Going vertical:

A new integration era in the semiconductor industry

accenture

Table of contents

Executive overview

Like many industries, the semiconductor industry is not immune to waves of diversification and consolidation through inorganic and organic growth. While inflection points with large-scale systemic changes in the value chain are relatively rare, our perspective is that there is a systemic change currently trending in the industry.

Since the inception of the industry, semiconductor companies have recognized the value of technology. Accordingly, the market has rewarded semiconductor companies for specializing in distinct parts of the value chain by developing technological advantages by investing in R&D and by scaling technology through horizontal integration. This way of working transformed an industry that was initially vertically integrated (semiconductor design, semiconductor manufacturing, and system integration) into an ecosystem focused on specific areas of design, manufacturing, and/or systems.

In the past five years, business value in some segments has moved from underlying technology to specific use cases to better monetize end-customer data and experience.

- **5G, automotive, AI, cloud, system integration and hardware-software integration**

System integrators and software and cloud platform companies are no longer just important customers for the semiconductor industry—they are directly expanding into multiple upstream areas.

- Taking advantage of silicon and system design
- Control more of the technology stack
- Optimize system performance
- Improve the customer experience

This vertical integration trend is distinctly different from the vertical integration which occurred at the inception of the semiconductor and integrated device manufacturing industry more than 50 years ago. Now, vertical integration is all about capturing more value from the end-customer.

Today, to best retain and grow market share and increase resiliency in the face of stiff competition, semiconductor companies have a few options:

01 Focus and hyper-specialize in specific areas of the value chain

02 Forge close partnership with software companies to co-develop silicon, systems, and application software

03 Become more vertically integrated in high-growth by developing strong software capabilities and/or robust partnerships

In this perspective, we explore these trends and suggest key steps semiconductor companies can leverage during the next wave(s) of industry growth.

Integration in the semiconductor industry

In the beginning: vertical integration

The semiconductor industry began when a trio of Bell Labs/AT&T researchers first successfully demonstrated the capabilities of a transistor in 1947. Their findings were published the following year and they would eventually go on to win the Nobel Prize. The early 1950s kickstarted the semiconductor industry when, in 1952, 34 companies licensed the original AT&T semiconductor patents. Since then, the semiconductor industry has changed dramatically, much in part to a significant resurgence of M&A activity. Texas Instruments happens to be the only remaining original licensee!

Between 1950 and 1970, semiconductor companies became more vertically integrated. Companies like Texas Instruments, Fairchild, and Motorola designed, fabricated, and packaged their semiconductor chips for consumption largely by systems companies. These integrated device manufacturers (IDMs) developed their own process cores and manufactured chips in their own fabs. Vertical integration afforded control all facets of their value chain, eliminating value loss from double marginalization and helping to protect core IP. Because this integrated business model required heavy investment in state-of-the-art manufacturing facilities and continuously loaded factories, these companies recouped their R&D costs by selling high volumes of chips at higher margins.

One of the most successful vertically integrated companies during this time was IBM, which first shifted their burgeoning mainframe systems business from vacuum tubes to solid state transistors in the late 1950s. By the early 1960s, the company decided to bring all aspects of their business in-house (e.g., operating system and software, hardware components, manufacturing equipment and processes), including the development and manufacture of semiconductor devices.

By 1970, the industry faced its first wave of deconsolidation, as new entrants like National Semiconductor, Intel, and AMD stole market share from dominant industry players by targeting new applications like minicomputers, microcomputers and eventually, PCs. They did this using new microprocessor technologies).

The beginning of the fabless—foundry model

Two major developments fractured the integrated value chain and forced IDMs to rapidly shift strategies. First, in the late 1980s and 1990s, the development of the fabless/foundry model revolutionized the industry and lessened the need for vertical integration by creating value in specialization. Multiple factors led to the creation of the fabless/foundry model, including the rising cost of the development and maintenance of competitive fabs, and the global standardization of semiconductor manufacturing processes. Under Morris Chang's leadership, Taiwan Semiconductor Manufacturing Company (TSMC) became the world's first pure-play foundry. While IDMs were starting to provide spare capacity in their fabs to other companies, it was TSMC's market entry that launched the movement toward outsourced chip manufacturing. TSMC effectively lowered the cost of design innovation, which later became an important factor in the current wave of integration efforts to protect innovation. Customers that were entirely fabless could now focus on IP and design because they no longer faced a significant traditional barrier to entry. New, fabless players in the market, such as Xilinx and Qualcomm, didn't need strategic partnerships with IDMs to manufacture their silicon and could, instead, sell a smaller, niche line of products at scale.

Large system companies like Philips, Siemens, and Motorola succumbed to the cyclical nature of the chip industry and divested their unprofitable semiconductor businesses to stabilize financially. This, of course, led to the creation of NXP, Infineon, and Freescale, respectively. This trend continued when IBM, once the world's largest semiconductor manufacturer, sold its semiconductor business unit to GLOBALFOUNDRIES in 2014 as the cost of staying at the leading edge of semiconductor production had proven to be prohibitively expensive in the face of declining hardware sales.

The development of the fabless/foundry model revolutionized the industry and lessened the need for vertical integration by creating value in specialization.

