to support 5G-related multiple-input and multiple-output (MIMO) and beam-steering technologies, which will have an impact in that they will require more channels and expanded demand for bulk acoustic wave (BAW) filters, antennae, power management, and other devices.

Next-generation smartphones will have to contend with complex new challenges, specifically related to mobile RF front-end, as they will need to support 4G and 5G waveforms, unprecedented bandwidth, and new high-frequency bands. The size of the RF market has increased steadily over the last decade despite the maturation of the smartphone market, driven primarily by content gains per device, reflecting the increasing complexities associated with next-generation devices. The average RF content per device is $7 to $8 for a 4G device (but approaching $20 for a premium 4G smartphone) compared to $4 for a value 3G/4G smartphone and sub-$1 for a legacy 2G/3G device. The average RF content for a 5G smartphone eclipses $10, providing further growth for the space and significantly outperforming the overall growth trajectory for the semiconductor business.

The mobile space will be the initial beneficiary of the emergence of a 5G network, by our analysis, but we note the technology will have much greater implications in areas outside of mobile, like automotive and health care, over time. From a hardware perspective, we expect Apple, which we view as the mobile king, to be a beneficiary as we expect 5G smartphone sales over the next five years to far outpace 5G subscriber growth. This phenomenon was very similar when the industry adopted 4G (currently over 80% of smartphones sold are 4G-enabled while less than 50% of global subscribers are on a 4G network). High-end smartphone makers will see the biggest boon for 5G devices initially, as consumers that purchase these devices tend to be more data hungry and will be willing to pay a premium for the device as well as service. We anticipate that smartphone units will decline by a mid-single-digit percentage basis in 2022 after a 6% plus increase in 2021.

While RF chipmakers and modem providers will be the biggest beneficiaries in terms of revenue potential inside a 5G-enabled phone, we forecast the entire semiconductor business stands to gain from this transformational shift. From a network building perspective, programmable logic chip providers like Xilinx as well as analog chipmakers like Texas Instruments and Analog Devices stand to benefit, among others.

Megatrends within the Automotive Market Unlock Content Growth for Chipmakers

The auto market is just starting to witness a massive transformational change, which is going to be among the most evolutionary changes that the semiconductor space has ever seen. This will take place via three megatrends, in our view. The first trend is the shift to autonomous vehicles, where advanced driver-assistance systems (ADAS) are being developed to automate, adapt, and enhance vehicle systems for safety and better driving (*e.g.,* self-driving features include automatic parking, lane centering, collision avoidance, and pedestrian crash avoidance mitigation, among other things). The second trend is the electrification of the vehicle and need to drive down emissions, with more stringent regulations in Europe and China helping to support this initiative. Finally, the shift to a more connected vehicle will improve the user experience and capabilities of a car as it overtakes the smartphone as the ultimate consumer technology device. The semiconductor industry will be a major beneficiary of all three trends, as we envision 7%-9% annual growth in silicon content (near $500 per vehicle in 2022) in the coming years. In the following sections, we offer insight into where growth will be derived in different vehicle categories and which semiconductor providers are best exposed to take advantage of these inflections.

Chipmakers heavily exposed to the automotive market will likely outperform in the long term. We estimate that automotive sales will be about 11%-12% of total semiconductor sales in 2022, with the companies among the top 20 most exposed (above industry representation) to the automotive supply chain being Renesas, NXP Semiconductors, Infineon, STMicroelectronics, ON Semiconductor, Analog Devices, and Texas Instruments.

The ongoing shift to electric vehicles will aid average semiconductor content per vehicle growth. Technology advancements via more sensors (*e.g.,* radar, more camera systems, greater connectivity features) across the vehicle will, of course, support this trend (we highlight this in the coming sections). Just as important, the significant growth and expected greater representation of electric vehicles will also be a major contributor to content growth. According to an International Energy Agency (IEA) report, the market share of electric vehicles (EVs) came is seen at around 5% of global vehicle units in 2022. CFRA believes this lower-than-expected market share was due to a number of reasons, ranging from chip shortage, high costs of EVs, and lack of infrastructure(charging stations) supporting EVs in many countries (mainly Asian countries ex China). We note that a plug-in hybrid vehicle will add $400 of additional content relative to a combustion engine car, while a full battery electric vehicle adds $450 of content.

Content Growth Driven by Technology Advancements Across Five Main Categories
We highlight the five main categories in the diagram below and detail the key sensors/growth opportunities within each in the following sections:

LIST OF SEMICONDUCTOR PRODUCTS INSIDE A VEHICLE

CATEGORY	SENSORS	THINK-CONTROLLER	ACTIONS
Connectivity	Cellular Wi-Fi, BT, GNSS, NFC Smart Car Access	Connectivity Controller	
Autonomy (ADAS)	V2X Radar Camera Lidar	Sensor Fusion & Planning Controller	
Powertrain & Vehicle Dynamics	Motion & Pressure Speed Ultrasonic	Powertrain Controller	Engine, Transmission, Brake, Battery Management, Steering, Airbag, Suspension
Body & Comfort	Temp, Light, Humidity Switch Panels	Body Controller	HVAC, Interior Lighting, Doors, Seats, Steering Wheel, Mirrors, Wipers, Sunroof
Connected Infotainment	Radio & Audio Touch Displays Voice Recognition	e-Cockpit Controller	e-Cockpit, Amplifiers

Source: CFRA, NXPI.

We forecast that ADAS represents the largest potential growth opportunity while the connected infotainment arena is the most mature. We see Powertrain & Vehicle Dynamics being driven by the rising adoption of electric vehicles, while Body & Comfort will see more lighting as well as automated features for standard/economy vehicles. We note these categories created more than $40 billion in revenue for the semiconductor industry in 2021. Semiconductor content per vehicle continues to increase due to government regulation for improved safety and emissions, the standardization of higher-end options across a greater number of vehicle classes as well as consumer demand for greater fuel efficiency, advanced safety, and multimedia applications. Automotive safety features are evolving from passive safety systems to active safety systems with ADAS, such as radar, vision, vehicle-to-vehicle, and vehicle-to-infrastructure systems. Regulatory actions and consumer demand in both the developed and emerging markets will likely drive the increase in applications such as ADAS, electric and hybrid powertrains, vehicle gateway and secure connectivity, electronic safety, as well as stability control. Semiconductor content per vehicle is also increasing to address applications such as engine management, fuel economy improvement, driver comfort, convenience, and user interface.

- **Although connectivity semiconductors have seen significant innovation and demand over the last decade, 5G provides an added growth driver.** Advancements in 5G will likely help support the transformation of the vehicle and allow new capabilities that until now have not been possible. According to various forecasters, by 2025, about three-fourths of all new car sales will have cellular connectivity, up from about a third today. Given that 5G can bring up to 20 Gbps data speeds to devices and provides lower latency, it will enable automakers to put smarter, more connected vehicles on the road through vehicle-to-anything communications. Wireless connectivity, such as Bluetooth technology or Wi-Fi, is typically used to connect smartphones and tablets to the vehicle's human interface dashboard. Other popular chips for the connectivity of a vehicle include Global Navigation Satellite Systems (GNSS)/GPS capabilities for satellite navigation as well as Near Field Communication (NFC) to provide a more convenient/safer way to access vehicles (*e.g.,* keyless entry), among others.

- **Greater automotive capabilities provide the greatest potential for content growth and also drive greater demand across the other categories.** The shift from Level 1/Level 2 vehicles to Level 3/Level 4 offers a major inflection in terms of content growth (see definitions for ADAS Levels in the table below). We note that content per vehicle of $100-$150 at Level 1 and 2 jumps to $600 at Level 3 and $900 at Level 4. Complete autonomous cars (Level 5) will command an average silicon content increase of $1,200 compared to vehicles with no automation. The inflection at Level 3 and above vehicles largely represents the greater need for sensors related to radar, cameras, LiDAR, and V2X (vehicle-to-everything).

ADVANCED DRIVER ASSIST SYSTEMS SAE LEVEL DEFINITIONS AND POTENTIAL CONTENT GROWTH

Level	Description	Human Role	Vehicle Role	$ Content Increase
0	None	All driver control	No autonomous functions	No Automation
1	Limited + Safety	Almost all driver control	ABS, traction control	+$100
2	Limited, Active Safety, Convenience	Mostly driver control	Lane keeping, emergency braking, adaptive cruise control, parking assist	+$150
3	Significant Autonomy	Driver can disengage completely at times	Advanced controls in simple conditions (highway, slow-moving congestion, good weather)	+$600
4	High Autonomy	Driver not needed in some locations or conditions	Full conditional autonomous capabilities, more difficult conditions/locations not autonomous	+$900
5	Complete Autonomy	No driver needed	Autonomous driving in all locations/conditions possible, driver controls (brakes, steering wheel) not necessary	+$1,200

Source: CFRA, LMC Automotive, NXPI.

- **CFRA sees greater radar and camera systems in Level 3 and beyond vehicles driving ADAS unit/revenue growth.** The table below provides a perspective on the rising number of sensors needed for radar systems/LiDAR/cameras/V2X as we migrate towards more autonomous capabilities in a vehicle. We see the biggest growth area of ADAS being radar systems (the use of radio waves), which can constantly sense the distance between vehicles in real-time, improving driving efficiency and safety. Automotive radar systems are used for collision detection, warning, and mitigation. The number of radar sensors rises from about 1-3 units in a Level 1/Level 2 vehicle to 4-6 units at Level 3 and 6-10 units at Level 4/Level 5. LiDAR, contrary to radar, uses a pulsed laser to detect distance, velocity, and angle with high precision. LiDAR can classify objects, detect lane markings, and may also be used to accurately position an autonomous vehicle relative to a high-definition map. LiDAR sales are seen to remain minimal over the next three years, at less than 1 million annual units sold by 2023. V2X, or vehicle-to-everything, is a form of technology that allows vehicles to communicate with moving parts of the traffic system around them. V2X has several components, including vehicle-to-vehicle (V2V), which allows vehicles to communicate one another, and vehicle-to-infrastructure (V2I), which allows vehicles to communicate with external systems such as streetlights, buildings, and even cyclists or pedestrians. We forecast Qualcomm will be a key provider of this technology given its early initiatives. While the technology is resistant to interference and inclement weather, it will take time for the technology to develop as systems outside the vehicle, like traffic lights, will also need to embed the proper chipsets for V2X to be successful. The likes of Ambarella, among other chipmakers, are creating computer vision technology where camera systems will be embedded across the vehicle to help drivers with functions that include lane detection warning, forward collision warning, blind-spot detection, and driver monitoring. The number of camera sensors is seen rising to at least four units at Level 3 and six to eight units at Level 4/Level 5 from one at Level 1/Level 2.

SENSOR UNITS BY AUTONOMY			
	LEVEL 1/2	**LEVEL 3**	**LEVEL 4/5**
Silicon Value	$100 - $150	$600	$900 - $1,200
Sensor	**Units**	**Units**	**Units**
Radar	1 to 3	4 to 6	6 to 10
Camera	1	At least 4	6 to 8
Lidar	NA	0 to 1	1 to 3
V2X	NA	0 to 1	1 to 2

Source: Strategy Analytics, NXPI.

- **The electrification of the car will drive Powertrain & Vehicle Dynamics capabilities, by CFRA analysis.** Increasing electrification of the powertrains is being driven by the increasing shift away from a pure combustion engine. As a result, the electric motor is getting more powerful and complex, requiring more semiconductors in plug-in hybrids, range extended electric vehicles, and pure electrical vehicles. Greater charging functionality is driving the need for power semiconductors and control semiconductors, which will ultimately help support additional content of $450 per car, making this market extremely attractive for many chipmakers. We think it is plausible that by 2030, nearly half of all automobiles will have some sort of electrification supported by manufacturers like Volkswagen looking to shift their entire installed base to an electrified platform. This segment of the market is seen increasing significantly in the coming years, as the silicon market in this area can be simplified into two kinds of semiconductors. The first are high-voltage power switches that help power the vehicle (think about semiconductors like IGBTs and MOSFETs where a company like Diodes operates), which represent roughly 60% of this market and are expected to grow at an annual pace of about 15%-20%. The other 40% of this market segment utilizes high performance analog mixed-signal solutions to control the power. These are processors and analog chips that support solutions like battery management systems, motor control, voltage converters/chargers, and hybrid control, among other actions. Most of these areas are seen growing at a 20%-plus pace in the coming years.

- **Everything inside the car is becoming automated, driving the need for greater Body & Comfort sensors.** Beneficiaries of this shift will be those focused on creating sensors that help control the temperature, lighting, and humidity inside a vehicle. These semiconductors allow for capabilities like automatic climate control, electronic seat adjustment with memory, automatic wipers, and automatic/more lighting. We believe this segment of the market is less resilient to a decline in the broader automobile space content growth is more muted than in areas like ADAS, powertrain, and connectivity.

- **While the connected infotainment space has matured, greater demand for e-cockpits and relatively low penetration rates in China provide additional room for growth.** While most vehicles in the U.S. and Europe are sold with some sort of infotainment system, increasing adoption from Tier 1 auto manufacturers in China will likely help support growth of about 5% in this category. We also see more advanced e-cockpit systems, which could include gesture sensors so that passengers in the back seat can use motions to control music or the radio. In addition, increasing displays are being sold in a vehicle (front and rear screens), which is creating the need for more content sources, cell phone usage, and apps services, among other capabilities. In addition, greater content on the radio side is being added by digital radio, with new audio applications coming like active noise cancellation, engine sound enhancement (*e.g.,* makes your compact car sound like a Ferrari) and branded audio systems, with more channels and high-end applications.

CFRA LONG-TERM NORMALIZED TARGET GROWTH RATE AND KEY GROWTH DRIVERS BY SEGMENT

Market Segment	CFRA Long-Term Target Growth	Segment Growth Drivers	Segment Decription
Computing	5% - 6%	Higher Spending from Cloud Service Providers driven by explosion of data growth and greater enterprise appetite for AI capabilities. PC demand to level off in 2022.	Any technology hardware related to computing
Wired Communication	1% - 3%	Enterprise and Telecom providers will be prudent with spending; customer preference on wireless side.	Includes enterprise and telecom service providers, switching & routing, security appliances, 4G/5G/WiMax access, Broadband access etc…
Wireless Communication	4% - 6%	Higher content growth from 5G and infrastructure spending. Smartphone unit growth to remain lackluster.	Consists of mobile phones, smart phones, mobile base stations, and Wireless infrastructure.
Consumer	6% - 7%	Greater adoption in areas like gaming, wearables, and the smart home.	Consumer devices solely for entertainment and personal lifestyle use like game consoles, wearable devices, smart tvs/home systems, etc.…
Automotive	10%	Electric vehicles, autonomous capabilities, and focus on safety standards.	Automotive applications include engine and power train controls, infotainment such as radio and video circuits, air bags, antilock brakes, active suspension, navigation circuits, engine control, display circuits, motor control, and autonomous vehicle systems.
Industrial	7%	Rising interest in factory automation, renewables, and health care coupled with an improving economic backdrop.	Industrial applications including factory automation, industrial electronic circuits, electronic circuits used in power/energy (such as solar, wind), military/aero applications, and medical applications.
Overall Semiconductor Industry	**6% - 7%**		

Source:CFRA

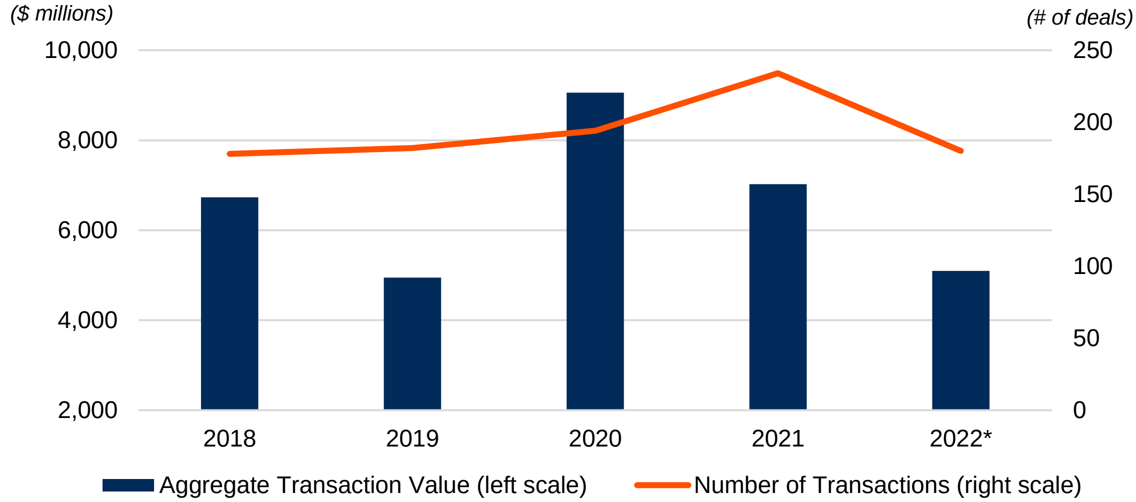
Rise in Tailored AI Chips

AI has fundamentally changed what software can make and how software can be made. The first wave of AI learned perception and inference, like recognizing images, understanding speech, and recommending a video or an item to buy. The next wave of AI is robotics – AI planning actions. Digital robots, avatars, and physical robots will perceive, plan and act, according to Nvidia CEO Jensen Huang (during Nvidia's 2022 GPU Technology Conference).

Nvidia forecasts that most machine-learning or AI tasks have spurred a 25-fold increase in the need for processing power every two years, while one of the most advanced natural-language-processing models needs 275 times the computing power every two years to work. This demand for huge computing power has also created opportunities for smaller chip companies that focus on making specialized chips for AI.

Big players like Intel, Samsung, Qualcomm, and Nvidia have been active participants in the chip startup scene. While the reasoning behind these strategic investments could be as simple as getting exponential returns (5x-10x), according to Eclipse Ventures partner Greg Reichow, there is also the chance of immersing these startups' technology at the factories and seeing how it performs.

VENTURE CAPITAL CHIP STARTUP FUNDING AND DEALS



*As of October 2, 2022
Source:S&P Global Market Intelligence.

While chip startups do not necessarily use the most advanced manufacturing techniques for their silicon-wafer-sized AI chips, their expertise in developing chips and software around parallel processing, which takes on simpler tasks at far greater volume compared to a traditional processor that competes with a single, usually more complex, calculation at a time is highly desired.

Chip startups are nowhere near taking a tiny fraction of the market from Nvidia, Intel, AMD, or others; however, they provide platform for testable hypotheses more rapidly and explore concepts that are currently untestable or too expensive to investigate using older systems. It lowers the opportunity costs, speeding up the introduction of new ideas and approaches to future AI.

Today, designing and manufacturing processors are no longer exclusive to specialized companies like Intel, AMD, or Samsung Electronics. Anyone can design efficiently using highly advanced Design Automation Tools and produce custom processors with optimized functions for their own applications through foundries that provide cutting-edge processing. In fact, Apple uses chips of its own design in the application processors (AP) of iPhones and has even designed its own CPU for PC devices, significantly improving the performance and energy efficiency of Mac, which used to use Intel chips.

Semiconductor Equipment

Semiconductor equipment companies are positioned to benefit from future technology node transitions more than ever before. Semiconductor equipment companies are currently experiencing the perfect storm, benefiting from sustainably higher wafer fabrication equipment (WFE) spending and the newly adopted roadmap for the technology transition to smaller semiconductor nodes (5nm, 3nm, 1nm, etc.).

The transition from immersion systems to extreme ultraviolet lithography (EUV) systems has caused a domino effect for the semiconductor equipment space, creating market share shift opportunities in various processes, like inspection, deposition, etch, and more. This inflection has also resulted in the profound and sustainable growth of longer-term services revenue for several semiconductor equipment names (*e.g.,* AMAT and KLAC) that are reducing their exposure to cyclical downturns. In our view, it is more likely for Microsoft to lose all its market share with PCs than for ASML to lose its lithography monopoly for leading edge chips. It would take any emerging competitor more than a decade to enter the EUV system space, and by then, ASML would have newer lithography systems (e.g., High-NA) for the most advanced chips.

The legacy systems to EUV are called immersion systems, which have long been known as the workhorses of the semiconductor industry. But the most advanced chip manufacturers are trading in their horses for spaceships, and the spaceship manufacturer is far from then only beneficiary.

EUV adoption not only allows for technological advances but provides ROI to leading edge chip makers that embrace EUV over legacy processes. Using extreme ultraviolet lithography (EUV) provides value to customers in three forms: fewer defects, reductions in cost, and shorter cycle times. Manufacturing leading edge chips with legacy technologies like immersion lithography involves a significant increase in process steps related to very large multi-patterning schemes. Using EUV reduces the number of lithography layers and, as a result, reduces the number of process steps. Because every layer requires some additional step to support patterning, this is the best way to reduce defects, improve cycle times, and reduce costs. Samsung, when adopting EUV for memory chips, saw a 20% defect reduction. This reduces costs and increases yields, allowing customers to advance their roadmaps as a result of limiting the amount of complexity they combat in patterning wafers.

Memory Equipment: Oversupply Well Into 2023 As End-Demand Drops
Historically, memory customers have accounted for the largest percentage of equipment spending – as much as 70%-80% of total semiconductor equipment sales, according to CFRA estimates. While we believe customers like Samsung are seeing a more stable memory pricing landscape versus a year ago, we question the sustainability of this trend given uncertain end-demand across consumer-related areas (*e.g.,* smartphones) and potential double ordering. We believe previous consolidation in the memory space will allow customers to better sustain a healthy industry landscape and create more predictable cyclical corrections. In addition, we think China's desire to grow its local semiconductor manufacturing business is supporting demand for equipment.

DRAM market revenue is forecasted by IDC to increase by 2.6% to $96.9 billion in 2022. Cloud service providers drove strong growth as the working environment changed drastically. Consumer demand dropped in 2022, particularly for products like PC, laptops, and smartphones. Samsung, SK Hynix, and Micron Technology Inc. virtually control the DRAM market (94.7% of total industry supply in 2Q 2022).

On the other hand, IDC expects NAND market revenue for 2022 to increase by 6.5% to $70.5 billion. IDC attributes lockdowns in China continue to constraint global supply chain besides the ongoing geopolitical turmoil, rising inflation, and recession fears. IDC observes that system makers extremely control memory orders, resulting in NAND makers' inventory hikes. Market sentiment then deteriorates and pushing down pricing. Slight oversupply is forecasted well into the second half of 2023 in the market, but by then, seasonality will work and demand will grow to meet the benefit of low pricing.

Logic Equipment: Intel to Remain Heavy Investors in 2022
Logic equipment spending is expected to increase in 2022 compared with the 2021 level, according to CFRA. Capital investment from this segment is concentrated on one large North American customer: Intel Corp. Intel has revised its full-year capital spending to reach $24 billion in 2022, up from the actual spending of $21.7 billion in 2021. On January 21, 2022, Intel announced plans for an initial investment of over $20 billion in two new leading-edge chip factories in Ohio. The investment will help boost production to meet the demand for advanced semiconductors. Intel has started construction of two new Foundry fabs named Fab 52 and Fab 62 in Arizona in the Ocotillo complex, which will now consist of six factories. The fabs will support both internal products and provide capacity for new foundry customers. Intel will benefit from the desire for a non-Asia footprint by U.S. and European governments and corporations. However, it faces obstacles and gaining a significant customer base could prove challenging as Intel lags peers on the technology front. CFRA thinks the company is likely to receive financial incentives and subsidies to build or expand domestic capacity and support research and development (R&D) programs as part of the *CHIPS Act*.

