



“Linchpin” Semiconductor Firms Are Propelling Innovation

We focus on select companies with vital technologies.

September 2019

KEY INSIGHTS

- The cloud, artificial intelligence, and other emerging technologies are driving ballooning demand for high-performance semiconductors, even as designing and manufacturing more powerful, next-generation chips becomes increasingly difficult.
- We are focused on the “linchpin” companies in the semiconductor industry that could enable the next round of innovation.
- We also invest in other semiconductor firms that are well positioned in fast-growing end markets, such as sensor chips for the automotive industry.

What keeps technology moving forward? And why do we take for granted that the smartphones, computers, and other devices that we rely on will be better in five years?

Of course, many factors are at work, but the remarkable improvement in semiconductors has been central to the digital revolution over the past several decades. Further progress in chip technology will be necessary to support artificial intelligence (AI), 5G mobile communications, autonomous driving, and other technologies. Nevertheless, investors often overlook the crucial role of chipmakers, as well as the challenges semiconductor firms face as integrated circuits grow smaller and more complex.

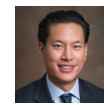
In the Global Technology Fund, we focus on a handful of “linchpin” semiconductor companies involved in the most crucial steps of chip production. We believe a small number of industry leaders offer unique investment opportunities because

of the vital role they play in moving technology forward. We also have select exposure to several of their customers—companies that design and sell chips targeted at especially promising markets.

A Complex Ecosystem Where Select Companies Play a Vital Role

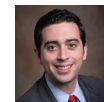
The semiconductor industry is a large, global, and complex ecosystem in which no firm functions independently. The production of an integrated circuit requires the technology of separate firms specializing in design, intellectual property, software, equipment, materials, and manufacturing.

A small number of companies serve as linchpins in the design and production process, however. One prominent set is the three companies that stand alone in being able to manufacture leading-edge semiconductors: Intel, South Korea’s Samsung Electronics, and Taiwan Semiconductor Manufacturing Corporation (TSMC).



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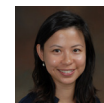
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nanometer

A nanometer is a thousand times smaller than a micrometer and a billion times smaller than a meter.

“Perhaps the largest challenge chipmakers have faced in recent years has come from the slowdown in their ability to shrink chips and increase processor speed.”

Intel first developed the microprocessor five decades ago and remains the world’s dominant manufacturer of central processing units (CPUs)—the electronic nerve center of a computer—while also being a leader in the design of many other types of chips. The company is the largest and most self-sufficient in the industry, but challenges to both its design and manufacturing dominance have emerged, especially from firms with greater focus on individual markets.

We see more promising opportunities in TSMC, which recently became the first company to cross an important manufacturing threshold. In 2017, TSMC began producing chips at the 7 nanometer (nm) process node—a measure of how finely transistors can be etched onto silicon and, thus, how many transistors can fit on a chip of a given size. Having beaten Intel in the race to the latest-generation manufacturing process, TSMC is seeing very strong demand for its new generation of 7nm chips, especially for use in smartphones and high-performance PCs. Most prominently, TSMC uses its 7nm process to manufacture Apple’s new A12 Bionic chips, which power the iPhone XS and XS Max.

Designing the latest generation of chips requires advanced software tools. Silicon Valley’s Synopsys is another linchpin company as the leading maker of electronic design automation (EDA) software, which helps chip designers analyze how the billions of components on a chip will work together. As semiconductors become more complex and shrinking transistors becomes more difficult, we believe EDA software and intellectual property will become increasingly important to the semiconductor design process.

Moore’s Law Has Slowed

Perhaps the largest challenge chipmakers have faced in recent years has come from the slowdown in their ability to shrink chips and increase processor speed. According to Moore’s Law, named

after Intel cofounder Gordon Moore, chipmakers could be expected to double the number of transistors on a given area of a chip roughly every two years. For roughly four decades, the pattern held true. The exponential effect was extraordinary: According to the company, Intel’s 4004 processor contained 2,300 transistors when it was released in 1971; by 2010, an Intel core processor held 560 million transistors. (For comparison’s sake, Apple’s latest A12 Bionic chip contains 6.9 billion transistors.)

This remarkable progress relied in large part on the development of ultraviolet lithography, which essentially allowed circuits to be “printed” (although the process is considerably more complex) onto silicon wafers. In the past few years, however, the latest generation of lithography technology, deep ultraviolet (DUV) lithography, has reached the physical limits of how finely it can lay down circuitry at the leading edge—akin to trying to use a fat-tipped marker to fill out a small form.