The story of Texas Instruments (TI)

TI has maintained its position as a market leader through re-invention of their value chain

Currently one of the world's oldest semiconductor companies, Texas Instruments (TI), founded in 1951, was the first company to ever sell commercial silicon transistors (1954). It grew in size and status in 1957, when it signed a deal with IBM to become IBM's biggest transistor supplier for its computers. However, TI's most important breakthrough occurred in 1958, when it released the world's first integrated circuit, the core of modern microelectronics. TI maintained a dominant market presence through the 1980s as it expanded into consumer electronics (e.g., digital watches and calculators) and grew as a result of soaring demand for chips worldwide.

TI was forced to rethink its growth strategy as it battled a cyclical slump in chip demand and inconsistent profits from its consumer electronics business. As a result, the company embarked on a new mission to expand its partnerships, including the development of memory technology with its 1988 partnership with Hitachi (16-megabit DRAM). Sun Microsystems, Sony, and General Motors soon followed TI by also developing microprocessors. In this competitive landscape, TI doubled down on strategic partnerships by using joint ventures as a means to expand manufacturing capabilities. This included their 1991 alliance with Canon, Hewlett-Packard, as well as the Singapore government. It also included their 1994 partnership with Samsung and a repeat partnership with Hitachi. TI also organically refined its strategic direction by specializing in specific technologies, such as DSP chips; while inorganically focused on growing market share through acquisitions, including the acquisitions of Intersect Technologies, Sensor Solutions, and GO DSP.

1954 - 1958
TI sells the world's first commercial silicon transistor and first IC

1957 - 1969
TI grows in size and status as one of the world's top mainframe (e.g., IBM) suppliers

1972 - 1979
TI enters the consumer electronics market with home computers and calculators

1988
TI sells unprofitable memory business to Micron for $880m

2011
TI acquires National Semiconductor for $6.5b to strengthen analog products portfolio

2012
TI exits the smartphone and consumer tablet market to focus on core markets

The story of NXP

1961

Signetics is established by a group of scientists working or Fairchild Semiconductor

1973

Signetics becomes a publicly traded company

1975

Philips acquires Signetics, which is rebranded as Philips Semiconductors

2006

Private equity companies purchase Philips Semiconductor, which is rebranded as NXP

2015

NXP acquires Freescale (divested from Motorola) to strengthen position in automotive market

2016

Qualcomm makes a failed bid to acquire NXP

NXP created value by venturing into new markets and re-designing their business model

Now Europe's second-largest semiconductor company, NXP can trace its roots to Philips N.V., then a major radio manufacturer using vacuum tubes. Eventually NXP would become one of the original signatories to the 1952 AT&T licensing agreement that gave birth to the semiconductor industry. Another important lineage fact comes from Philips acquisition of Signetics, one of the world's first integrated circuit (IC) companies, established in 1961 by a group of scientists working for one of the world's largest semiconductor companies at the time, Fairchild Semiconductor (which went public in 1973). After Phillips Corporation acquired Signetics in June 1975, the company later re-branded as Philips Semiconductors. In 2006, Philips was forced to divest Philips Semiconductors to improve bottom-line stability and enterprise value (given the high volatility of the semiconductor industry during that time). Philips Semiconductors was sold to a consortium of private equity companies as "NXP." As a standalone company, NXP later acquired Freescale, a semiconductor company born as a carve-out from Motorola, in 2015. Combined, NXP and Freescale became the largest semiconductor supplier to the automotive industry. While NXP has retained its manufacturing facilities, it also offloads excess demand and/or specialized technology to third-party foundries.

A wave of horizontal consolidation and increased modularity

During the last forty years, the industry has transformed in response to the need for heavy capital investments in manufacturing capabilities. This has enabled semiconductor companies to increase operating profitability by specializing in specific technologies and/or application segments and by decreasing time to market for innovative products.

Many industry players chose to focus on horizontal integration as the primary growth catalyst to quickly scale core capabilities and divest non-core assets. Standardization of various processes in the value chain, including modular IP blocks for chip design, standard foundry PDKs, and packaging standards, simplified inter-company integration challenges enough so that the fabless/foundry model eventually became the defacto and dominant business model. Companies that specialized and consolidated horizontally earned higher market shares and operating margins by achieving cost synergies and boosting economies of scale.