Lord of the Chips: The Fellowship of Chips

On April 6, 2022, Intel announced it would join Micron, Analog Devices, and MITRE Engenuity to accelerate semiconductor research, development, and prototyping. This collaboration establishes a domestic semiconductor alliance to build a more robust U.S. semiconductor industry, foster advanced manufacturing in the U.S., and protect intellectual property amid rising global competition. This alliance will propose the foundation for a while-of-nation approach for a more innovation-focused U.S. semiconductor industry and supply chain.

CFRA finds this alliance will prove strategically vital to the U.S. in the long run amid China's huge annual investments and its repetitive stance on Taiwan. As Laurie Giandomenico, MITRE's chief acceleration officer, puts it: "By forging innovative partnerships based on trust and neutrality, Intel, Micron, Analog Devices, and MITRE Engenuity through the Semiconductor Alliance are aligning the interest of industry, government, and universities to collaborate and grow the semiconductor industry on U.S. soil."

Intel reiterated that it expects the majority of its 2023 products to be sourced internally with its 7nm process. The company is considering leveraging foundries partners such as TSMC and Samsung to manufacture its next-generation chips. Intel continues to make solid progress on its 7nm processes and is on track to launch its first product Meteor Lake (client CPU) in the second quarter of 2021 and Granite Rapids (server CPU) in 2023. We like the progress on the 7nm development, as Intel appears to have resolved prior issues and embraced extreme ultraviolet.

Allies Joining Hands to Strengthen the Semiconductor Supply Chain

On April 12, 2022, Semiconductor Industry Association (SIA) signed a memorandum of understanding with the India Electronics and Semiconductor Association (IESA) to identify potential areas of collaboration between the U.S. and India. The Indian government announced a $10 billion Semicon India Program to develop a self-reliant semiconductor ecosystem with the help of SIA. According to the IESA's chairman Rajeev Khushu, 20% of the global workforce in semiconductor design comes from India, which is the country's biggest strength. The Indian semiconductor market is currently valued at $15 billion and is estimated to reach $63 billion, according to the Ministry of Electronics and Information Technology (MeitY). TSMC and UMC are currently reportedly in talks with the Tata Group to develop an outsourced semiconductor assembly and test (OSAT) facility, with an initial investment of $300 million. CFRA believes that despite India can't be mentioned along the lines of top semiconductor manufacturing countries, the abundant engineering talent and cheaper labor force can be well utilized in the semiconductor supply chain, especially in chip design.

Foundry Equipment: TSMC and Samsung Push Spending Higher

Foundries are companies that serve chipmakers looking to outsource their manufacturing operations. TSMC is the largest participant in this highly concentrated segment. Other foundries include GlobalFoundries, United Microelectronics Corp. (UMC), and Semiconductor Manufacturing International Corp. (SMIC). Samsung has also aggressively ramped up its capacity over the last several years and is now a major foundry player. However, TSMC may be ahead of Samsung in making the most advanced 3nm node chips, as indicated by its larger extreme ultraviolet (EUV) lithography machine installation numbers and the possibility it will be the first foundry to roll out 3nm trial runs in the second half of 2022 with revenue contribution in 2023, mentioned in TSMC's Q2 2022 earnings call. TSMC and Samsung have also forecasted that 2nm chip production is estimated to enter production by the end of 2025.

Capital spending from the foundry players is set to rise considerably in 2021 and 2022 (*e.g.,* TSMC announced plans to invest $100 billion in capex from 2021 to 2023). Most of the spending will likely be concentrated on more capacity expansion at advanced technology nodes, with foundry powerhouse TSMC leading the way. China is also ramping up efforts to build a local semiconductor manufacturing business so that it doesn't need to be as dependent on the U.S., given trade tensions in recent years. The combination of these factors means significantly higher revenue potential for the chip equipment players over the next two years within an industry that typically goes through significant boom and bust periods.

Operating Environment

Specialization and Going Fabless

Although diversification has made some companies successful, the current trend leans toward specialization, in CFRA's view. This is due to several factors, including the rising costs of conducting research and building wafer fabrication plants (fabs), the proliferation of semiconductor usage in most end markets, and the advantages of owning patents and having a deep knowledge base about specific products. When companies focus their research on particular product areas, they can potentially develop a design advantage that, if it persists for a business cycle or two, may force competitors to shift their focus.

Going fabless – outsourcing semiconductor manufacturing operations – is another kind of specialization seen in the Semiconductors sub-industry. A growing number of firms are choosing to become dedicated design companies, which allows them to focus resources on core designing competencies and less on complex and expensive manufacturing processes. Without internal manufacturing operations, fabless or fab-lite firms rely on contract manufacturers or foundry partners to manufacture their products.

As chipmakers shed internal manufacturing, foundries are gaining importance in the industry. TSMC is the world's biggest dedicated chip foundry. Founded in 1987, the company played a key role in developing the stand-alone foundry strategy. TSMC is also one of the industry's technological leaders, offering advanced manufacturing processes. The company manufactures chips for a wide range of applications for many different end markets (including computer, communications, automotive, industrial, and consumer electronics), but makes relatively few memory chips. The world's top foundries are in the Asia-Pacific region.

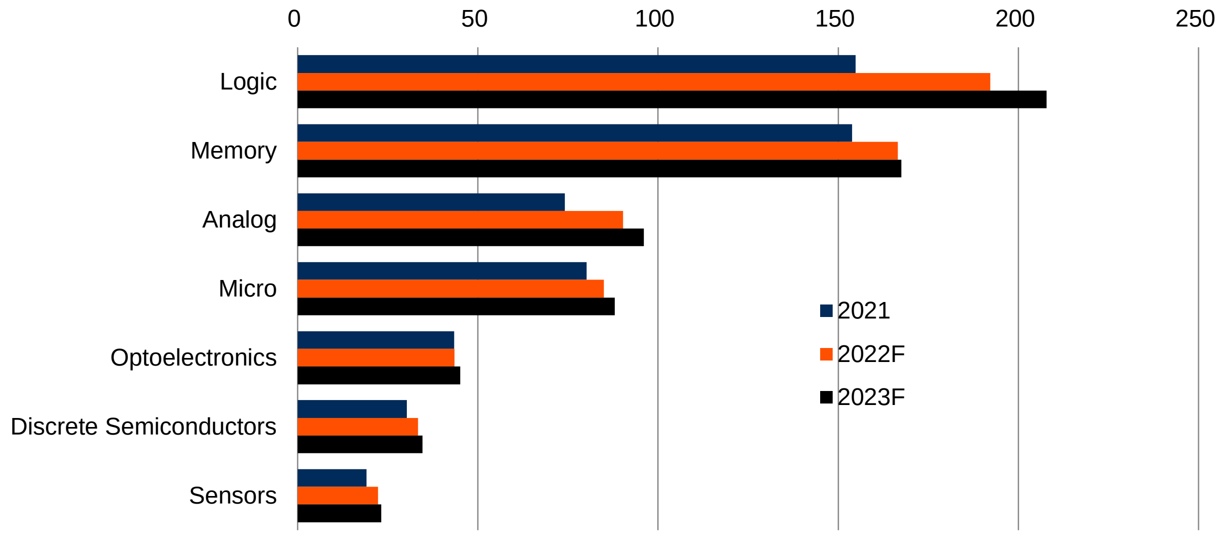
Digitization Supports Analog Sales

Ironically, as more information is digitized, more analog chips are required to assist the digital chips that process, transmit, and store information in the digital language of zeroes and ones. Analog or "linear" semiconductors handle continuous signals found in the real world, such as sound, light, heat, and pressure. For example, a mobile phone has a digital signal processor (DSP) at its heart but relies on a cluster of analog chips around the DSP chip to convert the voice signals to digital format for manipulation by the DSP, then translate them back to analog format for listening. Analog chips are also needed to manage power usage, which is particularly important for portable electronics, where battery life is a key product feature.

An important factor in analog's attractiveness is its relatively steady and profitable business model, as demonstrated over the past decade by many of the large analog players, including Texas Instruments and Analog Devices. Analog companies tend to have thousands of products and a very broad customer base, which lend stability to the revenue stream. In March 2017, Analog Devices completed its acquisition of Linear Technology, creating a dominant player in the analog chips business. In the summer of 2021, Analog Devices completed its acquisition of Maxim Integrated Products in an all-stock transaction – with Maxim shareholders receiving 0.63 of Analog's common stock for each Maxim common stock they hold (valued at approximately $21.8 billion) – strengthening its position as an analog semiconductor leader with increased breadth and scale across multiple attractive end markets.

Analog chips are also appealing because they are not commodity products. The market is fractured: thousands of designs are available, and many analog suppliers compete for the analog spots on proposed circuit boards. However, when a company wins a spot in a customer's product, the price is apt to be fixed for the run of the product – often a year or so – which makes for greater price stability than in many digital markets, where commodity pricing pressures prevail. Analog products typically contain high proprietary design content and are often sole-sourced, with equivalent products available from only a limited number of other analog chipmakers. In addition, analog products typically have longer product life cycles than digital products, are less subject to competition from Asian producers, and have lower capital requirements for production facilities.

GLOBAL CHIP SALES BY TYPE
(ranked by 2023 forecast sales, in $, billions)



F-Forecast. Spring 2022 Q2 update.
Source: World Semiconductor Trade Statistics.

A key barrier to entry in the analog business is the limited pool of analog circuit designers. The skill set is different for analog engineers than for digital designers, and companies say that it takes a decade of practical experience beyond graduate education to fully develop an analog engineer's skills. Thus, while the world wants more electronic gadgets that monitor and digitize real-world phenomena, the analog chips that help DSPs make that happen are at a premium.

Lithography Leads the Way to Lower Technology Nodes
Semiconductor equipment companies are positioned to benefit from future technology node transitions more than ever before. Semiconductor equipment companies are currently experiencing the perfect storm, benefiting from sustainably higher wafer fabrication equipment (WFE) spending and the newly adopted roadmap for the technology transition to smaller semiconductor nodes (5nm, 3nm, 1nm, etc.).

The transition from immersion systems to extreme ultraviolet lithography (EUV) systems has caused a domino effect for the semiconductor equipment space, creating market share shift opportunities in various processes, like inspection, deposition, etch, and more. This inflection has also resulted in the profound and sustainable growth of longer-term services revenue for several semiconductor equipment names (e.g., Applied Materials Inc. and KLA Corporation) that are reducing their exposure to cyclical downturns. In CFRA's view, it is more likely for Microsoft to lose all its market share with PCs than for ASML to lose its lithography monopoly for leading edge chips. It would take any emerging competitor more than a decade to enter the EUV system space, and by then, ASML would have newer lithography systems (e.g., High-NA) for the most advanced chips. The legacy systems to EUV are called *immersion systems*, which have long been known as the workhorses of the semiconductor industry. But the most advanced chip manufacturers are trading in their horses for spaceships, and the spaceship manufacturer is far from the only beneficiary.

EUV adoption not only allows for technological advances but provides ROI to leading-edge chip makers that embrace EUV over legacy processes. Using extreme ultraviolet lithography (EUV) provides value to customers in three forms: fewer defects, reductions in cost, and shorter cycle times. Manufacturing leading-edge chips with legacy technologies like immersion lithography involves a significant increase in process steps related to very large multi-patterning schemes. Using EUV reduces the number of lithography layers and, as a result, reduces the number of process steps. Because every layer requires some additional step to support patterning, this is the best way to reduce defects, improve cycle times, and reduce costs.

The increase in process control steps as semiconductor chips become smaller has been a driving factor in rising manufacturing costs, but EUV is the solution. The number of process steps has climbed significantly over the years as leading-edge chips tick down nodes but adopting EUV lithography rather than multi-patterning techniques with legacy lithography machines can lead to up to a 30% reduction in process steps from ASML's expectations (for DRAM customers). This reduction in process steps can drive significant ROI for ASML customers, and the continued adoption of EUV systems is also expected to result in at least a two-fold increase in wafer moves per year in 2025 compared to 2021 levels. This increase in wafers exposed to EUV is driven by both growing availability of systems and increased productivity of fabs. EUV, although not a new technology, is still in the infancy of high-volume manufacturing. Between 2021 and 2025, ASML is expecting a productivity increase for machines of between 25% and 60% and a 35% reduction in cycle times.

We think that the elevated levels of WFE are expected to be the new normal. WFE was in the mid-$80 billion range in 2021 and is expected to break over $100 billion in 2022. The semiconductor shortage, brought on by record demand and supply chain issues related to the COVID-19 pandemic, created a sense of urgency to increase capacity for both large semiconductor companies and entire countries, the latter noticing the issues related to not having their own production facilities domestically and the potential harm to their economies with the current over-allocation to China for certain supply chains. Lithography's wallet share of the WFE market has been between 18% and 25% for the last decade. However, EUV systems have climbed significantly, from less than 1% of the lithography market in 2012 to more than 35% of the market in 2021. We see EUV system sales rising to approximately 45% of the lithography market by 2025. Although EUV systems are the future for leading-edge chips, we expect the United States and Europe to begin increasing their own chip manufacturing presences through smaller and less efficient fabs, which benefits equipment suppliers but also places a ceiling on EUV's wallet share within the lithography market for the foreseeable future.

Regulatory Update

The Biden administration has banned the export of semiconductors and sensitive technology to Russia, with Russian retaliation a likely possibility. The conflict taking place between Russia and Ukraine will likely have broad implications, both good and bad, for the chip space ahead. Directly, neither Russia nor Ukraine is an important part of the global semiconductor supply chain because no major semiconductor giant firms are headquartered in these two countries. However, it will likely have implications in terms of supply availability for certain chips in the coming months. Recent turmoil also further reinforces the commitment by the U.S. as well as other global governments to further regionalize supply chains.

The semiconductor industry, including Taiwan Semiconductor Manufacturing, has halted sales to Russia following U.S. sanctions aimed to cut off the region's high-tech imports and constrain the country's ability to diversify its economy and support its military. The ban, which is also being enacted by major U.S. allies, is designed to restrict deliveries to defense and other high-tech buyers in the aerospace and maritime technology sectors, but not to block deliveries of consumer electronics. For instance, the sale of iPhones will not be curtailed, but we note that Apple has taken the proactive step of halting product sales to the region. That said, we think that Russia is unlikely to just sit and watch bans being placed across the globe. Rather, they will look to potentially retaliate against the U.S. and other Western regions by cutting off the supply of key components like neon gas, which is surely to create more headaches for the broader supply chain. Russian steel manufacturing plants produce crude neon, which is purified in Ukraine, according to Techcet.

China's New Five-Year Plan Looks for Greater Self-Sufficiency from U.S. Chipmakers

In response to the widening U.S. crackdown, China's political leaders have endorsed a five-year growth plan to increase domestic self-sufficiency in chip manufacturing. China stated that it will focus on R&D in integrated circuit design tools, key equipment and key materials as part of its 14th five-year plan, which would boost the R&D spending by more than 7% annually over the five years to the end of 2025. SMIC, backed by the China Integrated Circuit Industry Investment Fund as well as Singapore's sovereign fund GIC Pte and the Abu Dhabi Investment Authority, is expected to play a central role in that overall effort. However, SMIC remains three to five years behind industry leaders Intel, Samsung, and TSMC in terms of node technology; and we think it has a long way to be a global competitor.

China doesn't have the companies that can design and make the tools that its chip manufacturers require – it relies on companies from other countries. China imports more than $300 billion worth of integrated circuits each year and its semiconductor developers rely on U.S.-made chip design tools and patents, as well as critical manufacturing technologies from U.S. companies. However, supplies were just around 15.9% of its chips domestically. Given its overreliance on foreign technology, the Chinese government has been desperate to fast-track development of a domestic semiconductor business to attain "chip independence".

The Creating Helpful Incentives to Produce Semiconductors (CHIPS Act)

On August 9, 2022, the CHIPS Act was signed into law to boost US competitiveness, innovation and national security. The CHIPS Act directs $280 billion in spending over the next ten years. $200 billion from this will go to scientific R&D and commercialization. $52.7 billion is for semiconductor manufacturing, R&D, and workforce development, with another $24 billion worth of tax credits for chip production. $3 billion is slated for programs aimed at leading-edge technology and wireless supply chains.

According to the US Department of Commerce, the semiconductor shortages dented US economic growth by nearly a quarter-trillion dollars in 2021. To expand domestic manufacturing of mature and advanced semiconductors, the Department of Commerce will oversee $50 billion in investments over five years, including $11 billion for advanced semiconductor R&D and $39 billion to accelerate and drive domestic chip production ($6 billion of which can cover direct loans and loan guarantees).

U.S. Applies Restrict Sale of Semiconductors and Chip-making Equipment to China

The U.S. Department of Commerce has deployed sweeping regulations limiting the sale of semiconductors and chip-making equipment to Chinese customers. The restrictions cover production of logic chips using nonplanar transistors made with 16nm or anything more advanced than that, 18nm DRAM chips, and NAND chips with 128 layers or more. Nvidia has stated that due to the restrictions, they stand to lose approximately $400 million in potential sales to China in the third quarter of 2022, even as they are actively seeking exemptions. *Reuters* reported that KLA Corp will stop sales to China-based customers as it works to comply with the new export rules from the U.S. slated to curb the use of advanced chips in Chinese military applications. China represents KLA's largest geographic market, bringing in nearly 30% of its total revenue in the last fiscal year that ended in June, according to the company's filings.

Similarly, the European Union (EU) is considering building an advanced semiconductor factory in Europe in an attempt to avoid relying on the U.S. and Asia for technology at the heart of some of its major industries. The EU enacted a new goal of doubling its chip manufacturing output by 2030 under its new Digital Compass plan. The plan aims to boost "digital sovereignty" by funding various high-tech initiatives.

Other than doubling chip output, the EU also wants all households to have 5G access and gigabit internet connectivity by 2030 and all public services to be available online in every member state. Funding for these and other projects will come from the EU's €672.5 billion ($800 billion) coronavirus response fund, with 20% of this money earmarked for tech investment.

The EU's ambition to produce more semiconductor chips is particularly notable. Maintaining a steady supply of these chips has become a pressing concern for nations around the world as supply chain disruptions caused by the pandemic and the U.S.-China trade war have affected global supplies. As with the flow of key resources like oil, access to cutting-edge chips is essential for many industries and products, from iPhones to cars. Currently, the bulk of production is concentrated in Asia, particularly in Taiwan and Korea.

On March 15, 2022, Intel announced the first phase of plans to invest almost €80 billion in the EU over the next 10 years along the semiconductor value chain ranging from research and development to manufacturing to state-of-the-art packaging technologies. €17 billion will be invested initially into a semiconductor fab mega-site in Germany, to create a new R&D and design hub in France, and to invest in R&D, manufacturing, and foundry services in Ireland, Italy, Poland, and Spain. Intel plans to bring its most advanced technology to Europe, creating a European chip ecosystem and addressing the need for a more balanced and resilient supply chain.

M&A Environment

The Semiconductors & Semiconductor Equipment industry, along with the overall technology supply chain, remains in a multi-year period of consolidation. The technology hardware end markets such as smartphones, tablets, and PCs have been slowing, maturing, or declining, and while wearables and the connected car and home are good long-term opportunities, these areas represent a small percentage of the revenue potential for the supply chain. As a result, CFRA believes that there is now a need to grow inorganically.

Attractive balance sheets and customer consolidation across the supply chain are other obvious reasons to think that more consolidation is ahead. The ultra-low interest rate environment could also spark an acceleration of deals, in CFRA's view. Finally, we note that the supply chain is a game of scale, and the fear of being left behind if others are consolidating may be the biggest reason to project more deals for the industry.

Semiconductor Space Remains in a Multi-year Period of Consolidation

After experiencing two years of relatively quiet M&A activity, chip deals came back in 2020. We attribute the softness in 2018 and 2019 to geopolitical uncertainties, specifically with China, as it created a period where several large-scale deals failed to come to fruition. The relationship between China and the U.S. seems to be rocky currently, as bans on advanced chip sales to China do not help M&A activities, especially if it involves Chinese companies that are on the entity list.

We think the major reasons for additional chip M&A remain intact. Benefits from scale within an industry largely dependent on volume and inorganic growth are the primary reasons we are seeing consolidation in the space. Despite the soured relationship with China, CFRA believes cross-border M&A activity will continue to go on as semiconductor firms will avoid Chinese semiconductor firms for now and focus on firms in other countries.

NOTABLE M&A ACTIVITY

(deals of at least $1 billion, as of October 19, 2022)

DATE ANNOUNCED	BUYER	TARGET	TRANSACTION VALUE ($M)	TRANSACTION STATUS	DATE CLOSED
07/11/2022	Beijing Zhiguangxin Holding Co.	Tsinghua Unigroup Co.,Ltd	8,124	Closed	07/11/2022
02/15/2022	Intel	Tower Semiconductor Ltd	5,433	Announced	-
05/05/2022	MaxLinear Inc	Silicon Motion Technology Corp	3,583	Announced	-

Sources: CFRA, S&P Global Market Intelligence.

HOW THE INDUSTRY OPERATES

Since the mid-1990s, the Semiconductors & Semiconductor Equipment industry has contributed significantly to global economic growth. To varying degrees, semiconductors have affected economies around the world by providing the foundation for technological innovations that have led to the "Information Age." The industry's ability to produce chips with rising performance and declining costs has been at the heart of progressive advances in computing, communications, and myriad electronic applications.

Transistor Race Sets the Industry Structure

Since the invention of the first transistor, semiconductors have directly or indirectly spawned technological advances in most devices in existence. From the early 1900s to the 1950s, vacuum tubes were the primary electronic components of electrical products. They adequately performed the important tasks of switching (turning a current on and off) and amplification (receiving and magnifying a small signal while retaining its electrical characteristics). However, vacuum tubes were fragile, bulky, unreliable, and power-hungry, and produced considerable heat.

The invention of the transistor in 1947 by John Bardeen, William Shockley, and Walter Brattain of Bell Laboratories overcame the inherent limitations of vacuum tubes. Transistors offered the electrical functioning of the vacuum tube, but with the advantages of solid state: no vacuum, small size, low weight, low-power requirements, and a long lifetime. The invention stimulated the design of increasingly complex circuits containing thousands of discrete components, such as transistors, diodes, rectifiers, and capacitors. For their work on the transistor, the three inventors shared the 1956 Nobel Prize in physics.

In 1958, Jack Kilby of Texas Instruments Inc. conceived of and proved the viability of integrating a transistor with resistors and capacitors on a single semiconductor chip – also called an "integrated circuit" (IC). This achievement, along with Dr. Jean Hoerni and Robert Noyce's idea of "junction isolations" for planar interconnections, underpins the great progress of intergrated circuits (ICs) and IT. By the late 1960s, 90% of all electronic components produced were ICs. Mr. Kilby was awarded half of the 2000 Nobel Prize in Physics for his pioneering work in integrated circuitry; Zhores Alferov and Herbert Kroemer won the other half for developing semiconductor heterostructures used in high-speed electronics and optoelectronics.

The invention of the IC was a landmark achievement that provided the catalyst for further electronic advances. In 1971, Intel Corp. put the key elements of a programmable computer on a single chip, the Intel 4004 microprocessor, which ran at 108 kilohertz and served as a component in a calculator. In 1974, Intel offered the more powerful 8080 microprocessor, which quickly led to the advent of PCs. In 1975, IBM introduced an early model PC, and Apple Computer Inc. (now Apple Inc.) introduced its Apple II in 1976. However, the most popular computer by far was the Commodore 64 (C64). During its lifetime, it sold between 12.5 million and 17 million units, making it the best-selling computer of that time. In fact, from 1983 to 1986, the C64 dominated the market with a market share between 30% and 40%. The growing demand for technology that is able to store, analyze, and transmit data promoted rapid industry growth. Today, advanced chips permit the development of Internet applications and the expansion of extensive wireless communications systems.