Figure 1 describes the strategic motives behind horizontal consolidation in each area of the value chain.
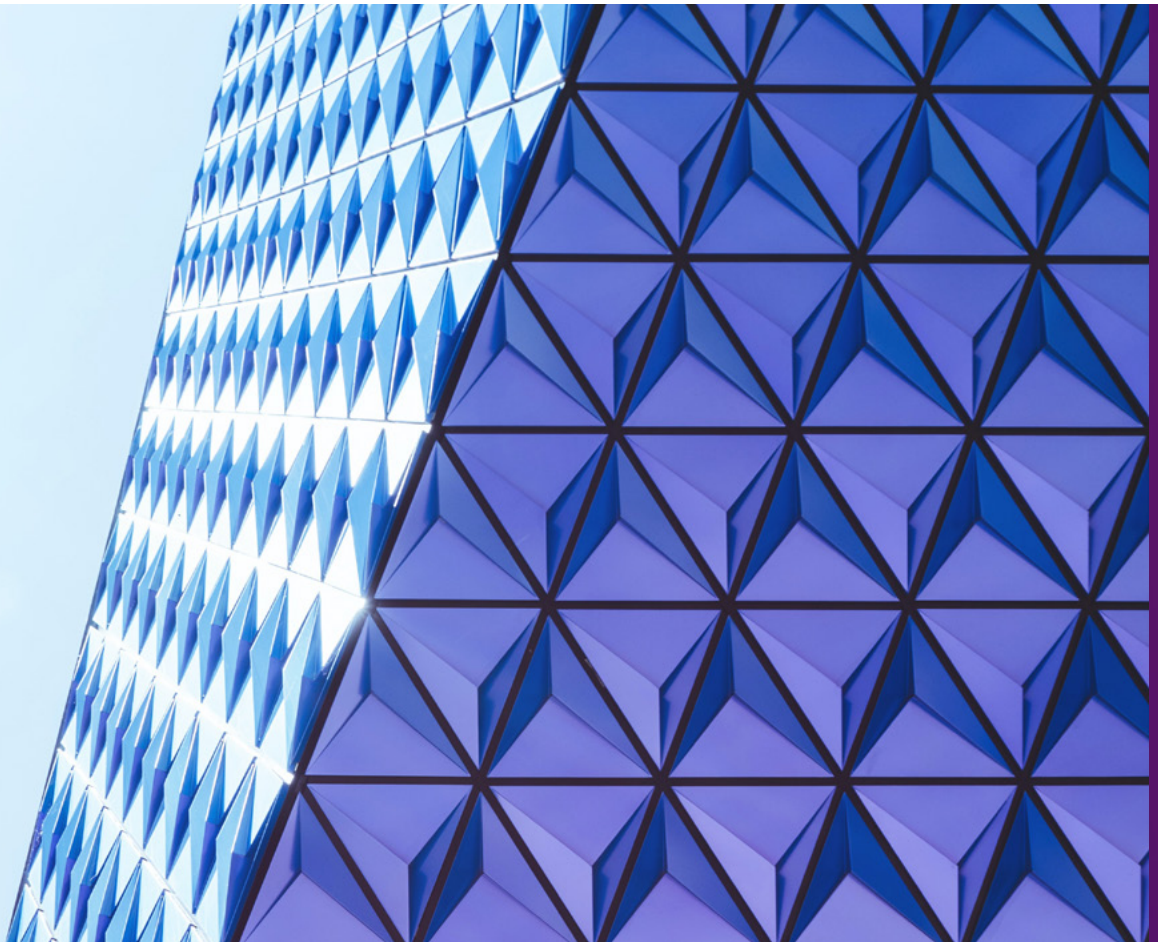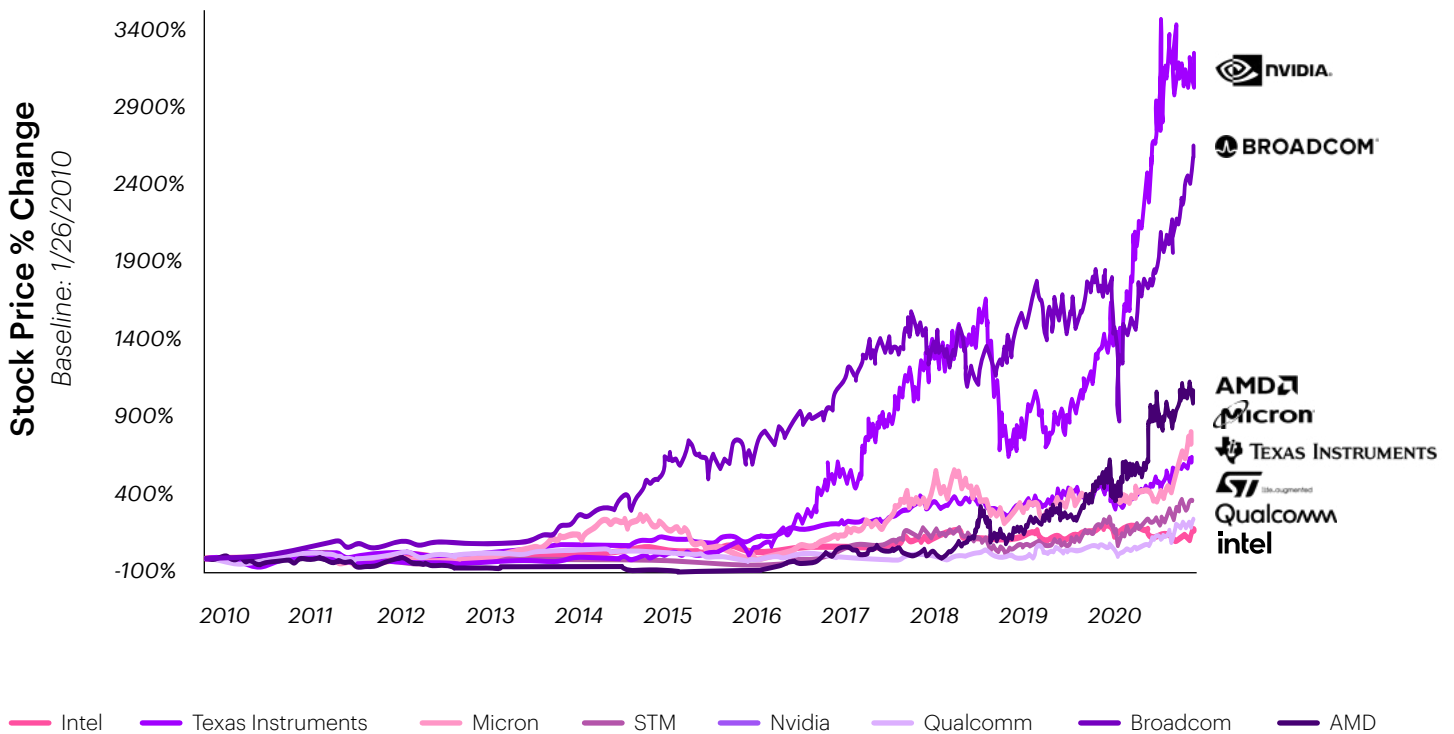
Figure 1. Horizontal consolidation across the semiconductor value chain—strategic rationale and current extent

| Value Chain	Extent of Horizontal Consolidation	Key Examples	Strategic Rationale
EDA	High	Cadence, Synopsis, and Mentor Graphics have each completed 50 acquisitions	High complexity of the solution. The Big 3 behave more as "platform companies" buying and integrating startups with new capabilities.
IP	Medium	ARM has completed more than 20 acquisitions	ARM is de facto standard, but EDA and open source (RISC V) companies ensure there is plenty of competition.
Digital Processors	Medium	AMD acquired ATI in 2006; Intel acquired Habana in 2019	New applications (AI, IoT, ADAS) drive chip design customization and deconsolidation. High design verification cost at advanced nodes further drives consolidation.
Memory	High	The DRAM divisions of Hitachi and NEC merged to form Elpida, which was later acquired by Micron	Economies of scale (increased operational capacity) drives consolidation.
Wireless/RF	Medium	Avago acquired Broadcom in 2015 (among many others)	New applications (IoT, 5G) drive deconsolidation. Economies of scale and revenue synergies drive consolidation.
Analog	High	Analog Devices announced acquisition of Maxim Integrated in 2020	Economies of scale and product synergies for end markets drives consolidation.
Foundry	High	Towerjazz acquired fabs from Maxim Integrated and Micron	Prohibitively high capital investment drives consolidation.
Equipment	High	KLA acquired SPTS in 2019	Product synergies and access to new customers drives consolidation.
Packaging	Low	Advanced Semiconductor Engineering acquired Siliconware Precision Industries Co in 2018	Economies of scale, niche technologies drives acquisition activity.

Figure 2. Stock Price Performance of IDMs and Fabless Companies from 2010 onwards

IDMs

TEXAS INSTRUMENTS   Micron

intel   ST life.augmented

Fabless

BROADCOM   AMD

NVIDIA.   Qualcomm
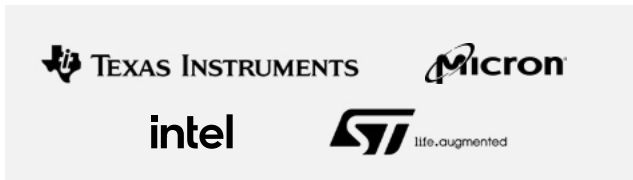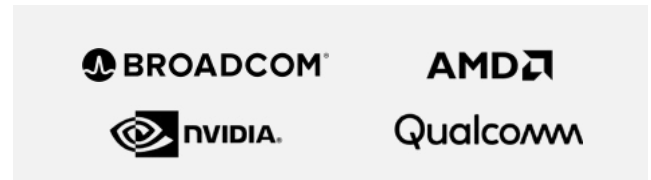
Markets have also recognized the potential for greater return on investment and the improved management of risk in the fabless/foundry model (where there is keen focus on domain specialization). Accordingly, the market has generally rewarded successful fabless companies with higher valuation multiples than their IDM counterparts. Even IDMs are realizing the positive effects of specialization in specific end markets. This is due to a greater focus on microprocessors for key verticals like AI and deep learning accelerators. Intel, for example, has been actively divesting: Recent divestitures include McAfee, Wind River, and its NAND memory business. Please see Figure 2.