Innovation: Moore's Law Sets the Pace

The continual improvement in semiconductor technology is expressed in the concept of Moore's Law, named after Gordon Moore, a co-founder of Intel. In 1965, Dr. Moore observed that, since the invention of the IC in 1958, the number of transistors on a chip had doubled every year, and he predicted that the trend would continue "for at least 10 years". His prediction has proved to be uncannily accurate for nearly half a century, in part because the law is now used in the semiconductors & semiconductor equipment industry to guide long-term planning and to set research and development (R&D) targets. (The doubling period is sometimes noted as every 18 months, though that timeframe refers to a doubling in chip performance – a measure that combines the effect of more transistors and their being faster – that was predicted in 1975 by Intel executive David House.)

R&D and Capital Equipment Outlays

The lifeblood of the industry is R&D, which can generate many forms of competitive advantage, including licensing intellectual property (as Qualcomm does), product specialization (Intel's Altera and Xilinx have dominated the multibillion-dollar market for programmable logic chips), developing core integration capabilities (Broadcom), or focusing on advanced manufacturing processes (Intel). CFRA estimates semiconductor capital spending to increase by 13.7% in 2021 to $115.0 billion, after a flat growth of 13.7% to $101.1 billion in 2020.

Linewidths, Wafer Sizes Are the Targets

In general, chipmakers have focused on two areas of technological improvement: smaller linewidths (the size of the transistor in an IC) and larger wafer sizes. Remarkable accomplishments in lithographic technology have permitted chipmakers to shrink device sizes at a persistent rate. The economic benefits of this trend are enormous, as the ability to condense more chips on a given expanse of silicon greatly decreases per-unit costs. Shifts to a larger wafer size have occurred less frequently – once or twice a decade throughout the history of the industry. Chips are currently being made on wafers in sizes of 200 millimeters (mm) and 300mm. As wafer diameter increases, more chips can fit on the wafer, allowing the fixed costs of processing a wafer to be spread over a higher number of chips, thereby improving production efficiency.

Managing the Cost of Manufacturing by Outsourcing

By any measure, the cost of manufacturing to stay at the leading edge of technology continues to increase. One of the largest costs is that of manufacturing. In 1984, construction costs for a state-of-the-art wafer fabrication facility, a "fab," were about $10 million. Currently, building a leading-edge fab can cost $3 billion–$8 billion, depending on the planned capacity and up to $10 billion as the industry ramps to 450mm wafer production, according to Intel. Further, the company estimates that one has to have annual revenue of around $9 billion–$10 billion to support a leading-edge fab. An industry report noted that costs related to fab and process development are rising 13% annually. The cost of building a leading-edge fab soared to $10 billion in recent years from $1.7 billion in 2001, according to a report from McKinsey & Co. Given this level of capital and revenue, only a few have the ability to maintain their own fabs. As a result, many semiconductor companies have outsourced manufacturing. The decision allows companies to focus resources on core designing competencies and less on complex and expensive manufacturing processes.

Factors affecting the decision of where to locate include proximity to markets, availability of an appropriately skilled labor force, and cost considerations involving labor, construction, transportation, and taxation. Many factories that develop and produce cutting-edge chips for computers and high-end communication networks are located in the U.S. – for example, in Silicon Valley and across southern California. Concentrations of wafer fabs also are found around Boston's Route 128 corridor and in Dallas and Austin, Texas. While Silicon Valley is a supportive environment for chipmaking, many new plant builders are seeking lower construction and living costs in places such as Phoenix, Arizona, and Portland, Oregon. Circuit design and research centers (as opposed to wafer fabs) are even more scattered; companies attempt to attract scarce engineering talent by situating their workplaces in smaller towns that offer desirable lifestyles.

Because they do not construct or maintain their own production facilities, fabless companies (*i.e.*, those that contract manufacturing operations to chip foundries) enjoy certain advantages that chipmakers with integrated operations do not. Fabless firms generally have higher and less volatile profit margins and healthier cash flows, reflecting this business model's relative lack of capital investment. In addition, fabless companies are able to devote a higher percentage of their resources to design R&D, which has enabled them to lead the way in offering innovative chips with smaller linewidths.

A fabless company's major disadvantage is that its access to foundry space is often limited during periods of rapid industry growth. Thus, when product demand is strong, fabless firms may be unable to procure enough chips to satisfy their customers' requirements. Despite this potentially negative factor, the number of fabless companies will likely continue to grow.

Product Cyclicality

Despite the high barriers to entry, the semiconductors & semiconductor equipment industry manufactures products with various life cycles. Short cycles can be seen in consumer-oriented devices such as cell phones, where a design win could last for one to three years (the life cycle of a handset). Long cycles, in contrast, can last for 10–30 years, as in the life cycles of machine automation, automotive, and industrial products.

These variations can fall along the lines of Clayton Christensen's *The Innovator's Dilemma* of disruptive and sustaining technologies. The new applications found in phones and tablets – such as touch, global positioning system (GPS), and voice recognition – are disruptive technologies. They have short life cycles due to constant changes in standards, performance, and technology that cause material share shifts among vendors from one design win to the next. In the sustaining category are products such as analog chips; their long-life cycles typically include improvements on existing functionality, but share shifts are rarer here.

Customer and Distribution Ecosystem

Semiconductors are sold both directly to end customers (called original equipment manufacturers, or OEMs) and indirectly through distributors. Sales run the gamut, from being nearly 100% OEM-based to 100% distribution- or channel-based, but they are most often within a 30%–70% range. Companies serving the communications market tend to sell directly to OEMs such as Cisco or Alcatel-Lucent, while those serving the PC, consumer, and analog segments typically make a greater share of their sales through distributors.

Types of Chips

The semiconductors & semiconductor equipment industry comprises several broad product segments that, in turn, contain hundreds of sub-segments. This section describes various segments of the market and their characteristics.

Bipolar Versus Metal Oxide

Semiconductor chips today are based on either bipolar or metal-oxide technologies.

◆ **Bipolar technology.** Bipolar transistors work by sending a pulse across a "base," allowing an electrical signal to flow between "emitters" and "collectors." Used to create the first transistor and IC, bipolar technology remains in use today in a number of high-speed, high-radio frequency applications. Because it consumes relatively large amounts of energy, though, it has fallen out of favor in the most common computing devices.

◆ **Metal-oxide technology.** The dominant force in chip design today is metal-oxide semiconductor (MOS) technology. MOS chips combine layers of conductive metal, oxide, and semiconductor material to control the flow of electrical signals.

Early MOS designs included positive channel MOS (PMOS) and negative channel MOS (NMOS), which used positively and negatively charged base materials to enable the transmission of electrical signals. Complementary MOS (CMOS) chips reduce power consumption by integrating both PMOS and NMOS transistors onto a single chip. Most chips produced today are based on CMOS technology, which is used in each of the major chip types discussed in this section.

Discrete Semiconductors

Discrete semiconductors, or "discretes," contain only one device per chip and are designed to perform a single electrical function. These nonintegrated devices, which include transistors, diodes, resistors, and capacitors, can be used individually (for simple electrical switching and processing applications) or as parts of larger circuit designs.

Analog Semiconductors

Analog semiconductors, also known as linear circuits, process continuous signals from real-world phenomena, such as light, heat, pressure, and sound. They are used in a variety of applications, such as computers, cellphones, and industrial products. Types of analog chips include the following:

- *Amplifiers*, which augment the voltage of a device;
- *Voltage regulators*, which control the voltage of a device at a specific level;
- *Interface circuits*, which act as an intermediary to transfer signals between or within electronic systems;
- *Data converters*, which change analog signals into digital signals and vice versa.

Digital Semiconductors

Digital semiconductors process information in binary form as a series of zeroes and ones. The three types of digital semiconductors are microprocessors, memory chips, and logic devices.

◆ **Microprocessors.** Also known as central processing units (CPUs), microprocessors are frequently described as the "brains" of a computer because they have complex logic circuitry that controls the central processing of data in PCs and other computers. Although they contain the basic arithmetic, logic, and control elements of a computer, they require external memory to function. Well-known microprocessors include Intel's Pentium and Core brands, which are used in the vast majority of PCs worldwide. Microprocessors also are used in other applications, such as consumer electronics and telecommunications, automotive, and industrial equipment.

◆ **Memory chips.** These devices store programming instructions and data. Memory chips often are classified as volatile or nonvolatile. Volatile devices lose their retained information when power is interrupted, while nonvolatile devices keep all their stored data when power is interrupted. Types of memory semiconductors include dynamic random access memory (DRAM), Static random access memory (SRAM), and flash memory.

- **DRAM.** These semiconductor devices, which store digital information in the form of bits, provide high-speed data storage and retrieval. As high-density, low-cost-per-bit memory components, DRAM chips are the most widely used semiconductor devices in PC systems. Chipmakers have also developed synchronous DRAM (SDRAM), which is faster than regular DRAM, partly due to an input that synchronizes all operations. In 2002, double data rate (DDR) features began to be commonly incorporated with SDRAM chips; these systems permit faster speeds by allowing data to be transferred at both the beginning and the end of a clock cycle (the time interval of an electronic pulse). As a result, DDR SDRAM has become a popular memory chip category. The DRAM industry shifted production in 2006 toward a faster type of DDR DRAM known as DDR2. Samsung Electronics Co. Ltd. and many other memory makers developed DDR3 samples in 2005 and 2006, and began volume production in early 2007. As early as 2011, these memory makers went on to develop DDR4, which delivers about twice the speed and memory bandwidth of DDR3. Mass production for DDR4 began in 2013. A new version of DRAM, the DDR5, is designed to reduce power consumption, while doubling bandwidth. The standard, originally targeted for 2018, was released in July 2020.

- **SRAM**. These devices are memory circuits used in computers, data communications, telecommunications, and other electronic systems. SRAMs do not require electrical refreshment of memory contents to ensure data integrity, so they operate at high speeds. SRAMs involve substantially more circuitry than DRAMs, and thus have higher production costs and selling prices.

- **Flash memory**. These nonvolatile semiconductors are electronically erasable and programmable. Unlike other memory components, flash chips require that information be written in fixed blocks instead of byte by byte, greatly increasing the speed at which data can be recorded and erased. They represent the latest technology in nonvolatile devices, which also include erasable programmable read-only memories (EPROMs) and electrically erasable programmable read-only memories (EEPROMs). Flash memories are used in a variety of applications, including telecommunications, computers and peripherals, and consumer electronics.

- **NAND flash memory**. This type of flash memory is slow in reading data but fast in writing; it has become popular for products where large data storage or fast writing capability are needed, such as MP3 music players and digital cameras. The architecture's name is a reference to Boolean logic.

- **NOR flash memory**. This type of flash memory has relatively fast data reading capabilities and is commonly used to store executable code (*e.g.*, in mobile phones and personal digital assistants).

◆ **Logic devices.** The interchange and manipulation of data within a system requires logic devices. While designers of electronic systems use a relatively small number of standard architectures to meet their microprocessor and memory needs, they require a wide variety of logic circuits in order to achieve end-product differentiation. Types of logic chips include:

- **CPLDs and FPGAs**. Complex programmable logic devices (CPLDs) and field programmable gate arrays (FPGAs) are standard products designed to suit the needs of many customers and applications. Purchased by electronics manufacturers in a "blank" state, they can be custom-configured into specific logic functions by programming the devices with electrical signals.

- **ASICs.** Application-specific integrated circuits (ASICs) are chips that are custom designed for a particular customer for a specific application. Used in communications and computer products, they have a particularly strong presence in the consumer electronics market.

◆ **Microperipherals.** These chips augment the operations of overall CPU system performance. They encompass chips that offer systems support, such as clocks and memory management devices; they enable communications between a CPU and other components; they enhance graphics and imaging capabilities; and they control devices such as the computer mouse and keyboard.

◆ **Microcontrollers.** These devices perform computer functions without need for any external support circuitry. They are the "brains" of most electronics that are less complex than PCs. In contrast to the much larger microprocessor, the smaller, simpler microcontroller contains memory components, input/output controls, and a clock, all on a single chip. Microcontrollers can perform simple tasks as stand-alone devices, but sometimes require peripheral memory or logic devices to carry out complex tasks. Microcontrollers are used widely in many products, including toys, televisions, digital cameras, and automobile engines.

◆ **Standard cell logic.** These devices act as building blocks that ease the process of designing and building complex logic functions. These individually packaged and tested groups of transistors perform predetermined Boolean logic functions.

◆ **Optoelectronics.** These chips both transmit and receive optical signals, including continuous wave laser signals and other light-wave signals. (This category excludes liquid crystal displays, incandescent displays, and other optical displays, which are categorized separately as electronic components.) Optoelectronic components are used primarily in fiber-optic networking devices such as switches, routers, and hubs.

◆ **Digital signal processors (DSP).** These digital chips can receive, decode, process, enhance, and encode data converted from analog format at extremely fast, real-time speeds. Used in products such as DVD players, digital cameras, and wireless telephones, DSPs enable high-speed digital transmission of sound, voice, and video signals. DSPs require analog-to-digital and digital-to-analog signal converters in order to function, though the data converters often are integrated directly on DSP chips.

How Chips Are Made

Before describing the different types of semiconductor equipment, it is necessary to explain the steps in the chip manufacturing process. Semiconductors are produced through what is perhaps the most advanced and complex manufacturing process in the world, involving an average of 500 individual process steps.

The two basic stages in chip production are known as the “front end” and the “back end.” The front end involves materials preparation (circuit design, photomask making, and the manufacture of raw wafers) and wafer processing (repeated cycles of deposition, etch, doping, planarization, and in-process testing). The back end consists of assembly, packaging, and final test operations.

The Wafer: A Slice of Silicon

The basic component in the manufacture of semiconductor devices is a thin, circular crystalline silicon wafer. Wafers are cut from a silicon column fashioned from melted sand to which a seed crystal was added. Wafers today typically have a diameter of 300mm (12 inches) or 200mm (8 inches).

The wafer is cleaned throughout the manufacturing process. As device geometries on wafers shrink further, reducing contamination becomes increasingly important. To ensure that microscopic particles do not interfere with fabrication, semiconductors are manufactured in a “clean room” – a small windowless space fitted with superfine air filters. Human presence is minimized in the clean room, and production workers wear “bunny suits” that cover the entire body.

Wafer Processing

After the cut wafer receives its initial cleaning, a primary layer of ultrapure crystalline silicon is grown on the wafer’s surface, in a process called epitaxy. This epitaxial layer, or “epilayer,” performs better than the bare surface of the raw, bulk wafer in subsequent fabrication steps. Following epitaxy, the wafer is cycled through each of the major wafer process steps about 16 to 24 times, in order to create up to 25 layers of materials and as many as 12 wiring levels.

The four basic types of operations in wafer processing are layering, patterning, doping, and heat treatments. The process description that follows draws on Peter Van Zant’s textbook, *Microchip Fabrication: A Practical Guide to Semiconductor Processing* (listed in the “Industry References” section of this *Survey*).

◆ **Layering.** In layering operations, also referred to as deposition, thin films of insulating (dielectric) or conductive (metal) materials are either grown or deposited on the wafer. Layers may be grown, in a manner akin to rusting, through oxidation or nitridation. Deposition techniques include chemical vapor deposition (CVD), evaporation, and sputtering.

In CVD – the most common thin film deposition method – high heat and low pressure are applied to gaseous mixtures to facilitate the deposition of a thin film layer. Evaporation involves melting a conductive metal (often aluminum) to a liquid state, so the atoms or molecules evaporate into the chamber’s atmosphere. Sputtering (also called physical vapor deposition, or PVD) is a physical, rather than a chemical, process in which positively charged argon gas atoms strike the atoms of a target material, scattering them throughout the chamber, with some moving to the wafer’s surface.

◆ **Patterning.** Patterning involves the transfer of a circuit design to the wafer surface. This process, also known as photolithography or photomasking, is very similar to the photographic process. Microscopic images of electronic circuits are imprinted in chrome on a clear quartz plate known as a photomask or reticle.

The photomask is placed together with the wafer in a piece of equipment called a step-and-repeat projection aligner, or “stepper,” which operates like a photographic enlarger except that it typically reduces the projected image. Inside the stepper, a light source is used to project the images from the photomask onto the wafer’s surface, which is coated with a layer of light-sensitive liquid called photoresist. When light hits the photoresist layer, the exposed photoresist is rendered insoluble and hardens. The stepper then repositions the wafer so that the process can be repeated on a different section of the wafer to imprint another die with the circuit.

In a step called etching, or simply “etch,” solvents are introduced that remove the portion of the wafer layer not protected by the hardened photoresist. This leaves a pattern on the wafer that exactly matches the circuit pattern on the mask after doping (deposition). The hardened photoresist is later removed with another chemical, in a step known as strip. Both etch and strip may be performed using “wet” techniques (using liquid chemicals) or “dry” techniques (using reactive gases).

◆ **Doping.** In doping operations, specific amounts of impurities (called dopant atoms) are introduced through exposed portions of the wafer to create electrically active areas. The two doping techniques are thermal diffusion (a chemical process) and ion implantation (a physical process that is more precise).

- In *thermal diffusion*, a solid, liquid, or gaseous mixture containing the desired dopants is vaporized and allowed to contact the wafer in a heated environment. When the wafer is heated to about 1,000 degrees Celsius, the dopants are driven into the wafer and redistributed both vertically and horizontally throughout the wafer’s depth.
- In *ion implantation*, a magnetically focused beam of charged particles (ions) is used to shoot dopants into the wafer surface in a process similar to a pistol firing bullets into a wall.

◆ **Heat treatments.** In heat treatment operations, wafers are heated or cooled to achieve certain results; no materials are introduced or removed. One example is the “anneal” step, in which damage to the wafer’s crystal structure (resulting from ion implantation) is repaired by heating the wafer above 700 degrees Celsius. Heat treatments also are used to “alloy” deposited stripes of metal to the wafer to ensure proper electrical conduction. Cooling treatments are used to freeze and control water vapor, oils, gases, and other contaminants in wafer process chambers.

In-Process Testing and Smoothing

Inspection and measurement of the wafer and its individual integrated circuits (ICs) is performed throughout the wafer fabrication process. Electrical parameters are measured to verify the reliability of the entire process, and wafers are examined for unwanted particles. In-line monitoring is becoming increasingly popular (and necessary) as a way of detecting defects at the moment of production, as opposed to waiting for final test results of the finished products to discover problems. These activities are part of yield management efforts to discover, analyze, and correct inefficiencies in processing procedures.

The process step known as chemical mechanical planarization (CMP) uses a polishing procedure involving abrasive slurries to smooth the surface of a wafer after each metal interconnect layer is created. CMP began to be widely used in the 1990s. As linewidth geometries have shrunk, CMP has grown in importance. The smoothing is necessary to correct irregularities on the wafer’s surface that can impede the photolithographic process and reduce the yield.

The Back End: Assembly, Packaging, and Testing

The steps of wafer dicing, die bonding, and wire bonding are known collectively as assembly. The back end of the chip manufacturing process begins when the finished wafer is cut into individual devices with a dicing saw that uses diamond-embedded saw blades. Depending on the size of the devices (which varies widely), more than 2,400 ICs can fit on a 300mm wafer, while only 1,000 ICs can fit on a 200mm wafer. The actual yield (the percentage of usable finished devices produced per wafer) depends on the number of defects.

A die bonder takes each good IC (also known as a chip or a die) and bonds it to a package that is typically a stamped metal or ceramic leadframe. The package is then moved to a wire bonder. In order to create the electrical connection necessary for the device to function, very fine gold or aluminum wire is bonded between specific bond pads on the die and corresponding leads on the package. In an emerging alternative technology known as “flip chip,” bumps on the die make the connections to the package, thus eliminating the need for wire bonding.

Next comes packaging, which commonly involves encapsulation of the die and lead frame in molded plastic packages that protect the chips and help to dissipate heat. For chips that will operate in harsh environments, a hermetic seal can be achieved with metal and ceramic enclosures.

Finished packages are subjected to a final test process. Environmental tests check the package’s resistance to temperature change and leakage; if air can get in, then it can contaminate the chip with particles and moisture. Electrical tests ensure that the chip functions within required parametric specifications.

Test equipment includes computer-controlled mainframe testers, test heads connected to the testers, and handlers that insert the packages into the test head’s sockets. An optional burn-in test often is used to evaluate the chips in operation at various temperatures; it seeks to stress the chip and package connections to eliminate chips prone to failure early in their lifetime.

Wafers: Bigger Is Better

Historically, semiconductor manufacturers moved to a larger wafer size every seven or eight years. In the early 1970s, the standard wafer size was one and one-half to two inches. Today, standard wafer sizes are eight and 12 inches (200mm and 300mm, respectively). To process 300mm wafers, chipmakers have had to purchase new equipment, which on average costs 1.3 times as much as equipment for making 200mm wafers. Initial margins on 300mm tools were lower than those for 200mm tools, until manufacturing volumes increased and efficiencies developed. However, as the technologies matured and sales increased, 300mm sales have helped equipment makers’ revenues and margins.

Lithography: Smaller Is Better

Another critical technology for the production of devices with ever-smaller transistor sizes is imaging (or lithography) equipment, which prints complex circuit patterns onto the wafers that are the primary raw material for ICs. In a process similar to making prints from photographic negatives, lithography projects visible light (optical lithography), or x-rays or electron beams (non-optical lithography) through circuit patterns onto silicon wafers. Because it is one of the most expensive and critical steps in the manufacturing process of semiconductors, there is a need for cost-efficient enhancements to production technology.

ASML Holding NV is a major participant in the photolithography equipment industry, with its Step-and-Scan systems, which combine stepper technology with a photo-scanning method. As the size of the electronic features of semiconductors has shrunk, advanced chips’ features are now smaller than the shortest wavelength of light used in the photolithography process. The problem is analogous to that of trying to draw a one-eighth inch line with a quarter inch pen.

One way of dealing with the light-wave problem is through special photomask techniques that “trick” light into resolving very fine features. However, such tricks have caused sharp increases in the complexity (and hence the price) of photomasks. The result is that the cost of masks, and of developing new mask technologies, is spiraling out of control.

To reduce photomask costs, foundries sometimes offer multi-project wafers in which several chips share the same set of photomasks. As another cost-reduction method, chipmakers also use programmable logic chips, which are off-the-shelf chips that allow for some customization, especially when they design a chip for low-volume production. This eliminates the high fixed costs of manufacturing custom-designed chips and the need for a unique set of photomasks.

Photomask makers continue to aggressively pursue technology to reduce the cost of manufacturing photomasks. With the photomask market fairly competitive, lower costs enable photomask makers to increase their margins and/or gain market share through more competitive pricing.

Deep ultraviolet (DUV) lithography tools in production today are either krypton and fluorine, with a 248-nanometer (nm) wavelength, or argon and fluorine (193nm wavelength). Depending on the kind of chip being manufactured, krypton and fluorine light sources are used to pattern features from 250nm to as small as approximately 90nm. Argon and fluorine sources are used to pattern features of approximately 120nm but is being replaced by extreme ultraviolet (EUV) sources, which is being adopted at next generation nodes.

Immersion lithography – whereby a layer of water is inserted between the final lens element and the wafer to reduce the wavelength of the light to enable the patterning of even smaller critical dimensions – and double patterning is extending existing technology.

In double patterning applications, using one of several potential approaches, the most critical layers on the wafer will be patterned twice in order to reduce feature sizes beyond those achievable using immersion alone. When double patterning reaches its critical dimension limit, the next wavelength will involve the use of extreme ultraviolet illumination sources.

Tools of the Trade

Semiconductor equipment is typically categorized according to the two stages in chip production: front end or back end. In the long term, growth in front-end equipment will likely outpace that of the back-end segment. This reflects prospects for significant technology upgrades of front-end tools, which will enable the production of devices with smaller linewidths on larger wafers.