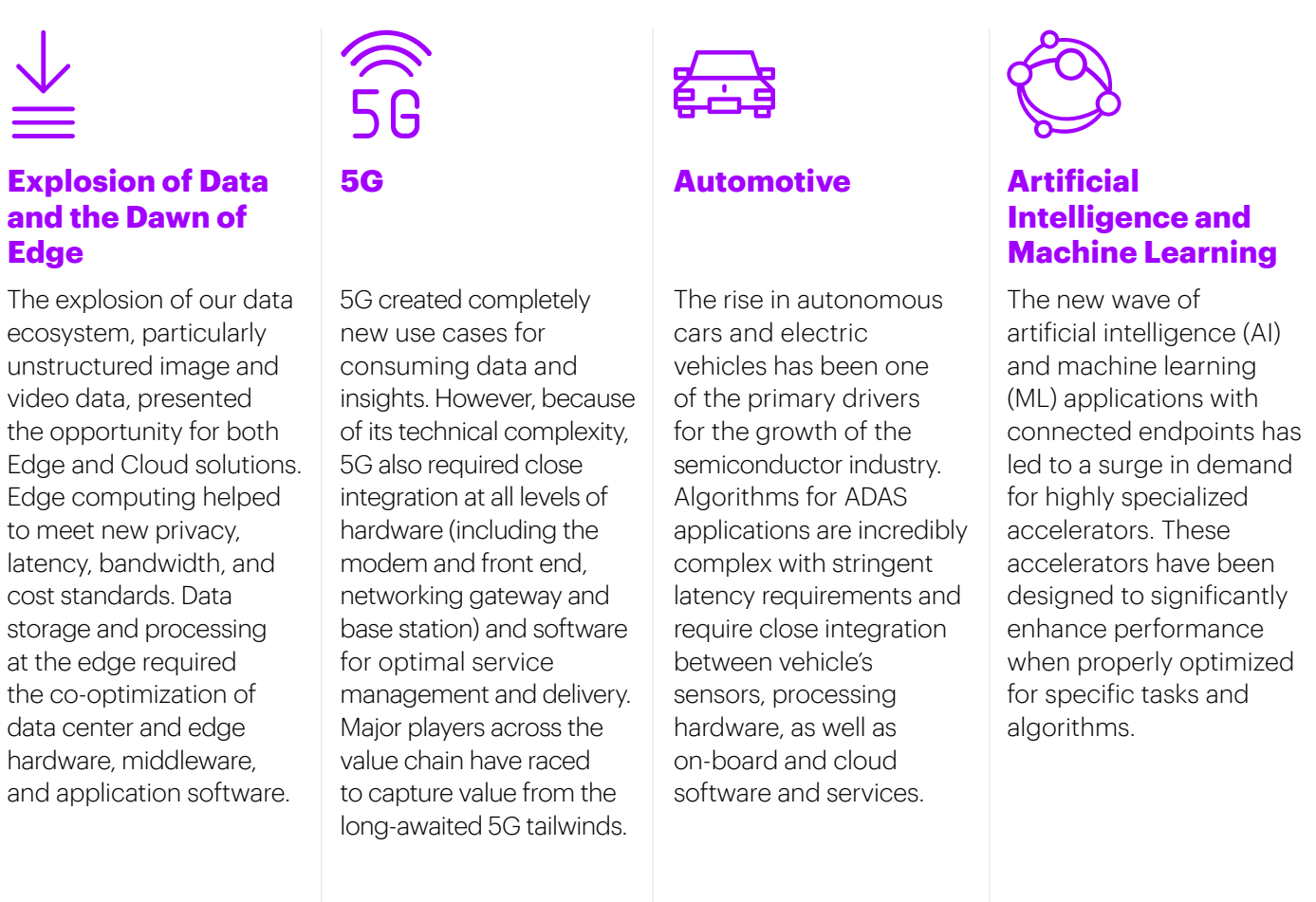# The reversal of the horizontal consolidation trend

In the past five years, we've seen another significant change in the industry: Broad trends have evolved use cases for semiconductor chips so that it's more beneficial to co-design the chip along with the entire system and software layers (Accenture research 2018, "Chips in the Stack"). Reminiscent of IBM in its 1960s to 1970s heyday, and bolstered by the foundry—fabless model, system integrators and software companies began investing in workload-specific chip designs and system architectures. This compounded with the commoditization of Semiconductor manufacturing, has led to the vertical re-consolidation in all parts of the value chain, except for manufacturing (foundries and equipment), as outside of the most advanced nodes, manufacturing technology became commoditized in an industry now dominated by fabless players.
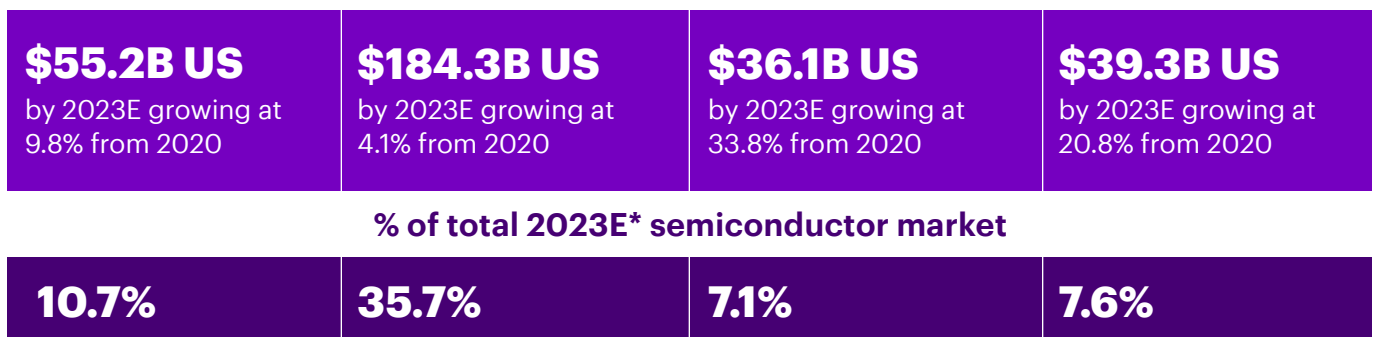
Major trends driving vertical integration

Four trends that have heightened the demand for system integration and have shifted the balance of power in favor of delivering targeted end-customer solutions (see Figure 3):

Figure 3. High growth use cases

Explosion of Data and the Dawn of Edge

The explosion of our data ecosystem, particularly unstructured image and video data, presented the opportunity for both Edge and Cloud solutions. Edge computing helped to meet new privacy, latency, bandwidth, and cost standards. Data storage and processing at the edge required the co-optimization of data center and edge hardware, middleware, and application software.

5G

5G created completely new use cases for consuming data and insights. However, because of its technical complexity, 5G also required close integration at all levels of hardware (including the modem and front end, networking gateway and base station) and software for optimal service management and delivery. Major players across the value chain have raced to capture value from the long-awaited 5G tailwinds.

Automotive

The rise in autonomous cars and electric vehicles has been one of the primary drivers for the growth of the semiconductor industry. Algorithms for ADAS applications are incredibly complex with stringent latency requirements and require close integration between vehicle's sensors, processing hardware, as well as on-board and cloud software and services.

Artificial Intelligence and Machine Learning

The new wave of artificial intelligence (AI) and machine learning (ML) applications with connected endpoints has led to a surge in demand for highly specialized accelerators. These accelerators have been designed to significantly enhance performance when properly optimized for specific tasks and algorithms.

Revenue projection from 2020 to 2023E

$55.2B US by 2023E growing at 9.8% from 2020	$184.3B US by 2023E growing at 4.1% from 2020	$36.1B US by 2023E growing at 33.8% from 2020	$39.3B US by 2023E growing at 20.8% from 2020

% of total 2023E* semiconductor market

10.7%	35.7%	7.1%	7.6%

Sources: Gartner, Semiconductor Forecast Database, Worldwide, 3Q20 update (October 2020), AI Semiconductor Forecast 2020.

Software platform companies and system integrators are customers and competitors

Hyperscale cloud service providers like Amazon, Alphabet, and Microsoft traditionally focused on the software layers for their cloud platform and application stacks while sourcing hardware from OEMs. They have now taken a multi-pronged approach to controlling their supply chain and have become formidable semiconductor companies in their own right.

Hyperscale cloud platform companies as customers: OEM disruption

In the last few years, software platform companies have disaggregated hardware and software within their datacenters, often running in-house or independent software vendor (ISV)-sourced software on top of commercial off-the-shelf (COTS) hardware often sourced from lower-cost Original Design Manufacturers (ODMs). This has disrupted the integrated proprietary software-hardware business models used by established enterprise hardware OEM players. Examples of this disaggregation and white-boxing of hardware are seen in Facebook's Open Compute Project for datacenters, as well as in OpenRAN technology being adopted for 5G by various cloud service providers and telecommunications companies.

## Hyperscale cloud platform companies as competitors: moving down the stack

Besides disrupting the OEM business model, platform companies are further optimizing their stack by designing their own chips for consumption by their consumer or enterprise products. They are leveraging the fabless/foundry ecosystem and their capital and scale (compare Google's $1 trillion market cap to Intel's $200 billion) to compete with semiconductor chip-centric incumbents by focusing on overall system optimization.

One high-profile example of this strategy is Apple's recent shift to using in-house central processors (M1) for Mac computers instead of the Intel chips that had powered Apple products since 2006. In addition to cost benefits, these new processors serve as a critical focal point of Apple's product differentiation strategy, as the company has touted its custom chip's optimized performance specifications. This, coupled with announced 5G chips (a few years after having completed the acquisition of an Intel business unit), distinguishes Apple as the most vertically integrated fabless company. Other companies like Microsoft have announced its intention of pursuing a similar strategy.