Front-End Tools

Front-end tools perform manufacturing steps from the creation of the silicon wafer to the production of ICs on the wafer. Wafer process equipment typically accounts for about 75% of total industry revenues from equipment sales. Other front-end equipment (including masks, wafer manufacture, and facility automation and equipment) account for another 5%.

The broad front-end category comprises photolithography equipment, deposition equipment, and etching and cleaning tools. Process diagnostics, ion implantation, and chemical mechanical polishing tools are other types of front-end manufacturing equipment.

Back-End Tools

Back-end tools comprise equipment used in the latter stages of manufacturing, after ICs have been produced on the wafer, and typically account for about 20% of total industry revenues from equipment sales. These steps include assembly, packaging, handling, and testing of individual chips. The market leaders in this segment are Advantest Corp. and Teradyne Inc.

HOW TO ANALYZE A COMPANY IN THIS INDUSTRY

Like many areas of technology, the Semiconductors & Semiconductor Equipment industry's business environment is highly competitive and subject to rapid and often unanticipated changes. This dynamic business climate poses significant challenges for a firm's management team and requires that companies adapt quickly to evolving industry conditions.

Anticipating the Ups and Downs
It is important to appreciate that the industry has been highly cyclical, historically, and to analyze a company's performance and valuation within that context. Cycles typically last for three to seven years, and industry revenues have fluctuated by 30% or more in either direction.

Due to the industry's cyclicality (especially following the 2000 to 2002 cyclical decline and the years of losses that followed), companies and investors place a strong emphasis on total profitability across the cycle. In recent years, companies in the semiconductor & semiconductor equipment industry have been reducing the high fixed costs of their businesses by outsourcing noncore functions. Some examples of this outsourcing include chip fabrication (to foundries), testing (to subcontractors that offer chip testing and package services), photomask manufacturing, and the manufacture of subassemblies, to varying degrees, by equipment makers.

Looking forward, CFRA sees a decline in the degree of cyclicality, as a more diversified spectrum of geographic and end-product markets lead to less volatility in demand for chips. We think that as more and better information is shared across the industry through tighter supply chains, the severity of the divergences from the natural supply-demand equilibrium will decline, leading to softer cycles.

Qualitative Factors

An examination of historical results gives a strong indication of management's past success in running an enterprise in various stages of the business and product cycles, and is a good initial guide to the future. Given the industry's highly cyclical nature, operating results for a company in the semiconductors & semiconductor equipment industry should be considered within the context of the overall market situation.

For example, operating performance during an industry downturn is an indicator of management's ability to weather storms. How a company performs relative to its competitors is key. Often, industry leaders will use a decline in business conditions to streamline operations and focus on new product offerings. Such activities position a company to outperform its peers during the next upcycle.

Quantitative Factors

Ultimately, the qualitative factors discussed earlier will reveal themselves in a company's financial statements. Those firms with experienced management and strong competitive positions in attractive market segments typically will display strong financial profiles.

Looking at the Income Statement
A company's income statement provides a comprehensive review of its revenues, costs and expenses, and earnings during an accounting period. As such, it is an important tool for identifying growth and profitability trends.

In many industries, trend analysis is done mainly on a year-to-year basis (comparing current quarter results with those of the same quarter a year earlier). In a field as dynamic as the semiconductors & semiconductor equipment industry, though, it is often more revealing to examine results on a sequential basis (comparing current-quarter results with those of the immediately preceding quarter). This type of analysis will give a clearer picture of more recent changes in business conditions.

The analyst, however, should be cognizant of seasonal factors that could influence a company's quarterly results. For example, many chip companies experience a slowdown during the summer months, reflecting decreased business volume from European countries. Demand from the region typically falls in the third quarter of a calendar year but picks up in the fourth quarter once employees have returned from vacation and companies gear up for the year-end holiday season. A similar, but less pronounced, slowdown occurs in the first quarter of the calendar year for companies doing business in certain Asian countries, where New Year's festivities can create up to a weeklong hiatus in order booking and production.

◆ **Sales and orders.** It is very important to take note of chipmakers' sales trends, as this "top-line" figure gives a general picture of the overall tone of business. The semiconductors & semiconductor equipment industry is unusual in that, under normal market conditions, prices fall at a steady rate. Consequently, semiconductor companies often report strong growth in unit sales volume, while showing flat or declining revenue trends. This dynamic increases the difficulty of forecasting future sales.

Order backlogs (orders that have been received, but not delivered) can be pushed out or canceled by the customer, so semiconductor companies do not recognize revenues until products are shipped. Beginning in 2001, this practice became even more conservative, with companies tending to recognize revenue only upon the product's full acceptance by the customer, rather than upon its departure from the producer's premises. It avoids the embarrassment of having to explain revenue shortfalls when a downturn sets in and chips that were ordered but not paid for suddenly become stranded in distribution channels. Many (though not all) companies provide order backlog data. (Order backlog is not listed on the income statement.)

Nevertheless, order trends are a good leading indicator of sales and are closely followed by analysts. The book-to-bill ratio (quarterly orders divided by quarterly sales) concisely measures order trends in relation to sales. A book-to-bill above 1.0 indicates that current orders are greater than current sales, and portends sales growth in the near term. The opposite holds true for a book-to-bill ratio below 1.0.

Due to the cyclical nature of the industry and the wide swings in sales, it is important to measure sales not only by year-over-year comparisons (such as comparing results of one year to the previous year, or one quarter to the prior quarter), but also on a sequential basis (such as quarter to quarter, or month to month). This scrutiny provides information on the cycle and can illustrate the revenue peaks and troughs effectively.

For semiconductor equipment, it is often more useful to examine trends in orders than in sales, since orders are indicative of future prospects, whereas reported sales reflect the past. Nonetheless, the analyst should be aware that companies recognize revenue only upon shipment, and orders are vulnerable to delays and cancelations—usually without any penalty on the part of the firm requesting the cancelation. Cancelations often have a strong depressing effect on order rates during an industry down cycle.

Watch Out! *When companies accelerate revenue into the current period, they are essentially "stealing" revenue from future periods. As such, the reported revenue growth during a period in which revenue has been accelerated is likely unsustainable. There are many available tactics that management can use to accelerate revenue, some of which include allocating a higher proportion of transaction price to elements delivered upfront in contracts with multiple deliverables or performance obligations, faster recognition of deferred revenue, or large shipments at period-end.*

◆ **Margins.** Profit margins for companies in the semiconductors & semiconductor equipment industry vary widely, depending on market segment characteristics and prevailing industry conditions. Other factors that influence margins include capacity utilization, raw material pricing, operational efficiencies, and product mix. Typically, firms that sell proprietary products with distinctive performance traits have higher margins than do companies that make commodity products, such as dynamic random access memory (DRAM) chips. Commodity chip producers have little or no pricing power; their profitability levels are largely dependent on market forces and their ability to keep costs low. Producers of commodity-type chips tend to be aggressive adopters of new manufacturing techniques; they spend money on machine tools to save money by lowering the average cost of producing a chip.

For semiconductor companies in the semiconductors & semiconductor equipment industry, the cost of goods sold generally includes a high level of fixed charges, largely reflecting the significant depreciation charges associated with chip companies' manufacturing plants ("fabs"). Therefore, profit margins generally move in the same direction as sales, but the magnitude of the change in profits is greater than that of sales. Since variable costs are a small part of the equation, each incremental dollar of sales produces more profit on the bottom line, as fixed costs are spread over a larger sales base. This high degree of operating leverage can result in large swings in earnings as chipmakers move through business cycles. However, the increasing use of chip foundries helps integrated chip manufacturers shift some of the fixed costs of plant ownership from their books, thereby smoothing gross margins and reducing the severity of cyclical swings in earnings.

Watch Out! *Deferred profit is essentially deferred revenue less deferred cost of goods sold. Deferred gross margin is deferred profit expressed as a percentage of deferred revenue. Trends in deferred margins may be leading indicators of trends in actual margins. Specifically, a drop in deferred margin could mean that when this deferred revenue flows through the income statement as sales, it will be recognized at a lower actual profit margin. Similarly, CFRA cautions that any margin growth related to the recognition of deferred revenue more rapidly than deferred profit (i.e. leaving more costs on the balance sheet) may not be sustainable.*

◆ **Options expense.** The extent to which the income statements of US semiconductor and IT companies could be compared with those of companies in other sectors had diminished. This divergence was the result of the former's practice of compensating many employees with stock options rather than cash. Cash wages show up immediately in the cost of goods sold, which reduces gross margin on the income statement. Stock option compensation, however, typically did not show up on the income statement until later – sometimes as dilution to earnings per share (EPS), when the company issued new shares to employees who exercised options.

This has changed. The Financial Accounting Standards Board (FASB) and Securities and Exchange Commission (SEC) announced that companies must expense stock options starting in the first interim or annual reporting period that began after June 15, 2005. Thus, stock options are now appearing as a cost of goods sold, significantly reducing reported earnings for many chip companies. Those in the semiconductors & semiconductor equipment industry argued that this change would force them to reduce their issuance of options, thus making it more difficult to attract talent and encourage strong efforts by employees. Issuing stock options has also been an important way for startup companies to conserve cash. In addition, there has been much controversy over how to value stock option expense.

For periods before the change became effective, investors were able to examine the effect of stock options compensation by comparing the pro forma EPS data calculated under Statements of Financial Accounting Standards (SFAS) Rule 123 with the company's reported EPS; the difference was stock options expense. Typically, however, these figures were available only annually, in the 10-K reports.

A company's expense line items – typically research and development (R&D) and selling, general, and administrative (SG&A) costs – should be evaluated against industry norms. (SG&A costs are sometimes broken down into two categories: marketing and selling, and general and administrative.) It is preferable for these expenses to increase more slowly than sales, but that is not always possible, especially for R&D. This is particularly true during downturns, when stronger companies invest heavily in R&D to gain market share.

Financial statement analysis would be incomplete without some discussion of return on investment (ROI), of which the most popular measure is return on equity (ROE), or net income divided by average common shareholders' equity. Again, a comparison with industry norms should prove useful, making sure to compensate for differences in operating and financial leverage and net cash positions, which can affect ROE.

Looking at the Balance Sheet

The balance sheet, or statement of financial condition, shows the status of a company's assets, liabilities, and shareholders' equity on a given date. With these data, an analyst can determine much about a company's financial health, including its liquidity, asset turnover, and capital structure.

◆ **Liquidity.** Liquidity is an important indicator of a firm's ability to fund its day-to-day operational needs. The simplest measure of liquidity is working capital, or the excess of current assets over current liabilities. Working capital represents a liquid reserve that companies can draw upon to finance the cash cycle of the business (the time required to convert raw materials into finished goods, finished goods into sales, and accounts receivable into cash). Two other liquidity measures are the current ratio (current assets divided by current liabilities) and the quick ratio (current assets less inventory, divided by current liabilities). These financial ratios show a company's ability to pay its current obligations out of current assets.

Future liquidity may be inferred from the turnover ratios for inventory and accounts receivable. Inventory turnover, calculated by dividing inventory into cost of goods sold, shows how many times a firm's inventory is sold and replaced during an accounting period. Low turnover relative to comparable firms in the semiconductors & semiconductor equipment industry is an unhealthy sign, as it indiates a firm may be carrying excess inventory, which would make it vulnerable to falling prices. Furthermore, excess inventory represents an inefficient use of capital since the investment carries a very low rate of return.

The numbers do not always tell the whole story, however. Chip companies and semiconductor equipment makers sometimes build inventory in anticipation of rising sales. While this practice may result initially in lower inventory turnover, the bullish sales forecast actually would be a positive indicator for the firm.

◆ **Accounts receivable turnover.** The accounts receivable turnover ratio is obtained by dividing total credit sales by accounts receivable during an accounting period. The ratio, which measures the number of times that the receivables portfolio has been collected during the period, is used to determine bad debt risk. A rising ratio could indicate that a chip company's customers are facing cash flow problems and cannot pay their account balances. Many chipmakers have significant sales exposure to Asian countries; given the region's history of credit crunches, analysts should keep a close watch on receivables turnover to gauge credit risk.

◆ **Days of outstanding inventory.** The industry constantly faces periods of oversupply and undersupply. Since these periods tend to impact sales and margins, we think it is important to keep a close eye on inventory. Commonly used in the cash conversion cycle, the days of outstanding inventory (DOI) can also gauge inventory health, especially when compared with historic and seasonal averages. It is useful to run the analysis not only for chipmakers, but also for the companies throughout the supply chain so that investors can watch for inventory buildups. DOI is calculated by dividing 365 (or the number of days in the period) by the inventory turnover ratio (cost of sales divided by average inventory).

Watch Out! *Inventory represents one of the most substantial assets on the balance sheets of semiconductors and semiconductor equipment companies and can be a leading indicator of financial condition. Therefore, a company's choices with respect to inventory accounting can have a significant impact on its results. Analysts should assess whether or not a company has changed its inventory costing methodology, as this can impact comparability (and potentially flatter results) versus prior periods. Similarly, when analyzing a company relative to its peers, it is important to identify any differences in inventory costing policies between the companies.*

◆ **Debt.** The semiconductors & semiconductor equipment industry is capital intensive, requiring investment in plants and production equipment that can approach $6 billion per facility, all costs included. To fund this investment, many semiconductor companies carry a moderate amount of debt on their balance sheets. The ratio of long-term debt to total capital is useful in determining the relative risk that a company takes on by employing financial leverage. Debt can be an important and beneficial tool for firms seeking to fund growth through new product development or expansion into new markets. However, firms with a high level of indebtedness must allocate a large portion of cash flow to debt service. The times-interest-earned ratio (income before interest expense and taxes, divided by interest expense) measures a company’s ability to pay its interest charges; this ratio should be closely examined for firms with high debt-to-capital ratios.

SELECT METRICS TO DETERMINE FINANCIAL HEALTH OF CHIP COMPANIES

Company	Ticker	STARS	Market Cap ($Millions)	Cash - Short + Long Term Investments ($Millions)	Debt Due - Less Than 1 Year ($Millions)	Total Debt ex. Leases - $Millions	Net Cash/Debt ($Millions)	LTM FCF ($Millions)	LTM FCF Less Acq, Dividends, and Repurches ($Millions)	Net Debt/EBITDA	Long Term Debt to Capital (%)	WACC
Advanced Micro Devices, Inc.	AMD	4	109,532	6,068	312	2,777	3,291	3,330	(492)	NM	5.5	13.4%
Ambarella, Inc.	AMBA	3	2,407	198	0	0	198	48	(259)	NM	1.8	12.9%
Analog Devices, Inc.	ADI	3	77,650	1,525	0	6,253	-4,728	3,741	287	0.9	14.6	12.9%
Broadcom Inc.	AVGO	5	194,198	9,977	269	39,434	-29,457	15,304	(193)	1.6	65.4	12.9%
Cirrus Logic, Inc.	CRUS	3	4,010	454	0	0	454	204	(306)	NM	9.8	12.9%
Cree, Inc.	CREE	3	14,292	1,199	0	1,022	177	(799)	(828)	NM	30.7	12.9%
Diodes Incorporated	DIOD	4	3,348	309	9	239	69	160	60	NM	17.1	12.9%
Intel Corporation	INTC	3	111,601	32,973	2,882	35,430	-2,457	(1,583)	(7,601)	0.3	25.9	12.9%
Lattice Semiconductor Corporation	LSCC	3	7,598	118	17	149	-31	176	(49)	0.3	29.0	12.9%
Marvell Technology Group Ltd.	MRVL	4	40,891	655	654	4,601	-3,946	912	229	2.4	23.5	12.9%
Maxim Integrated Products, Inc.	MXIM	3	-	2,291	0	995	1,296	859	722	NM	30.2	12.9%
MaxLinear, Inc.	MXL	4	2,865	249	0	246	2	320	229	0.2	33.4	12.9%
Microchip Technology Incorporated	MCHP	3	37,083	379	0	7,564	-7,185	2,648	1,405	2.1	56.0	12.9%
Micron Technology, Inc.	MU	4	60,254	10,978	0	6,020	4,958	3,114	96	NM	13.2	12.9%
Monolithic Power Systems, Inc.	MPWR	3	18,498	814	0	0	814	284	161	NM	0.4	12.9%
NVIDIA Corporation	NVDA	4	326,806	17,344	1,249	10,949	6,395	6,264	(1,688)	NM	33.2	12.9%
NXP Semiconductors N.V.	NXPI	5	41,751	3,555	0	11,160	-7,605	2,331	(830)	1.6	60.7	12.9%
ON Semiconductor Corporation	ON	4	30,435	1,838	165	3,213	-1,375	1,244	683	0.6	39.2	12.9%
Qorvo, Inc.	QRVO	3	8,820	887	1	2,046	-1,159	789	(679)	0.8	32.3	12.9%
QUALCOMM Incorporated	QCOM	3	140,689	6,848	0	13,600	-6,752	6,669	(5,484)	0.5	49.2	12.9%
Rambus Inc.	RMBS	4	3,114	353	49	49	303	202	71	NM	9.3	12.9%
Semtech Corporation	SMTC	4	1,857	378	0	172	206	216	85	NM	19.4	12.9%
Silicon Laboratories Inc.	SLAB	3	4,599	1,478	0	529	949	(164)	(1,891)	NM	24.8	12.9%
Skyworks Solutions, Inc.	SWKS	4	14,859	662	499	2,188	-1,526	976	(3,035)	0.8	31.2	12.9%
Texas Instruments Incorporated	TXN	3	152,169	8,387	499	7,244	1,143	5,889	(290)	NM	34.0	12.9%
Western Digital Corporation	WDC	3	11,769	2,851	0	7,022	-4,171	758	668	1.5	37.5	12.9%

Source: CFRA, S&P Global Market Intelligence (as of October 6, 2022)

Cash Flow

The statement of cash flows reports a firm's sources and uses of cash by category: operations, investments, and financing activities. This is valuable information regarding a company's transactions. The statement illustrates, among other things, how a company generated or used cash from its business, funded capital expenditures, or paid debt.

U.S. accounting standards allow some degree of latitude in how companies can present certain aspects of their financial condition. For example, the rate at which a company depreciates its assets and the method it uses to account for its inventory can have a significant impact on net income. Consequently, analysts often look to the statement of cash flows for a more accurate assessment of financial health. Quite simply, it is cash, not net income, that must be used to repay loans, fund capital spending, and pay dividends.

Free cash flow is defined as cash flow from operations less capital expenditures and changes in working capital. This figure, sometimes referred to as "owners' earnings," represents the cash flow that accrues to the firm after all obligations have been met. For semiconductor companies, free cash flow can fluctuate dramatically from year to year, depending on the condition of the semiconductors & semiconductor equipment industry and a firm's capital spending requirements. Given these fluctuations, it is helpful to observe free cash flow trends over an extended period to determine how a company has performed through various semiconductor cycles.

Performance and Valuation Metrics to Consider

Drawing from both the income statement and the balance sheet, two important measures of a company's overall financial performance are return on assets (ROA) and ROE. These measures, along with growth projections, provide key indicators for a valuation analysis.

In evaluating the relative attractiveness of a company's current stock price, performance metrics and growth rates should be considered alongside price-related valuation ratios such as price-to-earnings (P/E), price-to-sales (P/S), and price-to-cash flow. The analyst should compare valuation ratios with the company's own historical ratios and with those of peer companies and the overall stock market.

◆ **ROA and ROE.** The two most popular measures of return on investment (ROI) are ROA and ROE. ROA (net income divided by average total assets) measures the operating efficiency of a firm or the return earned on assets under management's discretion. ROE (net income divided by average total shareholders' equity) measures the return earned on shareholders' capital. Both ratios measure management's ability to earn a reasonable profit on the assets and capital entrusted to them.

Watch Out! *Companies record special charges for unusual or infrequent items (e.g., restructuring charges). Such charges are often excluded from non-GAAP earnings, and therefore provide management with the ability to enhance analysts' perception of its profitability through aggressive use of these special charges. Significant and/or recurring use of special charges is a red flag that a company may be using special charges to flatter non-GAAP results. Specifically, we caution that companies may boost non-GAAP earnings in the current period by bundling normal, recurring costs into the special charges.*

◆ **P/E and PEG.** To arrive at the price-to-earnings (P/E) ratio of a stock, simply take the stock price and divide by the current year's projected earnings. For a forward projection, one can use the forecasted earnings for the next year. A variation of this ratio, which can be used to weigh the strength of earnings growth as part of valuation assessments for a given company relative to its peers, is referred to as the P/E growth (PEG) ratio, or the P/E divided by the company's projected average three-year earnings growth rate.

◆ **Price-to-sales.** Dividing the current share price of the company by its projected revenues for the current year on a per-share basis is how price-to-sales (P/S) ratio is derived. This ratio is used in times when earnings are not available (the company is operating at a loss), or when earnings forecasts are in question.

◆ **Price-to-cash flow.** This ratio is calculated by taking the price of a company's stock and dividing by the sum of the current year's forecasted cash flow. The most commonly used proxy for a company's cash flow is referred to as earnings before interest, taxes, and depreciation and amortization (EBITDA). The real-world use of this ratio is generally derived using the forecast of EBITDA for the next year. This ratio is typically used a company's earnings are penalized by high capital intensity.

CHIPMAKER VALUATIONS

Ticker	Company Name	CFRA STARS	P/E 2021	P/E 2022	5YR Historical Fwd Avg	10YR Historical Fwd Avg	P/E 2022 Above/Below 5YR Avg	P/E 2022 Above/Below 10YR Avg
AMD	Advanced Micro Devices, Inc.	4	16.1	14.5	42.7	41.9	-66%	-65%
AMBA	Ambarella, Inc.	5	58.7	39.5	118.3	70.2	-67%	-44%
ADI	Analog Devices, Inc.	3	15.2	15.9	21.4	20.7	-25%	-23%
AVGO	Broadcom Inc.	4	12.2	11.7	14.9	14.2	-22%	-18%
CRUS	Cirrus Logic, Inc.	3	11.0	11.7	17.1	13.9	-31%	-15%
CREE	Wolfspeed, Inc.	0	0.0	0.0	0.0	0.0	NM	NM
DIOD	Diodes Incorporated	4	10.3	10.2	18.4	20.9	-45%	-51%
INTC	Intel Corporation	3	12.1	10.1	12.6	13.1	-20%	-23%
LSCC	Lattice Semiconductor Corporation	3	33.1	28.0	49.3	34.4	-43%	-18%
MRVL	Marvell Technology, Inc.	5	20.7	17.0	28.6	21.7	-41%	-21%
MCHP	Microchip Technology Incorporated	3	12.0	11.8	16.7	17.0	-29%	-30%
MU	Micron Technology, Inc.	4	8.7	46.9	11.5	12.1	306%	287%
MPWR	Monolithic Power Systems, Inc.	3	31.4	27.5	46.2	37.0	-40%	-26%
NVDA	NVIDIA Corporation	4	38.9	29.0	39.7	29.3	-27%	-1%
NXPI	NXP Semiconductors N.V.	4	11.2	11.4	16.1	14.9	-29%	-24%
ON	ON Semiconductor Corporation	4	13.7	14.2	17.1	15.1	-17%	-6%
QRVO	Qorvo, Inc.	3	8.9	9.4	14.1	13.4	-33%	-30%
QCOM	QUALCOMM Incorporated	3	9.8	9.4	18.3	16.0	-49%	-41%
RMBS	Rambus Inc.	5	17.2	16.6	22.5	34.0	-26%	-51%
SMTC	Semtech Corporation	4	10.3	10.3	26.5	22.1	-61%	-54%
SLAB	Silicon Laboratories Inc.	5	31.6	29.4	43.5	33.0	-32%	-11%
SWKS	Skyworks Solutions, Inc.	3	8.3	7.7	15.0	13.6	-48%	-43%
TXN	Texas Instruments Incorporated	3	17.4	18.8	23.6	21.3	-21%	-12%
WDC	Western Digital Corporation	3	8.5	10.8	10.7	10.1	1%	6%
	Median		**12.1**	**13.0**	**18.4**	**18.8**	**-29%**	**-31%**
	Mean		**17.4**	**17.2**	**26.9**	**22.5**	**-36%**	**-24%**
	S&P 500 Semiconductors (Market Cap Adjusted)		**14.1**	**14.1**	**15.1**	**14.5**	**-7%**	**-3%**

Source: CFRA, S&P Global Market Intelligence (as of October 6, 2022)

GLOSSARY

Advanced driver assistance system (ADAS)—Systems developed to automate/adapt/enhance vehicle systems for better safety and driving. This system includes safety and adaptive features that could warn the driver of potential problems, avoids collision by taking control over the vehicle, automate lighting and braking, adaptive cruise control, etc.