Hyperscale cloud platforms leveraging strength in customer data

Software and platform companies further benefit from in-house chip design due to their unparalleled access to data and strong ecosystem partnerships and grounded understanding of end-customer use cases. For example, after being the first large cloud provider to challenge Nvidia's GPUs with its own ASIC TPUs for cloud AI training/inference and edge inference, Google is now deploying its in-house TPUs in 20% to 30% of its data servers. As a result, Google is creating a market entry roadmap for other cloud providers to follow. By leveraging data from cloud platforms and expansive customer portfolios in prime end markets, Google can boost adoption of their solutions.
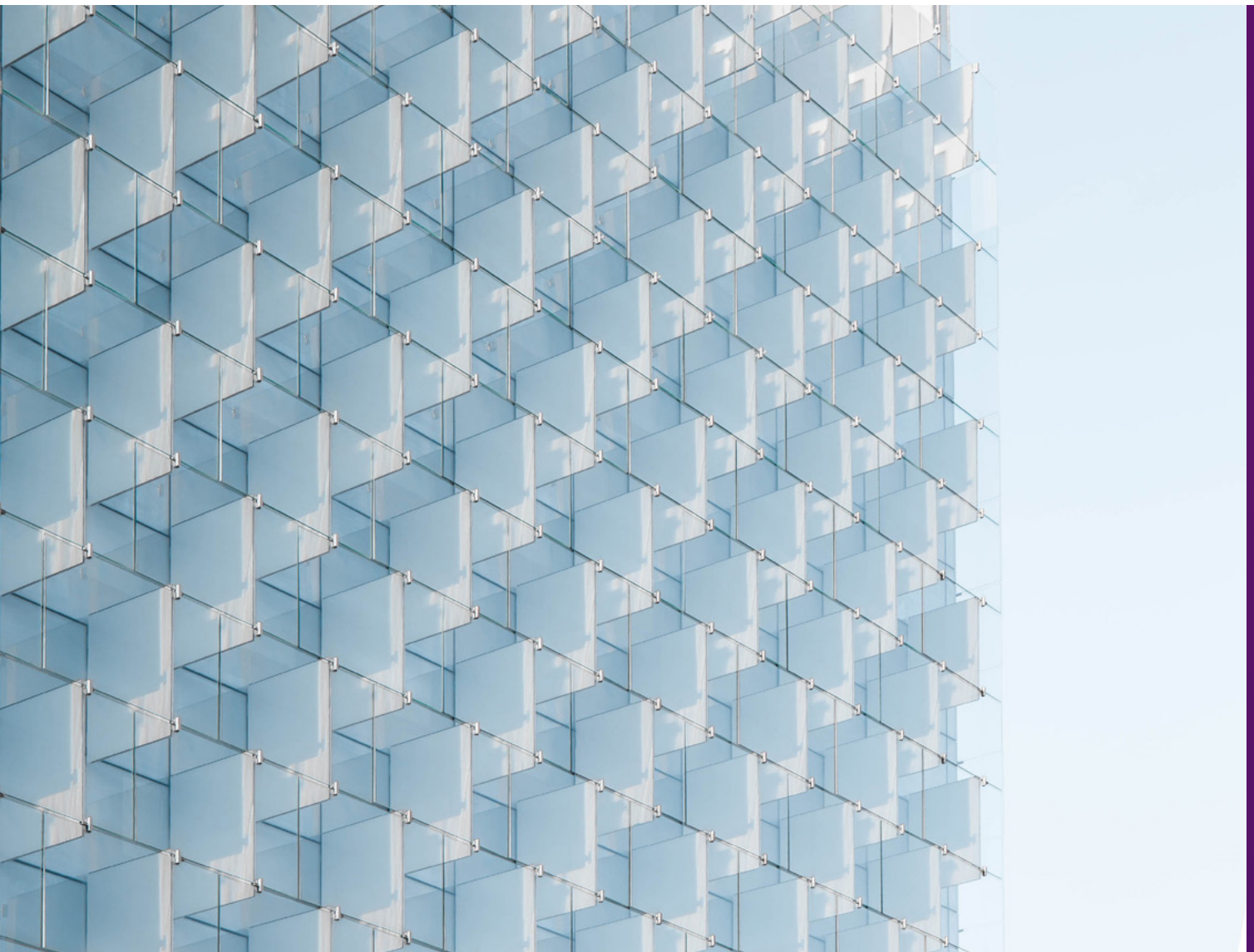
Specific use cases are now the main drivers of
semiconductor development—fostering a shift
from selling devices to selling solutions

OEMs are joining the vertical integration race

Enterprise OEMs have started to shift their business models away from relying on slowing
hardware growth rates by moving down the value chain and entering the increasingly lucrative
software and services businesses. In addition, some are also moving up the value chain—Cisco
and Bosch, for instance, are acquiring semiconductor design and manufacturing capabilities.

- Cisco acquired fabless firm Leaba
- Semiconductor in 2016 to design edge networking chips
- Luxtera in 2018 to enter the silicon photonics market for within datacenters
- Acacia in 2021 to bring coherent optical interconnect technology in-house.

Bosch is currently investing in expanding its SiC manufacturing footprint to support its automotive
business unit. In addition to strategic acquisitions, OEMs have been playing key roles in their respective
ecosystems. For example, automotive OEMs are investing in deep learning accelerator startups, while
data center OEMs are investing in technology ecosystems (like OpenRAN, OCP, and OpenFlex).

New drivers changing semiconductor development

The semiconductor business has traditionally been about selling devices to the customer
immediately downstream in the value chain, with Moore's law and other technological advances
driving R&D spending. This created a virtuous cycle: As hardware performance is improved,
software companies can further improve their products and increase end-customer adoption,
expanding the size of the pie for everyone in the industry.

But technology is no longer the primary driver of semiconductor development. With the
breakdown of Moore's Law and the rise of the importance of customer data, specific use cases
are now the main drivers of semiconductor development—fostering a shift from selling devices
to selling solutions. Similarly, consumer personas have also changed. Rather than targeting the
engineering and procurement departments of immediate downstream customers, semiconductor
companies must coordinate their activities with a wider array of ecosystem partners—with the
end-customer use case in mind.

Strategic options for semiconductor companies

The rapid transformation of end markets has threatened to disrupt the lives of every semiconductor company. Semiconductor companies must now get creative to maintain their growth trajectory or risk becoming commoditized by their customers. They have three competitive plays to capture value as more businesses bring their hardware development in-house.
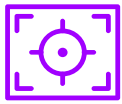
Companies can hyper-specialize in a specific niche, making them an attractive partner to system integrators and OEMs while creating a high barrier to entry in the market as a defensive play. Semiconductor companies focused on analog (e.g., Analog Devices), foundry (e.g., TSMC), and IoT (e.g., Syntiant) are prime examples.
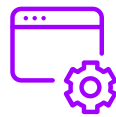
Alternatively, semiconductor companies can increase application software engineering input into their design through a partner program with customers. Many vendors of AI chips have partnerships with automobile manufacturers, for instance.

Finally, semiconductor companies can build end-to-end solutions to compete successfully with newcomers. This strategy offers semiconductor companies additional security by broadening their influence over the entire technology stack in multiple ecosystems and allows them to capture previously untapped revenue drivers in the value chain by expanding their customer base.

Semiconductor companies must now get creative to maintain their growth trajectory or risk becoming commoditized by their customers.

Multiple companies have successfully pursued this strategy with much success

Nvidia, for example, used its semiconductor expertise to establish itself as an AI and deep learning titan and has made several strategic decisions to support its dominant position. In 2019, the company purchased the Israeli semiconductor company Mellanox to integrate networking solutions into Nvidia's deep learning accelerator products. The company's recent announcement to acquire IP vendor ARM would allow Nvidia to add CPU compute to their existing portfolio. Most significantly, Nvidia has also forged strong partnerships with customers and software developers alike to form a robust ecosystem with end-to-end solutions in a wide range of verticals.

A similar effort to provide a one-stop-shop of AI solutions to customers is seen in Intel's recent acquisitions in the AI space, including Nervana (2016), Movidius (2016), Mobileye (2017), Vertex.ai (2018), and Habana (2019).

Qualcomm's acquisitions have revolved around enhancing increasing technological strength in 5G. In 2019, Qualcomm completed the acquisition of its RF360 joint venture with TDK. This enabled Qualcomm to develop its own RF Front-End for 5G, offering it as a solution along with its 5G modems and baseband processors. In 2021, Qualcomm entered into an agreement to acquire NUVIA for its SoC and CPU technology, enabling Qualcomm to control more of the product stack.

Moving forward: what semiconductor companies must consider today

With a market filled with surprises, competition and disruption, semiconductor companies can engage in actionable steps to redefine their strategy and stay ahead of the curve.

Invest in the ecosystem to better understand the end-customer

Semiconductor companies have traditionally been B2B businesses and somewhat abstracted from the end-customer. With the rising importance of solutions for end-customer use cases, semiconductor companies must develop a clear ecosystem and partnership strategy. This strategy should showcase that the valuable customers are also the most strategic partners—especially in high-growth verticals like automotive, IoT, and AI. By sharing knowledge with their customers, semiconductor companies can identify ways to customize their hardware for application-specific performance. Better understanding their customer's customer in prioritized end markets will only help semiconductor companies hedge the risk against the threat of new entrants who have strong end-customer application expertise and data. Moreover, strategic partnerships will allow semiconductor companies to scale R&D capabilities more efficiently. The increasing demand for customized chip and solutions to satisfy the rising number of use cases can easily stretch a standalone company's resources— by restructuring R&D operations to develop solutions jointly with ecosystem partners, semiconductor companies can serve a much larger number of customers.

Invest in right-skilling engineering workforces

The growing importance of co-developing hardware and software, whether under one roof or through ecosystem partnerships, has meant that companies must more sharply focus on investing in the right workforce. Semiconductor companies need a workforce trained in software engineering, AI, big data techniques in addition to core engineering skills. The distributed nature of R&D, as well as our new remote work reality due to the impacts of COVID, makes hiring, retaining, reskilling, and upskilling a strategic priority.

Free up capital for reinvestment

Taking a cue from cloud service providers, semiconductor companies' business and monetization models are evolving from solely relying on chip sales to providing an array of complex products and services that can uncover fresh revenue streams. As-a-Service (AaS) models are becoming increasingly popular in the industry, particularly among new entrants. AaS enables recurring revenue streams and greater operational efficiency through a shift from high CapEx investments to steady OpEx flows—which helps de-risk a company's top line. In addition, AaS enables niche players to capture value in high-growth markets that demand high degrees of customization, such as AI and IoT. Semiconductor companies may also pursue data monetization as a new revenue driver. The vast majority of next-generation technology applications generate unparalleled amounts of data, and semiconductor companies that integrate across the stack have become well-positioned to capitalize on the growing demand for this data. Semiconductor companies can free up capital through operational efficiencies such as, additional automation enhanced root cause analysis, improved connectivity with hybrid cloud, and the remote maintenance and service of equipment.

There's no doubt that, throughout its history, the semiconductor industry has been marked by ongoing change and, at times, major disruptions that have upended established order. We're in the midst of such upheaval today, and semiconductor companies must respond accordingly. The business models of old are ill-suited to meet technology and customer demand. Those semiconductor companies that move quickly to adapt to the new norms.

About Accenture Semiconductor Practice

Accenture Semiconductor is committed to working with semiconductor manufacturers and companies to help capitalize on the opportunities created by digital disruption and optimize efficiencies across product development, manufacturing, supply chain and business operations. We have deep relationships, experience, and expertise across the semiconductor ecosystem: IDM, IP designers, fabless, foundries and equipment manufacturers. We also have dedicated practice areas and proven results in growth strategy, mergers and acquisitions, engineering operations, silicon design services, supply chain operations, system implementation and manufacturing analytics. **www.accenture.com/semiconductors**.

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About the authors

Arjun Krishnan
Manager
Accenture Strategy
arjun.s.krishnan@accenture.com

Aishwarya Saluja
Senior Analyst
Strategy Consulting
aishwarya.saluja@accenture.com

Deb Garand
Managing Director
Strategy & Consulting, High Tech
deborah.garand@accenture.com

Syed F. Alam
Managing Director Accenture Strategy, Semiconductor, Global Lead
syed.f.alam@accenture.com

Tim Chu
Senior Manager
Accenture Strategy
timothy.chu@accenture.com