Bandwidth—A measure of the data transmission capacity of any electronic line, including fiber-optic, twisted-pair, wireless, or computer bus.

Bit/byte—The first is a "binary digit," the basic building block of computer communications, with the value of 0 or 1, representing the two electrical states: on and off (or charge/no charge, or positive/negative). The second is a group of bits (usually eight) on which a computer operates as a unit.

Boolean logic—A set of rules that govern true/false logic functions. Developed by English mathematician George Boole in the mid-1800s, Boolean logic is based on the primary operations of "and," "or," and "not."

Central processing unit (CPU)—The computer component in which calculations and manipulations take place; sometimes referred to as "the brains."

Chemical mechanical planarization (CMP)—The use of a compound to polish a wafer's surface to eliminate imperfections in the manufacturing of semiconductors with linewidths of 0.50 micron or less.

Chemical vapor deposition (CVD)—The process of applying a thin film to a substrate using a controlled chemical reaction. CVD is used in the deposition of semiconducting and insulating materials.

Chip—A rectangular piece of semi-conductive material (typically silicon) on which large amounts of transistors and circuitry have been implanted; also known as a die, integrated circuit (IC), or semiconductor.

Clean room—A semiconductor manufacturing environment in which the humidity, temperature, and particulate levels are precisely controlled.

Clock cycle—The time between signal pulses generated by a microprocessor's oscillator. The speed of a microprocessor is measured in gigahertz (GHz), where one GHz equals one billion pulses, or clock cycles, per second.

Critical dimension—The size of the smallest circuit line, element, or feature that must be manufactured on a given layer of a chip; also called linewidth or minimum feature size.

Data center—A building, dedicated space within a building, or a group of buildings used to house servers and associated components, such as telecommunications and storage systems.

DDR SDRAM—Double data rate (DDR) synchronous dynamic random access memory (DRAM). The DDR feature on memory chips permits faster speeds by allowing data to be transferred on both edges of a clock cycle. SDRAM operates faster than DRAM partly due to a clock that synchronizes inputs.

Defect—Any imperfection on a layer of an integrated circuit that causes a short circuit or other problem with the performance of the device.

Deposition—The process by which a layer of electrically insulating or conductive material is deposited on the surface of a wafer.

Dicing (wafer dicing)—The process of cutting a wafer into individual chips, or dice; typically done with a diamond-bladed saw.

Die—A piece of a semiconductor wafer containing a single integrated circuit that has not yet been packaged. The plural form is dice. (See *Chip*.)

Die bonding—Attaching a die to the frame of a package before wire bonding.

Diffusion—The movement of one material into another; used in semiconductor manufacturing to introduce impurities, or dopants, into a semiconductor area to form a transistor junction.

Digital signal processor (DSP)—A high-speed digital circuit designed to process and enhance a broad range of "real-time" signals, such as voice or video, that have been converted from analog format.

Doping—The introduction of precise amounts of impurity to a semiconductor, via diffusion or ion implanting, to alter its electrical properties.

Dynamic random access memory (DRAM)—Pronounced DEE-ram, this is the cheapest and most widely used type of semiconductor memory chip. "Dynamic" means that the device's memory cells need to be periodically recharged. Information, stored in the memory cells as a positive or negative charge, is accessed randomly.

EPROM/EEPROM—Erasable programmable read-only memory and electrically erasable programmable read-only memory, respectively; these nonvolatile memory devices retain stored information when electrical power is interrupted.

Etching—The selective removal of thin films or layers to engrave a circuit pattern on a wafer's surface.

Extreme Ultraviolet Lithography (EUV)—Next generation lithography technology using a high-energy ultraviolet wavelength, currently expected to be 13.5nm.

Fab—The informal name for a chip manufacturer's wafer fabrication plant, where ICs are made.

Fabless—Semiconductor companies that design and market their own chips, but rely on others to manufacture them.

Fab-lite—Describes a semiconductor company that maintains in-house wafer fabrication facilities, but also contracts a significant amount of production to chip foundries.

Feature size—The dimensions, usually in microns or nanometers, of an electronic device or component in an integrated circuit; often used to mean "minimum feature size." (See *Linewidth*.)

Flash memory—Nonvolatile memory devices that can be electronically erased and reprogrammed with great speed.

Foundry—A wafer fab that makes chips on a contract basis for other companies.

Gate—The basic logic element in an IC; along with the source and the drain, one of the three regions of a field-effect transistor.

Integrated circuit (IC)—An electronic circuit in which many active or passive elements are fabricated and connected on a continuous substrate.

Interconnect layer—The alternate layers of wiring and insulation in an IC that form its electrical interconnections.

Ion—An atom that has been electrically charged by the loss or gain of electrons.

Ion implanting—The use of magnetically focused ion bombardment to inject charged particles (impurities known as "dopants") into a silicon wafer in order to change its electrical properties.

Lithography—Use of ultraviolet-sensitive photoresist and masks to create IC patterns, which are transferred from a mask to a silicon wafer; also called photolithography. (See *Photoresist* and *Mask*.)

Logic chip—A semiconductor device used for data manipulation and control functions requiring higher speeds than a microprocessor can provide.

Mask—A glass or quartz plate with an opaque pattern through which ultraviolet (UV) light is beamed in order to reproduce the design onto a silicon wafer's photoresist; also known as a reticle.

Memory chip—A semiconductor device that stores information in electronic form. Memory chips often are classified as volatile or nonvolatile. Volatile devices lose their retained information when power is interrupted, while nonvolatile devices keep all their stored data when power is interrupted. Types of memory semiconductors include DRAM, SRAM, and flash memory.

Metal-oxide semiconductor (MOS)—MOS chips combine layers of conductive metal, oxide, and semiconductor material to control the flow of electrical signals. Most chips designed today are based on complementary MOS (CMOS) technology.

Microcontroller—A stand-alone device that performs computer-like functions within an electronic system, such as a cell phone, without using other support circuits. A microcontroller contains memory functions—unlike the original microprocessor, which was paired with a memory chip. (See *Microprocessor*.)

Micron—A unit of length, equal to 1/1,000 of a millimeter, used to measure semiconductor linewidths.

Microprocessor—A central processing unit (CPU) fabricated on one or more chips, containing the arithmetic, logic, and control elements needed by a computer to process data. In 2003, Intel introduced microprocessors with integrated memory. (See *Microcontroller*.)

Moore's Law—The observation that the number of transistors on integrated circuits doubles approximately every two years.

NAND flash memory—A type of nonvolatile memory capable of fast data writing. NAND flash memory can retain information, even when there is no power. The acronym NAND stands for "not and," which refers to logic rules applied in digital technology.

Nanometer (nm)—One billionth of a meter, or 1/1,000 of a micron. As semiconductor feature sizes are reduced, minimum feature sizes are often referred to in nanometers instead of microns (*e.g.,* 90nm versus 0.09 microns).

Nonvolatile memory—A memory device that retains stored information when power is interrupted. (See *EPROM/EEPROM, NAND flash memory,* and *Read-only memory*.)

NOR flash memory—A type of nonvolatile memory capable of fast data reading, but slower write and erase functions than NAND.

Oxide—A common term for silicon dioxide, which is added as an insulating film on the surface of a wafer.

Photolithography—Use of light-sensitive photoresist and reticle masks to create integrated circuit patterns. These patterns are transferred from a mask to a silicon wafer using a light projector called a stepper; also called "lithography."

Photomask—A clear quartz plate containing microscopic images of electronic circuits, used as a template to transfer the circuit image to a silicon wafer; also called a mask or reticle.

Photoresist—A light-sensitive substance used in the process of etching IC patterns on silicon wafers. The photoresist is deposited evenly on a blank wafer, covered by a mask with the desired IC pattern, and exposed to UV light. The light hardens the photoresist on the uncovered areas, and the unhardened film is washed away to expose the silicon underneath, enabling circuits to be etched into the wafer.

Physical vapor deposition (PVD)—A deposition technique in which insulating or conductive material is transferred to a substrate by physical means, such as evaporation or sputtering.

Polysilicon—Highly purified silicon used in the electronic and solar industry. Often referred to as crystalline silicon.

Programmable logic device (PLD)—An electronic component used to build digital circuits that are reconfigurable.

Random access memory (RAM)—Makes up the basic read/write storage element in computers. May be written to or read from any address location in any sequence.

Read-only memory (ROM)—Permanently stores information that is used repeatedly (*e.g.*, data tables and electronic display characters). ROM with stored programmed data is also known as firmware. *(See EPROM/EEPROM.)*

Reticle—See *Photomask.*

Silicon—A nonmetallic element, made from melted sand, used to create wafers.

Sputtering—A method of depositing a thin film of material on wafer surfaces using radio frequency-excited ions; also called physical vapor deposition (PVD).

Static random access memory (SRAM)—An IC memory that requires no constant refreshing or recharging; it stores information as long as power is applied to the computer. SRAMs are much faster but more expensive than DRAMs.

Stepper—A device used to expose a photoresist-coated wafer surface by projecting light through a circuit pattern contained on a photomask. Its name is derived from the operation of making small step offsets to align the mask with each die position.

Substrate—The underlying material on which a microelectronic device is built, such as a silicon wafer.

Transistor—A three-terminal semiconductor device for amplification, switching, and detection.

Volatile memory—A memory device that does not retain stored information when power is interrupted. (See *Dynamic random access memory (DRAM)* and *Static random access memory (SRAM)*.)

Wafer—A thin circular silicon disk, usually 0.6 millimeters (mm) thick and 150 mm to 300 mm in diameter, that forms the substrate of an IC.

Waveform—An image that represents an audio signal or recording. It shows the changes in amplitude over a certain amount of time. The amplitude of the signal is measured on the y-axis (vertically), while time is measured on the x-axis (horizontally).

Yield—The percentage of dice that function normally out of the total number available on a wafer.

INDUSTRY REFERENCES

PERIODICALS

KrASIA
kr-asia.com
Digital media company reporting on the most promising technology-driven businesses and trends in the world's emerging markets.

protocol
protocol.com
Produces unbiased, fact-based news and analysis that decision-makers in tech, business, and public policy need to navigate a world in rapid change.

Reuters
reuters.com
One of the world's largest multimedia news providers. Having a global presence in 128 countries. Reuters' journalists work all over the world and are guided by the Trust Principles, which state that Reuters must report the news with integrity, independence, and freedom from bias.

Solid State Technology
electroiq.com/semiconductors
Semiconductor manufacturing news, data, and research sources. Website covers semiconductors, wafer fabrication, integrated circuits, and more.

Taiwan News
taiwannews.com.tw
Reports on Taiwanese society and modern global trends build a bridge of communication between cultures and nations.

TRADE ASSOCIATIONS

MITRE Engenuity
Mitre-engenuity.org
A trusted tech foundation that brings industry together to apply state of the art MITRE innovation for the public good. A wholly owned subsidiary of MITRE Corporation, MITRE Engenuity is made up of experts from throughout the industries and disciplines that drive the modern economy, from microelectronics to 5G to cybersecurity and beyond.

SEMI
semi.org
Global industry association serving the nano- and microelectronics manufacturing supply chains (including semiconductors). Its mid-year and year-end SEMI Capital Equipment Consensus Forecast are based on interviews with companies representing a majority of sales in the global semiconductor equipment industry.

Semiconductor Industry Association (SIA)
semiconductors.org
Trade group representing U.S. semiconductor companies. Provides various reports and forecasts, including the Global Sales Report (GSR), a 3-month moving average of semiconductor sales activity, and Semiconductor International Capacity Statistics (SICAS), capacity, and utilization of the total wafer start capacity of the integrated circuit manufacturing industry. Acts as a commercial distribution channel for WSTS reports.

World Semiconductor Trade Statistics (WSTS)
wsts.org
Industry membership organization that manages the collection and publication of trade shipments and forecasts.

RESEARCH FIRMS

Gartner Inc.
gartner.com
Information technology market research and consulting firm serving information technology suppliers and the financial and investment communities.

IC Insights Inc.
icinsights.com
Leading provider of market research and analysis for the integrated circuit industry.

IDC
idc.com
Leading global provider of information technology data and industry analysis to the IT, telecommunications, and consumer technology markets.

IHS Markit
ihs.com
Provides economic, financial, and political coverage of countries, regions, and industries.

IHS Markit Technology
technology.ihs.com
Provides information, analysis, and consulting on the electronics industry. Tracks industry performance and develops forecasts.

OMDIA
omdia.tech.informa.com
Omdia brings decades of industry experience, world-class research and consultancy, and actionable insights in over 200 markets.

PitchBook
pitchbook.com
A financial data and software company that tracks every aspect of the public and private equity markets, including venture capital, private equity and M&A.

TECHCET
techcet.com
Advisory firm focused on process materials supply chains, electronic materials technology, expert witness work and materials market analysis for the global semiconductor. Display, solar/PV and LED industries.

VLSI Research Inc.
vlsiresearch.com
Performs market research and economic analysis on the semiconductor and semiconductor equipment industries.

GOVERNMENT AGENCIES

Congress.Gov
congress.gov
Congress.gov is the official website for U.S. federal legislative information. The site provides access to accurate, timely, and complete legislative information for members of congress, legislative agencies, and the public.

Federal Reserve Bank of St. Louis
fred.stlouisfed.org
Provides the FRED Economic Time-Series Database, a well-organized government source for a wide range of statistical economic data, including GDP, interest rates, and more.

Ministry of Electronics & Information Technology(MeitY)
meit.gov.in
Executive agency of the Union Government of the Republic of India. This agency promotes e-Governance for empowering citizens, promoting the inclusive and sustainable growth of the electronics, IT & ITeS industries.

Ministry of Industry and Information Technology (MIIT)
miit.gov.cn
A state agency of the People's Republic of China (PBOC) responsible for regulation and development of the postal service, internet, wireless and communications.

COMPANY RESOURCES

Applied Materials
appliedmaterials.com
Many pictures of front-end wafer process equipment in the "Products & Technologies" section.

Intel Corp.
intel.com
intel.com/content/www/us/en/company-overview/intel-museum.html
The Intel Museum (at the second website listed) describes how a chip is made, how transistors work, the history of the microprocessor, what a clean room is like, and other background information.

KLA-Tencor Corp.
kla-tencor.com
Photographs of various measurement, wafer inspection, and yield control tools. The company also has a quarterly electronic magazine on yield management under the "Company" link.

Lam Research Corp.
lamresearch.com
Shows pictures of etch, chemical mechanical polishing, and wafer cleaning tools.

Taiwan Semiconductor Manufacturing Co. Ltd. (TSMC)
tsmc.com
The world's largest foundry provides monthly sales updates on its website (under "Investor Relations, Financials"); these are a leading indicator of impending industry turns.

Texas Instruments Inc.
ti.com
The latter site's "History of Innovation" timeline notes when certain kinds of semiconductors were introduced.

COMPARATIVE COMPANY ANALYSIS

					Operating Revenues																
					Million $							CAGR (%)			Index Basis (2013=100)						
Ticker		Company		Yr. End	2021	2020	2019	2018	2017	2016	2015	10-Yr.	5-Yr.	1-Yr.	2021	2020	2019	2018	2017	2016
SEMICONDUCTORS																				
AMD	[]	ADVANCED MICRO DEVICES, INC.		DEC	16,434.0	9,763.0	6,731.0	6,475.0	5,253.0	4,319.0	3,991.0	9.6	30.6	68.3	412	245	169	162	132	108
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITEI		JUN	656.9	464.9	450.9	421.6	383.3	335.7	327.9	6.2	14.4	41.3	200	142	138	129	117	102
ADI	[]	ANALOG DEVICES, INC.		OCT	7,318.3	5,603.1	5,991.1	6,224.7	5,246.4	3,421.4	3,435.1	9.4	16.4	30.6	213	163	174	181	153	100
AVGO	[]	BROADCOM INC.		OCT	27,450.0	23,888.0	22,597.0	20,848.0	17,636.0	13,240.0	6,824.0	27.9	15.7	14.9	402	350	331	306	258	194
CEVA	§	CEVA, INC.		DEC	122.7	100.3	87.2	77.9	87.5	72.7	59.5	7.4	11.1	22.3	206	169	146	131	147	122
CRUS	†	CIRRUS LOGIC, INC.	#	MAR	1,781.5	1,369.2	1,281.1	1,185.5	1,532.2	1,538.9	1,169.3	14.0	3.2	6.9	152	117	110	101	131	132
DIOD	§	DIODES INCORPORATED		DEC	1,805.2	1,229.2	1,249.1	1,214.0	1,054.2	942.2	848.9	11.0	13.9	46.9	213	145	147	143	124	111
FSLR	†	FIRST SOLAR, INC.		DEC	2,923.4	2,711.3	3,063.1	2,244.0	2,941.3	2,904.6	4,112.7	0.6	0.1	7.8	71	66	74	55	72	71
INTC	[]	INTEL CORPORATION		DEC	79,024.0	77,867.0	71,965.0	70,848.0	62,761.0	59,387.0	55,355.0	3.9	5.9	1.5	143	141	130	128	113	107
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	#	JAN	0.0	515.3	404.1	398.8	386.0	427.1	427.1	4.9	3.8	26.3	0	121	95	93	90	100
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS		OCT	606.9	530.0	499.7	570.4	698.8	544.3	420.6	6.9	2.2	14.5	144	126	119	136	166	129
MXL	§	MAXLINEAR, INC.		DEC	892.4	478.6	317.2	385.0	420.3	387.8	300.4	28.6	18.1	86.5	297	159	106	128	140	129
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	#	MAR	6,820.9	5,438.4	5,274.2	5,349.5	3,980.8	3,407.8	2,173.3	13.8	20.1	3.1	314	250	243	246	183	157
MU	[]	MICRON TECHNOLOGY, INC.		SEP	27,705.0	21,435.0	23,406.0	30,391.0	20,322.0	12,399.0	16,192.0	12.2	17.4	29.3	171	132	145	188	126	77
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.		DEC	1,207.8	844.5	627.9	582.4	470.9	388.7	333.1	19.9	25.5	43.0	363	254	189	175	141	117
NVDA	[]	NVIDIA CORPORATION	#	JAN	26,914.0	16,675.0	10,918.0	11,716.0	9,714.0	6,910.0	5,010.0	16.8	27.2	52.7	537	333	218	234	194	138
NXPI	[]	NXP SEMICONDUCTORS N.V.		DEC	11,063.0	8,612.0	8,877.0	9,407.0	9,256.0	9,498.0	6,101.0	10.2	3.1	28.5	181	141	146	154	152	156
ON	[]																			
POWI	†	POWER INTEGRATIONS, INC.		DEC	703.3	488.3	420.7	416.0	431.8	389.7	344.6	8.9	12.5	44.0	204	142	122	121	125	113
QRVO	[]	QORVO, INC.	#	APR	4,645.7	4,015.3	3,239.1	3,090.3	2,973.5	3,032.6	2,610.7	14.3	9.0	24.0	178	154	124	118	114	116
QCOM	[]	QUALCOMM INCORPORATED		SEP	33,566.0	23,531.0	24,273.0	22,611.0	22,258.0	23,554.0	25,281.0	8.4	7.3	42.6	133	93	96	89	88	93
RMBS	§	RAMBUS INC.		DEC	328.3	246.3	227.6	231.2	393.1	336.6	296.3	0.5	-0.5	33.3	111	83	77	78	133	114
SMTC	†	SEMTECH CORPORATION	#	JAN	740.9	595.1	547.5	627.2	587.8	544.3	490.2	2.7	4.0	8.7	151	121	112	128	120	111
SLAB	†	SILICON LABORATORIES INC.	#	JAN	0.0	720.9	473.8	868.3	768.9	697.6	697.6	3.9	0.7	41.1	0	103	68	124	110	100
SITM	†	SITIME CORPORATION		DEC	218.8	116.2	84.1	85.2	101.1	101.1	0.0	NA	NA	88.4	NA	NA	NA	NA	NA	NA
SWKS	[]	SKYWORKS SOLUTIONS, INC.		OCT	5,109.1	3,355.7	3,376.8	3,868.0	3,651.4	3,289.0	3,258.4	13.7	9.2	52.3	157	103	104	119	112	101
SGH	§	SMART GLOBAL HOLDINGS, INC.		AUG	1,501.1	1,122.4	1,212.0	1,288.8	761.3	534.4	643.5	NA	22.9	33.7	233	174	188	200	118	83
SYNA	†	SYNAPTICS INCORPORATED		JUN	1,339.6	1,333.9	1,472.2	1,630.3	1,718.2	1,666.9	1,703.0	8.4	-4.3	0.4	79	78	86	96	101	98
TXN	[]	TEXAS INSTRUMENTS INCORPORATED		DEC	18,344.0	14,461.0	14,383.0	15,784.0	14,961.0	13,370.0	13,000.0	2.9	6.5	26.9	141	111	111	121	115	103
OLED	†	UNIVERSAL DISPLAY CORPORATION		DEC	553.5	428.9	405.2	247.4	335.6	198.9	191.0	24.6	22.7	29.1	290	224	212	130	176	104
WOLF	†	WOLFSPEED, INC.		JUN	525.6	470.7	538.2	924.9	771.5	1,616.6	1,632.5	-6.1	-20.1	11.7	32	29	33	57	47	99

Note: Data as originally reported. CAGR-Compound annual growth rate.
[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.
Souce: S&P Capital IQ.

Operating Revenues

Ticker	Company	Yr. End	Million $ 2021	2020	2019	2018	2017	2016	2015	CAGR (%) 10-Yr.	5-Yr.	1-Yr.	Index Basis (2013=100) 2021	2020	2019	2018	2017	2016
SEMICONDUCTOR EQUIPMENT																		
AMKR	† AMKOR TECHNOLOGY, INC.	DEC	6,138.3	5,050.6	4,052.7	4,316.5	4,207.0	3,927.8	2,884.6	8.3	9.3	21.5	213	175	140	150	146	136
AMAT	[] APPLIED MATERIALS, INC.	OCT	23,063.0	17,202.0	14,608.0	16,705.0	14,698.0	10,825.0	9,659.0	8.2	16.3	34.1	239	178	151	173	152	112
ACLS	§ AXCELIS TECHNOLOGIES, INC.	DEC	662.4	474.6	343.0	442.6	410.6	267.0	301.5	7.6	19.9	39.6	220	157	114	147	136	89
COHU	§ COHU, INC.	DEC	887.2	636.0	583.3	451.8	352.7	282.1	269.7	11.1	25.8	39.5	329	236	216	168	131	105
ENPH	[] ENPHASE ENERGY, INC.	DEC	1,382.0	774.4	624.3	316.2	286.2	322.6	357.2	24.9	33.8	78.5	387	217	175	88	80	90
FORM	§ FORMFACTOR, INC.	DEC	769.7	693.6	589.5	529.7	548.4	383.9	282.4	16.3	14.9	11.0	273	246	209	188	194	136
ICHR	§ ICHOR HOLDINGS, LTD.	DEC	1,096.9	914.2	620.8	823.6	655.9	405.7	290.6	NA	22.0	20.0	377	315	214	283	226	140
KLAC	[] KLA CORPORATION	JUN	6,918.7	5,806.4	4,568.9	4,036.7	3,480.0	2,984.5	2,814.0	8.1	18.3	19.2	246	206	162	143	124	106
KLIC	§ KULICKE AND SOFFA INDUSTRIES, INC.	OCT	1,517.7	623.2	540.1	889.1	809.0	627.2	536.5	6.2	19.3	143.5	283	116	101	166	151	117
LRCX	[] LAM RESEARCH CORPORATION	JUN	14,626.2	10,044.7	9,653.6	11,077.0	8,013.6	5,885.9	5,259.3	16.3	20.0	45.6	278	191	184	211	152	112
MKSI	† MKS INSTRUMENTS, INC.	DEC	2,949.6	2,330.0	1,899.8	2,075.1	1,916.0	1,295.3	813.5	13.6	17.9	26.6	363	286	234	255	236	159
ONTO	§ ONTO INNOVATION INC. #	JAN	0.0	556.5	305.9	273.8	255.1	232.8	221.7	15.5	27.6	41.8	0	251	138	123	115	105
PDFS	§ PDF SOLUTIONS, INC.	DEC	111.1	88.0	85.6	85.8	101.9	107.5	98.0	5.2	0.7	26.1	113	90	87	88	104	110
PLAB	§ PHOTRONICS, INC.	OCT	663.8	609.7	550.7	535.3	450.7	483.5	524.2	2.6	6.5	8.9	127	116	105	102	86	92
SEDG	[] SOLAREDGE TECHNOLOGIES, INC.	DEC	1,963.9	1,459.3	1,425.7	937.2	607.0	490.0	325.1	NA	32.0	34.6	604	449	439	288	187	151
TER	[] TERADYNE, INC.	DEC	3,702.9	3,121.5	2,295.0	2,100.8	2,136.6	1,753.3	1,639.6	10.0	16.1	18.6	226	190	140	128	130	107
UCTT	§ ULTRA CLEAN HOLDINGS, INC.	DEC	2,101.6	1,398.6	1,066.2	1,096.5	924.4	562.8	469.1	16.6	30.2	50.3	448	298	227	234	197	120
VECO	§ VEECO INSTRUMENTS INC.	DEC	583.3	454.2	419.3	542.1	475.7	331.7	477.0	-5.0	12.0	28.4	122	95	88	114	100	70
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																		
ON	[] ON SEMICONDUCTOR CORPORATION	DEC	6,739.8	5,255.0	5,517.9	5,878.3	5,543.1	3,906.9	3,495.8	6.9	11.5	28.3	193	150	158	168	159	112
STM	STABILUS S.A.	SEP	937.7	822.1	951.3	962.6	910.0	737.5	611.3	8.6	4.9	14.1	153	134	156	157	149	121
TSM	TAIWAN SEMICONDUCTOR MANUFACTURING (	DEC	1,587,415.0	1,339,254.8	1,069,985.4	1,031,473.6	977,447.2	947,938.3	843,497.4	14.0	10.9	18.5	188	159	127	122	116	112
UMC	UNITED MICROELECTRONICS CORPORATION	DEC	213,011.0	176,820.9	148,201.6	151,252.6	149,284.7	147,870.1	144,830.4	6.2	7.6	20.5	147	122	102	104	103	102

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Souce: S&P Capital IQ.

Net Income

Ticker		Company		Yr. End	Million $ 2021	2020	2019	2018	2017	2016	2015	CAGR (%) 10-Yr.	5-Yr.	1-Yr.	Index Basis (2013=100) 2021	2020	2019	2018	2017	2016
SEMICONDUCTORS																				
AMD	[]	ADVANCED MICRO DEVICES, INC.		DEC	3,162.0	2,490.0	341.0	337.0	-33.0	-498.0	-660.0	20.5	NM	27.0	-479	-377	-52	-51	5	75
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITEI		JUN	58.1	-6.6	1.9	14.3	13.8	-2.9	-7.8	4.4	NM	NM	-749	85	-24	-184	-178	38
ADI	[]	ANALOG DEVICES, INC.		OCT	1,390.4	1,220.8	1,363.0	1,507.0	805.4	861.7	696.9	4.8	10.0	13.9	200	175	196	216	116	124
AVGO	[]	BROADCOM INC.		OCT	6,736.0	2,960.0	2,724.0	12,259.0	1,692.0	-1,739.0	1,364.0	28.4	NM	127.6	494	217	200	899	124	-127
CEVA	§	CEVA, INC.		DEC	0.4	-2.4	0.0	0.6	17.0	13.1	6.3	-31.9	-50.3	NM	6	-38	0	9	272	209
CRUS	†	CIRRUS LOGIC, INC.	#	MAR	326.4	217.3	159.5	90.0	162.0	261.2	123.6	0.7	11.9	36.3	264	176	129	73	131	211
DIOD	§	DIODES INCORPORATED		DEC	228.8	98.1	153.3	104.0	-1.8	15.9	24.3	16.3	70.4	133.2	942	404	631	429	-7	66
FSLR	†	FIRST SOLAR, INC.		DEC	468.7	398.4	-114.9	144.3	-165.6	-416.1	593.4	NA	NM	17.7	79	67	-19	24	-28	-70
INTC	[]	INTEL CORPORATION		DEC	19,868.0	20,899.0	21,048.0	21,053.0	9,601.0	10,316.0	11,420.0	4.4	14.0	-4.9	174	183	184	184	84	90
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	#	JAN	0.0	95.9	43.5	-26.3	-70.6	-54.1	-54.1	2.1	NM	102.4	0	-177	-80	49	130	100
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS		OCT	38.0	-46.1	-383.8	-140.0	-169.5	1.4	48.6	NA	92.6	NM	78	-95	-790	-288	-349	3
MXL	§	MAXLINEAR, INC.		DEC	42.0	-98.6	-19.9	-26.2	-9.2	61.3	-42.3	NA	-7.3	NM	-99	233	47	62	22	-145
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	#	MAR	1,285.5	349.4	570.6	355.9	255.4	164.6	324.1	-1.8	1.5	-38.8	397	108	176	110	79	51
MU	[]	MICRON TECHNOLOGY, INC.		SEP	5,861.0	2,687.0	6,313.0	14,135.0	5,089.0	-276.0	2,899.0	42.7	NM	118.1	202	93	218	488	176	-10
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.		DEC	242.0	164.4	108.8	105.3	65.2	52.7	35.2	33.7	35.6	47.2	688	467	309	299	185	150
NVDA	[]	NVIDIA CORPORATION	#	JAN	9,752.0	4,332.0	2,796.0	4,141.0	3,047.0	1,666.0	614.0	32.8	47.8	54.9	1588	706	455	674	496	271
NXPI	[]	NXP SEMICONDUCTORS N.V.		DEC	1,871.0	52.0	243.0	2,208.0	2,215.0	200.0	1,526.0	17.0	56.4	3,498.1	123	3	16	145	145	13
ON	[]	ON SEMICONDUCTOR CORPORATION		DEC	1,009.6	234.2	211.7	627.4	810.7	182.1	206.2	56.3	40.9	331.1	490	114	103	304	393	88
POWI	†	POWER INTEGRATIONS, INC.		DEC	164.4	71.2	193.5	70.0	27.6	48.9	39.2	17.0	27.4	131.0	420	182	494	179	71	125
QRVO	[]	QORVO, INC.	#	APR	1,033.4	733.6	334.3	133.1	-40.3	-16.6	-28.8	19.4	NM	119.4	NM	NM	NM	-462	140	57
QCOM	[]	QUALCOMM INCORPORATED		SEP	9,043.0	5,198.0	4,386.0	-4,964.0	2,445.0	5,705.0	5,271.0	7.8	9.7	74.0	172	99	83	-94	46	108
RMBS	§	RAMBUS INC.		DEC	18.3	-40.5	-86.0	-158.0	-22.9	6.8	211.4	NA	21.9	NM	9	-19	-41	-75	-11	3
SMTC	†	SEMTECH CORPORATION	#	JAN	125.7	59.9	31.9	69.6	34.6	54.7	11.5	-1.9	39.1	88.0	1093	521	277	606	301	475
SLAB	†	SILICON LABORATORIES INC.	#	JAN	0.0	2,117.4	19.3	83.6	47.1	61.5	61.5	50.5	103.0	16,797.3	0	3443	31	136	77	100
SITM	†	SITIME CORPORATION		DEC	32.3	-9.4	-6.6	-9.3	4.7	4.7	0.0	NA	NA	NM	NA	NA	NA	NA	NA	NA
SWKS	[]	SKYWORKS SOLUTIONS, INC.		OCT	1,498.3	814.8	853.6	918.4	1,010.2	995.2	798.3	20.8	8.5	83.9	188	102	107	115	127	125
SGH	§	SMART GLOBAL HOLDINGS, INC.		AUG	21.3	-1.1	51.3	119.5	-7.8	-20.0	-46.5	NA	NM	NM	-46	2	-111	-257	17	43
SYNA	†	SYNAPTICS INCORPORATED		JUN	79.6	118.8	-22.9	-124.1	48.8	72.2	110.4	2.2	2.0	-33.0	72	108	-21	-112	44	65
TXN	[]	TEXAS INSTRUMENTS INCORPORATED		DEC	7,769.0	5,595.0	5,017.0	5,580.0	3,682.0	3,595.0	2,986.0	13.3	16.7	38.9	260	187	168	187	123	120
OLED	†	UNIVERSAL DISPLAY CORPORATION		DEC	184.2	133.4	138.3	58.8	103.9	48.1	14.7	50.2	30.8	38.1	1255	909	942	401	708	327
WOLF	†	WOLFSPEED, INC.		JUN	-523.9	-191.7	-375.1	-280.0	-98.1	-21.5	-64.7	NA	89.3	173.3	810	296	580	433	152	33

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Souce: S&P Capital IQ.

Net Income

Ticker		Company		Yr. End	Million $ 2021	2020	2019	2018	2017	2016	2015	CAGR (%) 10-Yr.	5-Yr.	1-Yr.	Index Basis (2013=100) 2021	2020	2019	2018	2017	2016
SEMICONDUCTOR EQUIPMENT																				
AMKR	†	AMKOR TECHNOLOGY, INC.		DEC	643.0	338.1	120.9	127.1	263.6	175.5	51.1	21.5	29.6	90.2	1258	662	237	249	516	344
AMAT	[]	APPLIED MATERIALS, INC.		OCT	5,888.0	3,619.0	2,706.0	3,038.0	3,519.0	1,721.0	1,377.0	11.8	27.9	62.7	428	263	197	221	256	125
ACLS	§	AXCELIS TECHNOLOGIES, INC.		DEC	98.7	50.0	17.0	45.9	127.0	11.0	14.7	34.5	55.1	97.4	672	341	116	313	865	75
COHU	§	COHU, INC.		DEC	167.3	-13.8	-69.7	-32.2	32.8	3.0	0.3	26.7	122.9	NM	66930	NM	NM	NM	13137	1216
ENPH	[]	ENPHASE ENERGY, INC.		DEC	145.4	134.0	161.1	-11.6	-45.2	-67.5	-22.1	NA	NM	8.5	-659	-607	-730	53	205	306
FORM	§	FORMFACTOR, INC.		DEC	83.9	78.5	39.3	104.0	40.9	-6.6	-1.5	NA	NM	6.9	NM	NM	NM	NM	NM	431
ICHR	§	ICHOR HOLDINGS, LTD.		DEC	70.9	33.3	10.7	57.9	56.5	16.7	5.6	NA	33.6	113.0	1260	592	191	1029	1003	296
KLAC	[]	KLA CORPORATION		JUN	2,078.3	1,216.8	1,175.6	802.3	926.1	704.4	366.2	10.1	24.2	70.8	568	332	321	219	253	192
KLIC	§	KULICKE AND SOFFA INDUSTRIES, INC.		OCT	367.2	52.3	11.7	56.7	126.1	48.5	51.9	11.1	49.9	602.0	707	101	22	109	243	93
LRCX	[]	LAM RESEARCH CORPORATION		JUN	3,908.5	2,251.8	2,191.4	2,380.7	1,697.8	914.0	655.6	18.4	33.7	73.6	596	343	334	363	259	139
MKSI	†	MKS INSTRUMENTS, INC.		DEC	551.4	350.1	140.4	392.9	339.1	104.8	122.3	15.6	39.4	57.5	451	286	115	321	277	86
ONTO	§	ONTO INNOVATION INC.	#	JAN	0.0	31.0	1.9	45.1	32.9	37.0	18.0	18.9	31.0	358.8	0	173	11	251	183	206
PDFS	§	PDF SOLUTIONS, INC.		DEC	-21.5	-40.4	-5.4	-7.7	-1.3	9.1	12.4	NA	NM	-46.8	-173	-325	-44	-62	-11	73
PLAB	§	PHOTRONICS, INC.		OCT	55.4	33.8	29.8	42.1	13.1	46.2	44.6	13.1	3.7	64.0	124	76	67	94	29	104
SEDG	[]	SOLAREDGE TECHNOLOGIES, INC.		DEC	169.2	140.3	146.5	128.8	84.2	63.5	21.1	NA	21.7	20.6	801	664	694	610	399	300
TER	[]	TERADYNE, INC.		DEC	1,014.6	784.1	467.5	451.8	257.7	-43.4	206.5	10.6	NM	29.4	491	380	226	219	125	-21
UCTT	§	ULTRA CLEAN HOLDINGS, INC.		DEC	119.5	77.6	-9.4	36.6	75.1	10.1	-10.7	17.5	64.1	54.0	NM	-723	88	-341	-700	-94
VECO	§	VEECO INSTRUMENTS INC.		DEC	26.0	-8.4	-78.7	-407.1	-51.4	-122.0	-32.0	-14.7	NM	NM	-81	26	246	1273	161	382
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																				
ON	[]	ON SEMICONDUCTOR CORPORATION		DEC	1,009.6	234.2	211.7	627.4	810.7	182.1	206.2	56.3	40.9	331.1	490	114	103	304	393	88
STM		STABILUS S.A.		SEP	73.4	31.4	80.6	105.4	79.3	48.0	17.0	21.5	8.9	133.5	433	185	476	622	468	283
TSM		TAIWAN SEMICONDUCTOR MANUFACTURING (		DEC	592,359.2	510,744.0	353,948.0	363,052.7	344,998.3	331,713.7	302,850.9	16.0	12.3	16.0	196	169	117	120	114	110
UMC		UNITED MICROELECTRONICS CORPORATION		DEC	55,780.3	29,189.5	8,155.1	7,677.7	9,676.7	8,621.1	13,254.1	18.1	45.3	91.1	421	220	62	58	73	65

Note: Data as originally reported. CAGR-Compound annual growth rate.
[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.
Souce: S&P Capital IQ.

				Return on Revenues (%)						Return on Assets (%)						Return on Equity (%)					
Ticker		**Company**	**Yr. End**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**
SEMICONDUCTORS																					
AMD	[]	ADVANCED MICRO DEVICES, INC.	DEC	19.2	25.5	5.1	5.2	NM	NM	25.5	27.8	5.7	7.4	NM	NM	47.4	57.5	16.7	36.2	NM	NM
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITED	JUN	8.8	NM	0.4	3.4	3.6	NM	6.3	NM	0.3	2.1	3.5	NM	11.9	NM	NM	1.4	3.4	NM
ADI	[]	ANALOG DEVICES, INC.	OCT	19.0	21.8	22.8	24.2	15.4	25.2	2.7	5.7	6.4	7.4	3.8	10.8	5.6	10.3	11.9	14.1	10.5	16.8
AVGO	[]	BROADCOM INC.	OCT	24.5	12.4	12.1	58.8	9.6	NM	8.9	3.9	4.0	24.5	3.1	NM	27.6	12.1	10.6	50.7	7.9	NM
CEVA	§	CEVA, INC.	DEC	0.3	NM	0.0	0.7	19.5	18.0	0.1	NM	0.0	0.2	6.2	5.4	0.1	NM	0.0	0.2	7.5	6.6
CRUS	†	CIRRUS LOGIC, INC.	MAR	18.3	15.9	12.4	7.6	10.6	17.0	15.4	11.9	10.0	6.7	11.3	18.5	21.8	16.6	13.5	7.8	14.0	26.0
DIOD	§	DIODES INCORPORATED	DEC	12.7	8.0	12.3	8.6	NM	1.7	10.4	5.0	9.3	6.8	NM	1.0	20.4	9.2	14.5	11.4	0.0	2.2
FSLR	†	FIRST SOLAR, INC.	DEC	16.0	14.7	NM	6.4	NM	NM	6.3	5.6	NM	2.0	NM	NM	8.2	7.5	NM	2.8	NM	NM
INTC	[]	INTEL CORPORATION	DEC	25.1	26.8	29.2	29.7	15.3	17.4	11.8	13.7	15.4	16.5	7.8	9.1	22.5	26.4	27.7	29.3	14.2	16.2
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	JAN	0.0	18.6	11.6	10.8	NM	NM	NA	13.2	7.0	7.1	NM	NM	0.0	24.1	13.3	14.8	NM	NM
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS, IN	OCT	6.3	NM	NM	NM	NM	0.3	3.3	NM	NM	NM	NM	0.1	9.8	NM	NM	NM	NM	NM
MXL	§	MAXLINEAR, INC.	DEC	4.7	NM	NM	NM	NM	15.8	4.0	NM	NM	NM	NM	14.5	9.5	NM	NM	NM	NM	19.9
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	MAR	18.8	6.4	10.8	6.7	6.4	4.8	7.9	2.1	3.3	1.9	3.1	2.1	22.9	6.4	10.5	8.3	7.8	6.3
MU	[]	MICRON TECHNOLOGY, INC.	SEP	21.2	12.5	27.0	46.5	25.0	NM	10.0	5.0	12.9	32.6	14.4	NM	14.1	7.1	18.1	53.6	31.4	NM
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.	DEC	20.0	19.5	17.3	18.1	13.8	13.6	15.3	13.6	11.4	13.3	10.0	10.3	21.9	18.9	15.4	18.1	13.7	13.2
NVDA	[]	NVIDIA CORPORATION	JAN	36.2	26.0	25.6	35.3	31.4	24.1	22.1	15.0	16.1	31.2	27.1	16.9	44.8	29.8	26.0	49.3	46.1	32.6
NXPI	[]	NXP SEMICONDUCTORS N.V.	DEC	16.9	0.6	2.7	23.5	23.9	2.1	9.0	0.3	1.2	10.3	9.2	0.8	23.9	0.9	2.7	18.5	18.3	2.3
ON	[]	ON SEMICONDUCTOR CORPORATION	DEC	15.0	4.5	3.8	10.7	14.6	4.7	10.5	2.7	2.5	8.3	11.3	2.6	24.8	6.9	6.6	21.0	35.0	10.6
POWI	†	POWER INTEGRATIONS, INC.	DEC	23.4	14.6	46.0	16.8	6.4	12.5	16.2	7.9	24.1	11.9	4.4	8.8	19.1	9.3	30.9	13.0	5.3	10.5
QRVO	[]	QORVO, INC.	APR	22.2	18.3	10.3	4.3	NM	NM	13.8	10.2	5.1	2.3	NM	NM	22.5	16.4	7.7	2.9	NM	NM
QCOM	[]	QUALCOMM INCORPORATED	SEP	26.9	22.1	18.1	NM	11.0	24.2	21.9	14.6	13.3	NM	3.7	10.9	112.8	94.6	153.5	NM	7.8	18.0
RMBS	§	RAMBUS INC.	DEC	5.6	NM	NM	NM	NM	2.0	1.5	NM	NM	NM	NM	0.9	2.1	NM	NM	NM	NM	1.3
SMTC	†	SEMTECH CORPORATION	JAN	17.0	10.1	5.8	11.1	5.9	10.0	11.1	5.5	3.0	6.6	3.2	5.4	17.5	8.7	4.7	10.3	5.5	9.6
SLAB	†	SILICON LABORATORIES INC.	JAN	0.0	293.7	2.5	4.1	9.6	6.1	NA	71.6	0.6	1.2	5.1	3.1	0.0	NM	NM	NM	8.3	5.3
SITM	†	SITIME CORPORATION	DEC	14.8	NM	NM	NM	4.7	0.0	4.8	NM	NM	NM	6.3	NA	8.7	NM	NM	NM	0.0	0.0
SWKS	[]	SKYWORKS SOLUTIONS, INC.	OCT	29.3	24.3	25.3	23.7	27.7	30.3	17.4	16.0	17.6	19.0	22.1	25.8	31.7	19.7	20.8	22.5	26.6	29.7
SGH	§	SMART GLOBAL HOLDINGS, INC.	AUG	1.4	NM	4.2	9.3	NM	NM	1.6	NM	7.3	17.8	NM	NM	7.5	NM	22.3	88.6	NM	NM
SYNA	†	SYNAPTICS INCORPORATED	JUN	5.9	8.9	NM	NM	2.8	4.3	3.6	7.0	NM	NM	3.9	5.6	8.9	16.1	NM	NM	6.8	9.6
TXN	[]	TEXAS INSTRUMENTS INCORPORATED	DEC	42.4	38.7	34.9	35.4	24.6	26.9	31.5	28.9	27.8	32.6	20.9	21.9	69.0	61.8	56.1	57.7	35.4	35.2
OLED	†	UNIVERSAL DISPLAY CORPORATION	DEC	33.3	31.1	34.1	23.8	31.0	24.2	12.6	10.5	12.3	6.3	13.3	7.7	18.3	15.5	18.4	8.7	17.5	9.7
WOLF	†	WOLFSPEED, INC.	JUN	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

Note: Data as originally reported. CAGR-Compound annual growth rate.

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

			Return on Revenues (%)						Return on Assets (%)						Return on Equity (%)					
Ticker		Company	Yr. End	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016
SEMICONDUCTOR EQUIPMENT																					
AMKR	†	AMKOR TECHNOLOGY, INC.	DEC	10.5	6.7	3.0	2.9	6.3	4.5	10.6	6.7	2.6	2.8	5.8	4.3	24.2	15.7	6.4	7.2	17.1	13.6
AMAT	[]	APPLIED MATERIALS, INC.	OCT	25.5	21.0	18.5	18.2	23.9	15.9	22.8	16.2	14.2	17.2	18.1	11.8	51.6	38.5	35.9	37.5	42.5	23.2
ACLS	§	AXCELIS TECHNOLOGIES, INC.	DEC	14.9	10.5	5.0	10.4	30.9	4.1	13.1	8.0	3.1	8.4	26.0	3.6	19.3	11.1	4.1	12.0	45.7	5.7
COHU	§	COHU, INC.	DEC	18.9	NM	NM	NM	9.3	1.1	13.3	NM	NM	NM	7.8	0.9	24.0	NM	NM	NM	12.6	1.4
ENPH	[]	ENPHASE ENERGY, INC.	DEC	10.5	17.3	25.8	NM	NM	NM	7.0	11.2	22.6	NM	NM	NM	31.8	35.4	115.1	NM	NM	NM
FORM	§	FORMFACTOR, INC.	DEC	10.9	11.3	6.7	19.6	7.5	NM	8.2	8.2	4.7	14.3	6.3	NM	10.8	11.3	6.4	20.0	9.5	NM
ICHR	§	ICHOR HOLDINGS, LTD.	DEC	6.5	3.6	1.7	7.0	8.6	4.1	6.9	4.3	1.9	11.9	10.1	5.9	15.5	10.5	5.1	27.9	31.8	19.2
KLAC	[]	KLA CORPORATION	JUN	30.0	21.0	25.7	19.9	26.6	23.6	20.2	13.1	13.1	14.2	16.7	14.2	68.6	45.3	54.7	54.4	91.9	126.9
KLIC	§	KULICKE AND SOFFA INDUSTRIES, INC.	OCT	24.2	8.4	2.2	6.4	15.6	7.7	22.9	5.0	1.1	4.8	10.8	4.9	39.6	6.8	1.4	6.3	14.7	6.2
LRCX	[]	LAM RESEARCH CORPORATION	JUN	26.7	22.4	22.7	21.5	21.2	15.5	24.6	15.5	18.3	19.1	14.0	7.5	69.8	45.7	39.2	35.7	26.7	16.6
MKSI	†	MKS INSTRUMENTS, INC.	DEC	18.7	15.0	7.4	18.9	17.7	8.1	12.1	9.0	4.1	15.0	14.0	4.7	21.0	16.0	7.2	22.7	24.0	8.7
ONTO	§	ONTO INNOVATION INC.	JAN	0.0	18.0	5.6	0.6	16.5	12.9	NA	8.6	2.1	0.1	10.8	8.5	0.0	10.6	2.5	0.2	13.0	10.5
PDFS	§	PDF SOLUTIONS, INC.	DEC	NM	NM	NM	NM	NM	8.5	NM	NM	NM	NM	NM	4.1	NM	NM	NM	NM	NM	4.9
PLAB	§	PHOTRONICS, INC.	OCT	8.4	5.5	5.4	7.9	2.9	9.6	4.3	2.8	2.7	3.8	1.3	4.7	8.0	4.3	4.5	6.9	2.5	7.0
SEDG	[]	SOLAREDGE TECHNOLOGIES, INC.	DEC	8.6	9.6	10.3	13.7	13.9	13.0	5.8	5.8	9.8	13.4	13.1	14.9	14.1	14.8	21.0	26.5	24.5	0.0
TER	[]	TERADYNE, INC.	DEC	27.4	25.1	20.4	21.5	12.1	NM	26.6	21.5	16.8	16.7	8.3	NM	42.5	42.5	31.1	26.0	13.6	NM
UCTT	§	ULTRA CLEAN HOLDINGS, INC.	DEC	5.7	5.5	NM	3.3	8.1	1.8	5.9	7.0	NM	3.8	13.3	2.6	17.5	16.0	NM	9.8	29.1	4.8
VECO	§	VEECO INSTRUMENTS INC.	DEC	4.5	NM	NM	NM	NM	NM	2.9	NM	NM	NM	NM	NM	6.2	NM	NM	NM	NM	NM
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																					
ON	[]	ON SEMICONDUCTOR CORPORATION	DEC	15.0	4.5	3.8	10.7	14.6	4.7	10.5	2.7	2.5	8.3	11.3	2.6	24.8	6.9	6.6	21.0	35.0	10.6
STM		STABILUS S.A.	SEP	7.8	3.8	8.5	11.0	8.7	6.5	6.3	2.9	7.3	10.4	8.5	5.1	14.5	6.2	17.5	27.6	26.4	28.3
TSM		TAIWAN SEMICONDUCTOR MANUFACTURING COI	DEC	37.3	38.1	33.1	35.2	35.3	35.0	15.9	18.5	15.6	17.4	17.3	17.6	29.7	29.6	21.6	23.0	24.2	26.0
UMC		UNITED MICROELECTRONICS CORPORATION	DEC	26.2	16.5	5.5	5.1	6.5	5.8	12.0	7.7	2.2	2.1	2.5	2.2	21.3	12.4	2.2	1.6	3.1	1.9

Note: Data as originally reported. CAGR-Compound annual growth rate.

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

					Current Ratio						Debt/Capital Ratio (%)						Debt as a % of Net Working Capital					
Ticker		Company		Yr. End	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016
SEMICONDUCTORS																						
AMD	[]	ADVANCED MICRO DEVICES, INC.		DEC	2.0	2.5	1.9	1.8	1.7	1.9	0.0	5.4	14.7	46.8	69.0	77.5	0.0	8.9	21.7	71.6	118.2	121.2
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITEI		JUN	1.7	1.7	1.7	1.8	2.4	2.7	13.1	18.8	11.8	5.9	0.0	0.0	44.8	79.0	50.6	20.5	0.0	0.0
ADI	[]	ANALOG DEVICES, INC.		OCT	1.9	1.8	1.3	2.0	1.5	6.4	14.1	30.0	30.7	35.7	42.6	25.1	239.8	446.4	1,089.7	590.9	1,000.1	41.3
AVGO	[]	BROADCOM INC.		OCT	2.6	1.9	1.4	3.9	6.3	2.3	61.2	62.7	54.6	39.6	42.9	37.6	382.3	727.5	994.4	258.4	131.1	325.9
CEVA	§	CEVA, INC.		DEC	5.3	5.9	6.8	8.2	7.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRUS	†	CIRRUS LOGIC, INC.	#	MAR	3.2	3.9	4.1	5.4	4.4	5.4	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	9.5
DIOD	§	DIODES INCORPORATED		DEC	2.5	2.0	2.8	2.9	2.7	4.0	18.1	32.9	6.4	16.9	22.2	33.5	39.6	83.4	14.8	40.8	59.9	75.5
FSLR	†	FIRST SOLAR, INC.		DEC	4.4	3.6	2.7	4.6	5.9	4.2	3.8	4.1	8.3	8.3	7.8	3.5	9.6	11.0	20.2	15.6	13.5	6.5
INTC	[]	INTEL CORPORATION		DEC	2.1	1.9	1.4	1.7	1.7	1.7	26.0	29.5	24.6	25.7	26.7	23.8	110.8	150.7	283.4	210.5	207.6	136.0
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	#	JAN	0.0	2.8	4.2	2.6	4.1	3.1	NA	25.5	29.1	27.6	49.3	57.9	NA	72.1	62.2	76.9	116.9	166.7
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS		OCT	5.6	5.1	5.3	4.3	4.8	6.7	51.5	68.5	67.6	49.6	46.0	55.4	116.9	168.7	202.4	187.1	148.4	110.2
MXL	§	MAXLINEAR, INC.		DEC	1.9	1.5	2.7	2.5	2.6	3.9	38.5	48.2	33.3	39.0	47.3	0.0	155.6	283.9	179.6	232.4	278.3	0.0
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	#	MAR	1.8	0.9	1.4	0.9	1.7	3.3	56.6	58.7	61.4	62.9	34.9	47.0	729.6	NM	1,530.4	NM	131.3	181.2
MU	[]	MICRON TECHNOLOGY, INC.		SEP	3.1	2.7	2.6	2.8	2.3	2.0	12.0	13.3	10.2	8.9	31.7	38.6	44.3	52.6	41.3	31.5	127.3	174.4
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.		DEC	5.0	5.7	6.7	7.2	6.8	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NVDA	[]	NVIDIA CORPORATION	#	JAN	6.7	4.1	7.7	7.9	8.0	4.8	29.1	26.1	14.0	17.5	21.0	25.6	44.7	49.2	16.7	21.5	24.5	29.4
NXPI	[]	NXP SEMICONDUCTORS N.V.		DEC	2.1	2.1	1.8	1.5	2.2	2.2	61.0	45.4	43.3	36.8	29.7	44.0	380.8	329.8	499.0	338.0	173.9	295.6
ON	[]	ON SEMICONDUCTOR CORPORATION		DEC	2.5	1.9	1.7	2.2	2.1	1.9	38.8	45.4	46.4	45.1	49.1	62.5	130.2	196.1	239.4	154.7	177.4	224.6
POWI	†	POWER INTEGRATIONS, INC.		DEC	9.5	9.6	10.7	6.9	7.1	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
QRVO	[]	QORVO, INC.	#	APR	3.6	3.6	3.1	3.9	4.2	3.5	31.0	27.3	26.7	17.4	17.1	16.8	115.2	96.6	135.9	73.6	70.1	94.9
QCOM	[]	QUALCOMM INCORPORATED		SEP	1.7	2.1	1.9	1.5	4.0	3.1	60.0	73.8	76.0	101.2	40.7	28.1	174.8	159.7	178.0	273.1	62.4	75.0
RMBS	§	RAMBUS INC.		DEC	2.6	8.1	7.7	7.6	2.8	4.2	0.0	14.6	13.2	15.0	23.2	22.9	0.0	25.4	25.7	38.9	72.3	99.2
SMTC	†	SEMTECH CORPORATION	#	JAN	3.9	4.3	4.7	3.7	3.7	3.6	18.9	20.5	22.3	22.0	24.1	27.2	45.9	49.3	53.8	54.3	63.0	71.8
SLAB	†	SILICON LABORATORIES INC.	#	JAN	0.0	3.3	3.4	6.9	5.7	5.8	NA	0.0	26.3	24.8	24.9	26.4	NA	0.0	62.0	45.7	52.0	43.5
SITM	†	SITIME CORPORATION		DEC	16.7	5.9	1.9	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.0	0.0	NA
SWKS	[]	SKYWORKS SOLUTIONS, INC.		OCT	4.4	5.2	6.0	5.8	6.8	9.5	29.7	0.0	0.0	0.0	0.0	0.0	101.3	0.0	0.0	0.0	0.0	0.0
SGH	§	SMART GLOBAL HOLDINGS, INC.		AUG	1.6	2.0	2.0	1.8	1.4	1.4	55.4	40.9	40.0	49.6	65.2	100.6	99.6	71.3	77.9	81.4	144.2	250.4
SYNA	†	SYNAPTICS INCORPORATED		JUN	1.5	4.4	2.9	2.6	2.6	2.2	29.0	41.7	41.6	38.2	21.4	23.5	100.4	70.4	98.1	98.9	41.9	50.5
TXN	[]	TEXAS INSTRUMENTS INCORPORATED		DEC	5.3	4.3	4.1	3.3	3.9	3.3	35.2	40.5	37.3	32.4	25.7	22.1	65.1	79.6	79.9	76.8	55.2	57.3
OLED	†	UNIVERSAL DISPLAY CORPORATION		DEC	4.9	5.6	4.9	4.8	8.1	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WOLF	†	WOLFSPEED, INC.		JUN	3.3	5.5	5.3	3.6	5.2	5.2	28.0	27.3	18.7	12.4	6.1	6.3	80.0	60.2	41.0	45.5	16.3	17.1

Note: Data as originally reported. CAGR-Compound annual growth rate.

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

Ticker		Company	Yr. End	Current Ratio 2021	2020	2019	2018	2017	2016	Debt/Capital Ratio (%) 2021	2020	2019	2018	2017	2016	Debt as a % of Net Working Capital 2021	2020	2019	2018	2017	2016
SEMICONDUCTOR EQUIPMENT																					
AMKR	†	AMKOR TECHNOLOGY, INC.	DEC	1.7	1.6	1.9	1.4	1.2	1.4	24.9	29.9	39.6	39.6	41.9	50.6	83.7	123.1	138.7	237.5	380.6	356.3
AMAT	[]	APPLIED MATERIALS, INC.	OCT	2.5	3.0	2.3	2.7	3.1	2.3	30.8	34.0	36.5	43.7	36.2	32.2	55.8	61.1	81.8	79.5	60.3	70.4
ACLS	§	AXCELIS TECHNOLOGIES, INC.	DEC	4.1	5.6	5.5	4.7	4.3	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COHU	§	COHU, INC.	DEC	3.9	2.8	3.0	3.0	3.5	3.6	10.8	38.5	42.2	39.1	2.6	0.0	19.1	102.0	120.3	107.5	3.6	0.0
ENPH	[]	ENPHASE ENERGY, INC.	DEC	3.3	1.7	2.5	1.5	1.4	1.4	68.9	1.0	27.4	91.3	139.3	139.9	93.1	1.2	34.2	108.6	83.5	88.0
FORM	§	FORMFACTOR, INC.	DEC	3.5	3.2	3.1	3.3	3.3	3.1	1.9	3.2	2.4	5.7	16.0	23.8	4.1	7.5	5.5	14.9	40.8	72.9
ICHR	§	ICHOR HOLDINGS, LTD.	DEC	2.2	3.1	1.7	2.4	1.9	1.6	36.3	31.8	43.3	49.2	45.4	21.1	112.1	57.4	149.7	155.2	137.3	67.7
KLAC	[]	KLA CORPORATION	JUN	2.7	2.8	2.4	3.7	3.4	3.9	50.6	56.4	54.2	58.0	66.9	81.6	95.8	114.7	124.6	67.1	86.5	106.7
KLIC	§	KULICKE AND SOFFA INDUSTRIES, INC.	OCT	3.8	5.4	5.1	5.7	4.9	6.2	0.0	0.0	9.6	1.7	1.7	2.0	0.0	0.0	10.4	1.9	2.1	2.5
LRCX	[]	LAM RESEARCH CORPORATION	JUN	3.3	3.4	3.6	2.9	3.1	3.8	45.1	48.9	44.6	25.9	20.8	36.4	61.1	64.5	60.9	35.7	28.8	49.7
MKSI	†	MKS INSTRUMENTS, INC.	DEC	4.7	4.8	4.5	5.6	4.3	4.2	22.0	26.2	30.4	15.7	19.9	32.9	48.2	58.3	79.0	28.9	41.5	79.6
ONTO	§	ONTO INNOVATION INC. #	JAN	0.0	6.1	6.1	7.5	7.8	7.6	NA	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.0	0.0
PDFS	§	PDF SOLUTIONS, INC.	DEC	4.3	4.6	5.3	8.1	8.3	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PLAB	§	PHOTRONICS, INC.	OCT	3.1	3.5	2.8	2.6	5.5	5.4	5.5	5.9	5.3	0.0	6.2	6.5	15.6	16.7	18.4	0.0	15.6	15.9
SEDG	[]	SOLAREDGE TECHNOLOGIES, INC.	DEC	3.3	3.9	2.1	3.0	3.7	4.8	32.2	34.6	0.0	0.6	0.0	0.0	52.4	44.7	0.0	0.8	0.0	0.0
TER	[]	TERADYNE, INC.	DEC	3.2	3.4	3.1	3.6	5.0	4.4	3.4	14.6	21.1	20.0	15.8	16.2	5.0	22.0	35.2	30.2	20.2	28.2
UCTT	§	ULTRA CLEAN HOLDINGS, INC.	DEC	2.4	2.7	2.2	3.3	2.0	2.3	37.2	32.2	38.5	42.4	11.7	19.1	79.3	76.1	110.5	102.5	19.9	37.3
VECO	§	VEECO INSTRUMENTS INC.	DEC	2.9	4.0	4.0	3.2	2.7	3.5	34.4	44.0	44.5	39.6	24.7	0.1	63.7	72.9	83.9	79.8	73.9	0.2
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																					
ON	[]	ON SEMICONDUCTOR CORPORATION	DEC	2.5	1.9	1.7	2.2	2.1	1.9	38.8	45.4	46.4	45.1	49.1	62.5	130.2	196.1	239.4	154.7	177.4	224.6
STM		STABILUS S.A.	SEP	2.6	2.2	2.3	2.3	1.7	1.7	35.0	38.0	38.2	42.8	48.1	60.1	96.7	132.8	139.2	152.8	261.2	349.0
TSM		TAIWAN SEMICONDUCTOR MANUFACTURING (	DEC	2.1	1.7	1.4	2.7	2.2	2.3	26.3	16.5	8.8	8.5	9.8	14.0	85.8	74.9	64.0	24.5	33.1	45.0
UMC		UNITED MICROELECTRONICS CORPORATION	DEC	2.2	2.1	2.1	2.8	1.6	1.5	13.0	13.8	23.9	29.3	30.0	29.5	32.7	41.6	74.1	87.8	156.1	215.7

Note: Data as originally reported. CAGR-Compound annual growth rate.
[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.
Souce: S&P Capital IQ.

					Price/Earnings Ratio (High-Low)						Dividend Payout Ratio (%)						Dividend Yield (High-Low, %)					
Ticker		Company		Yr. End	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016
SEMICONDUCTORS																						
AMD	[]	ADVANCED MICRO DEVICES, INC.		DEC	62 - 28	46 - 18	149 - 55	95 - 28	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITEI		JUN	18 - 5	NM - NM	202 - 108	31 - 23	40 - 23	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
ADI	[]	ANALOG DEVICES, INC.		OCT	52 - 33	38 - 25	34 - 22	25 - 19	39 - 27	23 - 17	79.8	72.6	57.0	46.7	74.8	59.6	2.2 - 1.5	2.2 - 1.5	3.0 - 1.8	2.5 - 1.7	2.2 - 1.9	2.8 - 2.1
AVGO	[]	BROADCOM INC.		OCT	34 - 22	58 - 25	47 - 31	10 - 7	62 - 39	NM - NM	92.2	187.0	155.5	24.5	97.7	NM	3.7 - 2.4	3.7 - 2.8	7.7 - 3.3	4.7 - 2.8	3.5 - 1.4	2.4 - 1.2
CEVA	§	CEVA, INC.		DEC	4271 - 2363	NM - NM	25641 - 16820	1891 - 792	65 - 41	58 - 28	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
CRUS	†	CIRRUS LOGIC, INC.	#	MAR	27 - 15	31 - 14	30 - 21	28 - 16	16 - 8	19 - 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
DIOD	§	DIODES INCORPORATED		DEC	22 - 13	38 - 17	18 - 10	19 - 13	NM - NM	82 - 52	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
FSLR	†	FIRST SOLAR, INC.		DEC	27 - 16	28 - 8	NM - NM	57 - 27	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
INTC	[]	INTEL CORPORATION		DEC	14 - 10	14 - 9	13 - 9	13 - 9	23 - 16	17 - 13	28.4	26.6	26.5	26.3	52.8	47.7	5.8 - 2.5	2.9 - 2.0	3.0 - 1.8	2.9 - 2.1	2.8 - 2.1	3.3 - 2.3
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	#	JAN	66 - 20	67 - 22	26 - 16	NM - NM	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS		OCT	124 - 59	NM - NM	NM - NM	NM - NM	NM - NM	1661 - 1109	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
MXL	§	MAXLINEAR, INC.		DEC	140 - 56	NM - NM	NM - NM	NM - NM	NM - NM	24 - 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	#	MAR	121 - 47	47 - 23	69 - 41	91 - 66	98 - 62	32 - 25	39.2	111.1	61.4	96.8	132.1	191.6	1.5 - 1.0	2.6 - 1.0	1.8 - 1.3	2.4 - 1.4	2.0 - 1.5	3.2 - 2.0
MU	[]	MICRON TECHNOLOGY, INC.		SEP	18 - 9	25 - 14	9 - 5	5 - 3	8 - 4	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.8 - 0.4	0.6 - 0.5	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.		DEC	109 - 57	97 - 37	73 - 43	61 - 42	80 - 52	66 - 43	45.2	54.0	61.8	45.1	52.0	62.8	1.0 - 0.4	0.8 - 0.4	1.5 - 0.6	1.4 - 0.9	1.2 - 0.7	1.0 - 0.6
NVDA	[]	NVIDIA CORPORATION	#	JAN	83 - 28	55 - 29	42 - 19	48 - 19	38 - 8	30 - 17	4.1	9.1	13.9	9.0	11.2	15.7	0.1 - 0.0	0.3 - 0.1	0.5 - 0.3	0.5 - 0.2	0.6 - 0.3	1.7 - 0.5
NXPI	[]	NXP SEMICONDUCTORS N.V.		DEC	35 - 23	895 - 347	150 - 84	19 - 10	18 - 15	177 - 108	30.0	807.7	131.3	3.4	0.0	0.0	2.4 - 0.9	1.3 - 0.8	2.3 - 0.9	1.5 - 0.9	1.4 - 1.1	0.0 - 0.0
ON	[]	ON SEMICONDUCTOR CORPORATION		DEC	29 - 13	56 - 15	48 - 30	18 - 10	11 - 7	30 - 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
POWI	†	POWER INTEGRATIONS, INC.		DEC	40 - 27	67 - 33	15 - 8	34 - 21	91 - 67	41 - 25	19.8	35.2	10.6	26.9	60.2	30.8	1.1 - 0.6	0.7 - 0.5	1.0 - 0.6	1.1 - 0.7	1.3 - 0.7	0.9 - 0.7
QRVO	[]	QORVO, INC.	#	APR	31 - 14	42 - 21	81 - 52	NM - NM	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
QCOM	[]	QUALCOMM INCORPORATED		SEP	21 - 14	27 - 13	25 - 14	NM - NM	42 - 30	17 - 11	33.3	55.4	67.7	NM	133.0	52.4	2.5 - 1.4	2.4 - 1.6	4.3 - 2.1	5.0 - 2.8	5.0 - 3.3	4.4 - 3.0
RMBS	§	RAMBUS INC.		DEC	179 - 103	NM - NM	NM - NM	NM - NM	NM - NM	233 - 176	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SMTC	†	SEMTECH CORPORATION	#	JAN	90 - 29	119 - 83	57 - 30	78 - 60	40 - 19	171 - 82	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SLAB	†	SILICON LABORATORIES INC.	#	JAN	3 - 1	426 - 267	246 - 165	52 - 34	62 - 33	40 - 27	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SITM	†	SITIME CORPORATION		DEC	197 - 47	NM - NM	NM - NM	NA - NA	NA - NA		0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SWKS	[]	SKYWORKS SOLUTIONS, INC.		OCT	22 - 15	32 - 14	19 - 12	23 - 16	20 - 13	17 - 11	22.7	37.7	32.1	26.5	21.2	20.2	2.9 - 1.3	1.5 - 1.0	2.6 - 1.3	2.5 - 1.4	1.5 - 1.1	1.6 - 1.0
SGH	§	SMART GLOBAL HOLDINGS, INC.		AUG	64 - 27	NM - NM	16 - 8	10 - 3	NM - NM	NA - NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SYNA	†	SYNAPTICS INCORPORATED		JUN	65 - 26	24 - 8	NM - NM	NM - NM	49 - 34	48 - 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
TXN	[]	TEXAS INSTRUMENTS INCORPORATED		DEC	24 - 19	28 - 15	25 - 17	21 - 15	28 - 20	21 - 14	50.0	61.2	60.0	45.8	57.1	45.8	3.3 - 2.3	2.5 - 2.1	3.9 - 2.4	3.5 - 2.4	3.4 - 2.1	2.9 - 2.3
OLED	†	UNIVERSAL DISPLAY CORPORATION		DEC	67 - 37	86 - 38	77 - 27	166 - 65	87 - 26	72 - 41	20.6	21.3	13.6	19.2	5.4	0.0	1.3 - 0.5	0.6 - 0.2	0.6 - 0.2	0.3 - 0.2	0.3 - 0.1	0.2 - 0.1
WOLF	†	WOLFSPEED, INC.		JUN	NM - NM	NM - NM	NM - NM	NM - NM	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0

Note: Data as originally reported. CAGR-Compound annual growth rate.

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

Ticker	Company	Yr. End	Price/Earnings Ratio (High-Low)						Dividend Payout Ratio (%)						Dividend Yield (High-Low, %)					
			2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016
SEMICONDUCTOR EQUIPMENT																				
AMKR	† AMKOR TECHNOLOGY, INC.	DEC	11 - 6	11 - 4	30 - 13	22 - 11	11 - 8	17 - 6	8.0	0.0	0.0	0.0	0.0	0.0	1.3 - 0.8	1.1 - 0.6	1.4 - 1.1	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
AMAT	[] APPLIED MATERIALS, INC.	OCT	22 - 9	17 - 10	19 - 10	21 - 11	17 - 9	20 - 10	14.2	21.7	28.5	19.9	12.2	25.8	1.3 - 0.6	1.5 - 0.7	2.3 - 1.2	2.8 - 1.6	2.1 - 0.6	1.4 - 0.8
ACLS	§ AXCELIS TECHNOLOGIES, INC.	DEC	25 - 10	21 - 9	48 - 27	22 - 11	9 - 3	38 - 24	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
COHU	§ COHU, INC.	DEC	14 - 8	NM - NM	NM - NM	NM - NM	22 - 11	124 - 90	0.0	NM	NM	NM	20.0	209.0	0.0 - 0.0	0.0 - 0.0	2.4 - 0.0	2.1 - 1.2	1.4 - 0.9	2.0 - 0.9
ENPH	[] ENPHASE ENERGY, INC.	DEC	247 - 106	170 - 22	25 - 3	NM - NM	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
FORM	§ FORMFACTOR, INC.	DEC	47 - 31	44 - 16	50 - 25	12 - 8	32 - 19	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
ICHR	§ ICHOR HOLDINGS, LTD.	DEC	25 - 12	28 - 10	72 - 33	15 - 6	15 - 5	12 - 11	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
KLAC	[] KLA CORPORATION	JUN	26 - 13	25 - 15	17 - 11	24 - 17	18 - 11	17 - 10	26.9	42.9	39.9	49.3	36.2	46.1	1.3 - 0.9	2.1 - 1.0	3.0 - 1.7	3.7 - 2.3	3.0 - 2.0	3.1 - 2.1
KLIC	§ KULICKE AND SOFFA INDUSTRIES, INC.	OCT	13 - 4	34 - 22	138 - 101	35 - 24	13 - 7	20 - 14	9.1	57.8	270.9	14.4	0.0	0.0	1.8 - 1.0	2.2 - 0.8	2.6 - 1.7	2.7 - 1.9	2.1 - 1.7	0.0 - 0.0
LRCX	[] LAM RESEARCH CORPORATION	JUN	25 - 11	22 - 12	14 - 9	16 - 9	16 - 8	15 - 11	18.6	29.2	31.0	12.9	14.3	20.8	1.3 - 0.8	1.8 - 0.8	2.6 - 1.3	3.6 - 2.1	2.3 - 0.9	1.8 - 1.1
MKSI	† MKS INSTRUMENTS, INC.	DEC	20 - 14	25 - 11	45 - 25	17 - 8	17 - 9	31 - 16	8.6	12.6	31.0	10.8	11.3	34.7	1.2 - 0.5	0.6 - 0.4	1.1 - 0.6	1.4 - 0.7	1.2 - 0.6	1.2 - 0.7
ONTO	§ ONTO INNOVATION INC. #	JAN	20 - 7	64 - 51	NA - NA	NA - NA	NA - NA	NA - NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
PDFS	§ PDF SOLUTIONS, INC.	DEC	NM - NM	NM - NM	NM - NM	NM - NM	NM - NM	83 - 31	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
PLAB	§ PHOTRONICS, INC.	OCT	17 - 11	31 - 16	27 - 18	18 - 12	62 - 39	19 - 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SEDG	[] SOLAREDGE TECHNOLOGIES, INC.	DEC	114 - 63	116 - 25	31 - 11	24 - 11	20 - 6	19 - 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
TER	[] TERADYNE, INC.	DEC	27 - 17	26 - 9	25 - 11	21 - 12	34 - 20	NM - NM	6.5	8.5	13.1	14.9	21.5	NM	0.6 - 0.2	0.4 - 0.3	0.9 - 0.3	1.2 - 0.5	1.2 - 0.6	1.0 - 0.6
UCTT	§ ULTRA CLEAN HOLDINGS, INC.	DEC	24 - 11	19 - 6	NM - NM	28 - 7	15 - 4	34 - 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
VECO	§ VEECO INSTRUMENTS INC.	DEC	52 - 31	NM - NM	NM - NM	NM - NM	NM - NM	NM - NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																				
ON	ON SEMICONDUCTOR CORPORATION	DEC	29 - 13	56 - 15	48 - 30	18 - 10	11 - 7	30 - 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
STM	STABILUS S.A.	SEP	24 - 16	51 - 24	22 - 11	21 - 16	24 - 14	23 - 13	16.8	86.4	30.6	18.7	15.6	0.0	3.1 - 0.7	2.5 - 0.7	3.6 - 1.6	2.8 - 1.0	1.2 - 0.6	1.0 - 0.0
TSM	TAIWAN SEMICONDUCTOR MANUFACTURING (	DEC	29 - 23	27 - 13	25 - 15	19 - 15	18 - 13	15 - 10	44.9	50.8	73.3	57.1	52.6	46.9	2.8 - 1.6	2.0 - 1.5	4.0 - 2.0	4.1 - 3.0	3.8 - 2.6	3.4 - 2.8
UMC	UNITED MICROELECTRONICS CORPORATION	DEC	15 - 10	21 - 6	24 - 15	29 - 16	20 - 14	19 - 16	35.6	33.5	84.7	111.5	63.1	80.1	8.5 - 2.3	3.6 - 1.4	5.9 - 1.9	6.7 - 3.9	6.8 - 3.2	5.0 - 3.0

Note: Data as originally reported. CAGR-Compound annual growth rate.

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

					Earnings per Share ($)						Tangible Book Value per Share ($)						Share Price (High-Low, $)					
Ticker		Company		Yr. End	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016	2021	2020	2019	2018	2017	2016
SEMICONDUCTORS																						
AMD	[]	ADVANCED MICRO DEVICES, INC.		DEC	2.6	2.1	0.3	0.3	0.0	-0.6	5.7	4.4	2.0	0.7	0.1	-0.1	164.5 - 72.5	98.0 - 36.8	47.3 - 16.9	34.1 - 9.0	15.7 - 9.4	12.4 - 1.8
AOSL	§	ALPHA AND OMEGA SEMICONDUCTOR LIMITEI		JUN	2.1	-0.3	0.1	0.6	0.6	-0.1	13.7	10.9	11.2	11.0	11.2	10.5	63.3 - 23.7	29.2 - 5.8	14.2 - 8.2	17.8 - 9.0	23.0 - 14.8	23.9 - 8.0
ADI	[]	ANALOG DEVICES, INC.		OCT	3.5	3.3	3.7	4.0	2.3	2.8	-8.0	-10.6	-12.9	-15.6	-20.0	9.5	192.0 - 142.3	147.8 - 79.1	124.8 - 80.5	103.6 - 76.6	94.0 - 71.0	74.9 - 47.2
AVGO	[]	BROADCOM INC.		OCT	15.0	6.3	6.4	28.4	4.0	-4.9	-72.3	-89.3	-73.7	-27.0	-37.3	-52.5	677.8 - 419.1	438.5 - 155.7	331.2 - 230.3	274.3 - 197.5	285.7 - 173.3	184.0 - 114.3
CEVA	§	CEVA, INC.		DEC	0.0	-0.1	0.0	0.0	0.8	0.6	8.2	8.9	8.5	9.0	8.9	7.6	84.0 - 40.1	46.5 - 20.5	33.2 - 21.2	49.8 - 20.4	51.8 - 32.0	36.8 - 17.1
CRUS	†	CIRRUS LOGIC, INC.	#	MAR	5.5	3.6	2.6	1.5	2.5	3.9	17.8	18.7	15.6	13.3	12.3	11.3	103.3 - 71.1	91.6 - 47.0	83.6 - 31.3	55.1 - 31.5	72.0 - 48.6	60.0 - 25.1
DIOD	§	DIODES INCORPORATED		DEC	5.0	1.9	3.0	2.0	0.0	0.3	22.1	15.7	16.5	13.2	11.0	9.8	114.0 - 68.0	73.2 - 31.5	56.9 - 29.9	39.3 - 26.1	35.4 - 22.1	27.2 - 16.6
FSLR	†	FIRST SOLAR, INC.		DEC	4.4	3.7	-1.1	1.4	-1.6	-4.1	55.5	51.4	47.6	48.9	47.9	49.2	123.1 - 67.7	109.1 - 28.5	69.2 - 41.4	81.7 - 36.5	71.8 - 25.6	74.3 - 28.6
INTC	[]	INTEL CORPORATION		DEC	4.9	4.9	4.7	4.5	2.0	2.1	15.0	11.1	9.4	8.5	6.8	9.0	68.5 - 47.9	69.3 - 43.6	60.5 - 42.9	57.6 - 42.0	47.6 - 33.2	38.4 - 27.7
LSCC	†	LATTICE SEMICONDUCTOR CORPORATION	#	JAN	0.0	0.7	0.3	0.3	-0.2	-0.6	0.0	0.5	0.8	0.4	-0.2	-0.8	85.4 - 37.4	46.4 - 13.5	21.6 - 6.7	8.9 - 5.1	7.6 - 5.1	8.0 - 4.0
MTSI	†	MACOM TECHNOLOGY SOLUTIONS HOLDINGS		OCT	0.5	-0.7	-5.8	-2.6	-2.8	0.0	1.1	-2.2	-2.8	-2.4	-2.5	1.5	80.3 - 48.7	55.7 - 15.0	27.8 - 12.3	38.4 - 13.1	66.0 - 29.7	53.8 - 29.6
MXL	§	MAXLINEAR, INC.		DEC	0.5	-1.4	-0.3	-0.4	-0.1	0.9	0.4	-1.6	-0.2	-1.2	-2.5	2.6	77.9 - 30.5	38.6 - 7.8	28.7 - 16.5	28.1 - 14.9	32.5 - 20.4	23.1 - 12.7
MCHP	[]	MICROCHIP TECHNOLOGY INCORPORATED	#	MAR	2.3	0.7	1.1	0.7	0.5	0.4	-8.7	-11.2	-13.8	-17.0	-1.4	-2.6	90.0 - 64.5	72.7 - 26.6	53.1 - 33.1	52.1 - 30.4	48.0 - 31.1	33.4 - 19.5
MU	[]	MICRON TECHNOLOGY, INC.		SEP	5.1	2.4	5.5	11.5	4.4	-0.3	37.9	33.6	31.0	26.5	15.3	11.1	97.0 - 65.7	75.7 - 31.1	56.1 - 30.8	64.7 - 28.4	49.9 - 21.5	23.6 - 9.3
MPWR	[]	MONOLITHIC POWER SYSTEMS, INC.		DEC	5.1	3.5	2.4	2.4	1.5	1.3	26.8	21.2	17.6	14.9	12.4	10.3	580.0 - 301.5	367.1 - 130.1	183.5 - 107.4	152.2 - 102.0	126.8 - 81.8	88.1 - 55.1
NVDA	[]	NVIDIA CORPORATION	#	JAN	3.9	1.7	1.1	1.7	1.2	0.6	8.0	4.0	4.7	3.6	2.8	2.2	346.5 - 115.7	147.3 - 45.2	60.5 - 31.9	73.2 - 31.1	54.7 - 23.8	30.0 - 6.2
NXPI	[]	NXP SEMICONDUCTORS N.V.		DEC	6.8	0.2	0.9	6.7	6.4	0.6	-19.4	-11.7	-14.7	-9.6	-3.5	-15.7	239.9 - 156.0	167.3 - 58.4	129.5 - 71.6	125.9 - 67.6	118.2 - 96.0	107.5 - 61.6
ON	[]	ON SEMICONDUCTOR CORPORATION		DEC	2.3	0.6	0.5	1.4	1.9	0.4	5.0	3.4	2.6	4.0	2.9	0.3	70.3 - 32.3	32.9 - 8.2	24.7 - 15.6	27.1 - 14.6	22.2 - 12.4	13.3 - 7.0
POWI	†	POWER INTEGRATIONS, INC.		DEC	2.7	1.2	3.2	1.2	0.5	0.8	13.5	11.8	10.5	7.2	7.2	6.5	110.7 - 73.0	82.0 - 38.6	51.2 - 27.9	40.3 - 23.7	43.3 - 30.7	35.0 - 19.8
QRVO	[]	QORVO, INC.	#	APR	9.3	6.3	2.8	1.1	-0.3	-0.1	10.4	12.2	7.6	14.9	13.8	10.5	201.7 - 142.2	170.9 - 67.5	118.5 - 54.7	86.8 - 56.3	81.2 - 52.1	64.8 - 33.3
QCOM	[]	QUALCOMM INCORPORATED		SEP	7.9	4.5	3.6	-3.4	1.6	3.8	1.1	-1.7	-3.1	-7.1	13.8	15.3	192.7 - 122.2	161.1 - 58.0	94.1 - 49.1	76.5 - 48.6	69.3 - 48.9	71.6 - 42.2
RMBS	§	RAMBUS INC.		DEC	0.2	-0.4	-0.8	-1.5	-0.2	0.1	4.8	6.2	6.6	6.8	2.5	1.9	29.9 - 17.4	18.5 - 9.0	14.8 - 7.6	14.6 - 7.2	15.5 - 11.3	14.5 - 10.7
SMTC	†	SEMTECH CORPORATION	#	JAN	1.9	0.9	0.5	1.0	0.5	0.8	5.9	5.2	4.7	4.5	4.0	3.2	94.9 - 58.0	73.9 - 26.0	58.0 - 39.5	60.6 - 31.3	42.0 - 31.0	33.3 - 15.7
SLAB	†	SILICON LABORATORIES INC.	#	JAN	0.0	49.4	0.3	0.4	1.9	1.1	0.0	44.6	15.0	13.4	11.6	13.6	211.0 - 120.2	128.9 - 65.1	117.4 - 74.0	110.7 - 73.1	96.9 - 63.2	69.0 - 36.6
SITM	†	SITIME CORPORATION		DEC	1.5	-0.6	-0.6	-0.9	0.5	0.0	30.1	6.3	3.9	0.3	1.0	0.0	341.8 - 75.8	118.6 - 15.4	25.8 - 16.1	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
SWKS	[]	SKYWORKS SOLUTIONS, INC.		OCT	9.0	4.8	4.9	5.0	5.4	5.2	8.6	17.6	16.6	15.6	17.0	14.1	204.0 - 142.0	158.6 - 67.9	122.9 - 60.1	116.0 - 62.7	117.7 - 73.9	82.3 - 54.5
SGH	§	SMART GLOBAL HOLDINGS, INC.		AUG	0.4	0.0	1.1	2.6	-0.2	-0.7	2.8	3.1	2.6	2.6	0.7	-2.3	36.2 - 17.9	19.5 - 8.2	19.4 - 8.5	28.3 - 12.9	21.6 - 5.8	0.0 - 0.0
SYNA	†	SYNAPTICS INCORPORATED		JUN	2.1	3.4	-0.7	-3.6	1.4	1.9	2.7	10.7	4.2	3.9	12.5	9.6	299.4 - 95.9	98.0 - 44.4	68.9 - 26.3	55.3 - 33.5	64.5 - 33.7	90.9 - 47.1
TXN	[]	TEXAS INSTRUMENTS INCORPORATED		DEC	8.3	6.0	5.2	5.6	3.6	3.5	9.6	5.1	4.4	4.1	5.0	4.8	202.3 - 160.8	167.2 - 93.1	132.2 - 88.7	120.8 - 87.7	105.3 - 72.5	75.3 - 46.7
OLED	†	UNIVERSAL DISPLAY CORPORATION		DEC	3.9	2.8	2.9	1.2	2.2	1.0	21.5	17.1	14.6	11.6	10.6	7.3	262.8 - 139.8	247.0 - 105.1	230.3 - 78.8	209.0 - 78.8	192.8 - 56.2	74.4 - 40.4
WOLF	†	WOLFSPEED, INC.		JUN	-4.7	-1.8	-3.6	-2.8	-1.0	-0.2	14.0	14.4	12.3	13.0	13.6	14.3	142.3 - 75.1	109.2 - 27.8	69.2 - 39.6	51.8 - 30.8	40.2 - 20.5	32.9 - 20.8

Note: Data

[]Company included in the S&P 500. †Company included in the S&P MidCap 400. §Company included in the S&P SmallCap 600. #Of the following calendar year.

Souce: S&P Capital IQ.

			Earnings per Share ($)						Tangible Book Value per Share ($)						Share Price (High-Low, $)					
Ticker	**Company**	**Yr. End**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**
SEMICONDUCTOR EQUIPMENT																				
AMKR	† AMKOR TECHNOLOGY, INC.	DEC	2.6	1.4	0.5	0.5	1.1	0.7	11.9	9.5	8.0	7.5	7.0	5.7	29.5 - 14.8	15.8 - 5.4	15.2 - 6.3	11.7 - 5.7	12.5 - 8.3	12.5 - 4.1
AT	[] APPLIED MATERIALS, INC.	OCT	6.4	3.9	2.9	3.0	3.3	1.5	9.7	7.6	5.1	3.4	5.3	3.1	163.0 - 86.2	90.6 - 36.6	63.1 - 31.5	62.4 - 28.8	60.9 - 31.7	33.7 - 15.4
S	§ AXCELIS TECHNOLOGIES, INC.	DEC	2.9	1.5	0.5	1.4	3.8	0.4	16.2	14.3	12.9	12.5	11.0	6.8	75.4 - 28.5	31.5 - 13.0	25.0 - 14.0	31.6 - 15.5	37.1 - 14.0	14.7 - 7.2
IU	§ COHU, INC.	DEC	3.5	-0.3	-1.7	-1.0	1.1	0.1	9.7	0.3	-1.0	-0.4	7.3	5.9	51.9 - 29.0	41.0 - 8.9	23.0 - 11.4	27.8 - 14.1	26.2 - 12.6	14.4 - 10.0
H	[] ENPHASE ENERGY, INC.	DEC	1.0	0.9	1.2	-0.1	-0.5	-1.3	1.0	3.3	1.8	-0.5	-0.2	-0.1	282.5 - 108.9	189.4 - 21.5	35.4 - 4.6	7.6 - 1.8	3.5 - 0.7	3.7 - 1.0
M	§ FORMFACTOR, INC.	DEC	1.1	1.0	0.5	1.4	0.6	-0.1	7.2	6.1	5.1	4.4	2.4	1.2	52.4 - 32.7	45.9 - 16.4	26.3 - 12.9	17.2 - 11.1	18.7 - 10.5	12.1 - 6.2
R	§ ICHOR HOLDINGS, LTD.	DEC	2.5	1.4	0.5	2.3	2.2	0.7	2.6	7.1	-0.2	-1.4	-1.0	1.4	63.4 - 30.6	39.8 - 13.7	34.7 - 16.0	34.8 - 14.2	35.5 - 10.8	11.2 - 9.8
C	[] KLA CORPORATION	JUN	13.4	7.7	7.5	5.1	5.9	4.5	1.2	-5.0	-7.0	8.0	6.1	2.2	442.4 - 257.7	268.9 - 110.2	180.0 - 85.7	124.0 - 80.7	114.4 - 77.9	83.2 - 62.3
C	§ KULICKE AND SOFFA INDUSTRIES, INC.	OCT	5.8	0.8	0.2	0.8	1.8	0.7	15.8	10.8	10.6	11.5	11.4	9.5	75.3 - 31.9	34.2 - 16.9	27.5 - 18.8	28.7 - 17.4	28.7 - 16.0	16.9 - 9.6
X	[] LAM RESEARCH CORPORATION	JUN	26.9	15.1	13.7	13.2	9.2	5.2	30.9	24.2	20.6	30.0	31.0	24.6	728.4 - 473.3	516.7 - 181.4	299.4 - 131.4	234.9 - 122.6	219.7 - 105.8	110.4 - 63.1
SI	† MKS INSTRUMENTS, INC.	DEC	9.9	6.3	2.6	7.1	6.2	1.9	19.5	14.2	7.3	17.9	11.6	4.6	199.4 - 138.7	158.1 - 66.9	115.1 - 62.7	128.3 - 56.4	110.6 - 59.0	61.3 - 30.7
O	§ ONTO INNOVATION INC. #	JAN	0.0	2.9	0.6	0.1	1.7	1.3	0.0	16.9	13.1	11.7	10.7	9.6	103.8 - 47.3	49.1 - 20.3	36.8 - 31.3	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
S	§ PDF SOLUTIONS, INC.	DEC	-0.6	-1.2	-0.2	-0.2	0.0	0.3	4.9	5.3	5.8	6.0	5.9	6.1	33.8 - 16.4	26.4 - 8.6	17.4 - 8.2	16.8 - 7.6	23.9 - 14.1	24.4 - 8.7
B	§ PHOTRONICS, INC.	OCT	0.9	0.5	0.4	0.6	0.2	0.6	13.7	12.7	11.6	11.1	10.6	10.1	19.4 - 10.9	16.0 - 8.3	16.8 - 8.0	11.0 - 7.2	12.0 - 7.6	12.4 - 8.2
G	[] SOLAREDGE TECHNOLOGIES, INC.	DEC	3.1	2.7	2.9	2.7	1.9	1.4	21.2	17.0	12.4	10.6	9.0	7.0	389.7 - 199.3	335.8 - 67.0	96.7 - 34.1	70.7 - 30.8	39.9 - 12.3	30.5 - 11.4
	[] TERADYNE, INC.	DEC	5.5	4.3	2.6	2.4	1.3	-0.2	12.7	9.9	5.6	5.8	8.3	7.6	168.9 - 104.1	122.4 - 42.9	69.9 - 29.6	50.7 - 28.7	44.6 - 25.2	26.6 - 17.3
T	§ ULTRA CLEAN HOLDINGS, INC.	DEC	2.7	1.9	-0.2	0.9	2.2	0.3	7.4	5.0	2.1	2.4	5.4	2.8	65.3 - 31.6	37.0 - 11.8	24.2 - 8.1	27.2 - 6.9	34.6 - 9.4	10.7 - 4.5
O	§ VEECO INSTRUMENTS INC.	DEC	0.5	-0.2	-1.7	-8.6	-1.2	-3.1	4.4	3.6	2.7	3.5	3.4	10.4	28.7 - 17.4	19.8 - 7.4	17.2 - 7.3	20.6 - 6.3	34.4 - 10.9	30.5 - 15.3
O	§ VEECO INSTRUMENTS INC.	DEC	0.5	-0.2	-1.7	-8.6	-1.2	-3.1	4.4	3.6	2.7	3.5	3.4	10.4	28.7 - 17.4	19.8 - 7.4	17.2 - 7.3	20.6 - 6.3	34.4 - 10.9	30.5 - 15.3
OTHER COMPANIES RELEVANT TO INDUSTRY ANALYSIS																				
	[] ON SEMICONDUCTOR CORPORATION	DEC	2.3	0.6	0.5	1.4	1.9	0.4	5.0	3.4	2.6	4.0	2.9	0.3	70.3 - 32.3	32.9 - 8.2	24.7 - 15.6	27.1 - 14.6	22.2 - 12.4	13.3 - 7.0
	STABILUS S.A.	SEP	3.0	1.3	3.3	4.3	3.2	2.2	6.9	3.3	2.2	1.5	-2.8	-6.7	72.6 - 55.4	63.5 - 28.6	64.6 - 35.6	89.4 - 52.2	81.2 - 50.7	53.8 - 33.0
	TAIWAN SEMICONDUCTOR MANUFACTURING (	DEC	22.8	19.7	13.6	14.0	13.3	12.8	81.9	69.8	61.4	63.4	57.1	51.8	679.0 - 518.0	530.0 - 235.5	345.0 - 206.5	268.0 - 210.0	245.0 - 179.0	193.0 - 130.5
C	UNITED MICROELECTRONICS CORPORATION	DEC	4.5	2.3	0.7	0.6	0.8	0.7	22.2	18.6	16.9	17.0	16.8	17.1	72.0 - 43.1	51.7 - 13.1	17.1 - 10.6	18.7 - 10.4	16.8 - 11.3	13.6 - 10.8

:: Data as originally reported. CAGR-Compound annual growth rate.

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ce: S&P Capital IQ.

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