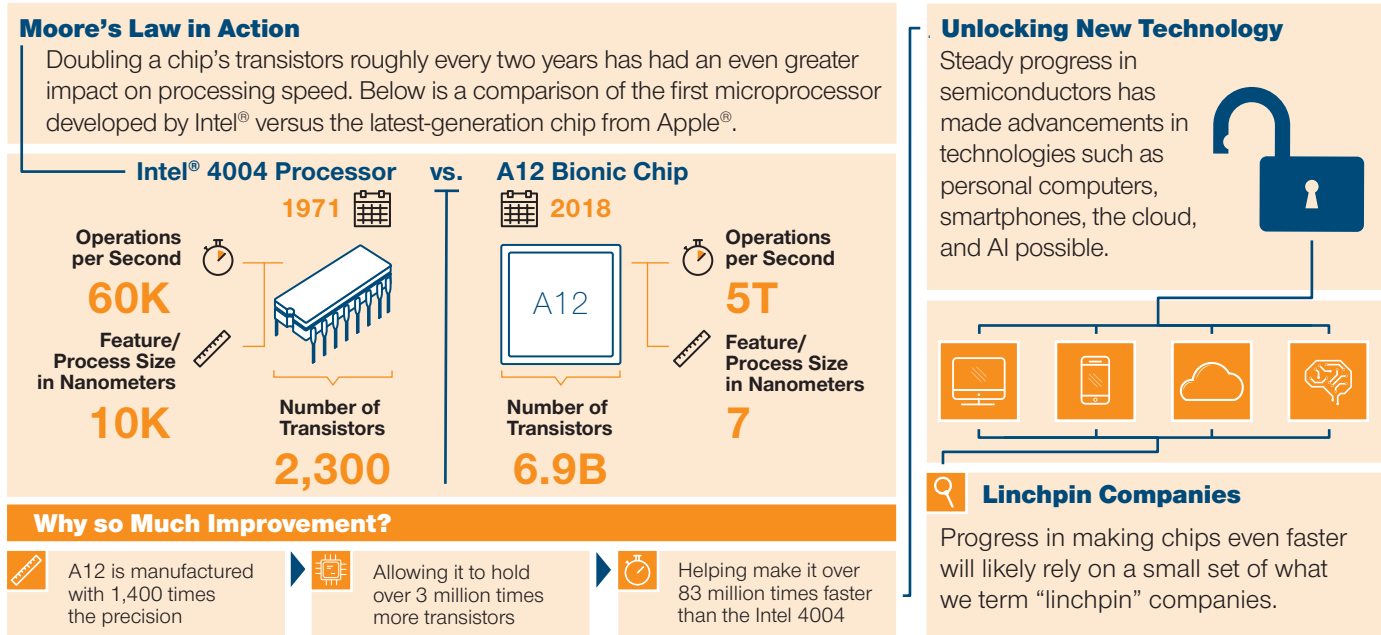
DUV lithography’s limits partially contributed to Intel missing the two-year doubling cycle predicted by Moore’s Law. Intel’s latest-generation 10nm fabrication process (roughly equivalent to TSMC’s 7nm process, but with a different naming convention) is just being introduced this year. This is three years later than originally predicted and Intel’s first shrink since 2014—a delay that has caused some to declare the end of Moore’s Law.

EUV Lithography Is at an Inflection Point

In our view, Moore’s Law is not dead. It has just slowed, perhaps only temporarily. Another linchpin company, Netherlands-based semiconductor equipment maker ASML Holding, has developed a solution—extreme ultraviolet (EUV) lithography. Using laser-produced plasma fired in a vacuum to lay down chip designs at extremely high resolutions, ASML’s machines are poised to come online in

Smaller, Better, Faster

The progress in semiconductors over the past half century has been astonishing.



Sources: Intel, Apple, History of Computing Project, and T. Rowe Price estimates.

EUR 130 million

Price of ASML EUV lithography machine

significant numbers in 2020, despite their EUR 130 million price tag (T. Rowe Price estimate).

This innovation will allow semiconductor makers to produce the latest-generation chips at volume, marking an inflection point in the industry. EUV technology should also allow Intel, TSMC, Samsung, and others to make the requisite leaps to the next few generations of chips. Given the 10 years and EUR 10 billion it took to bring EUV technology to market, ASML will likely remain the industry leader over the next decade. In our view, ASML is at the very center of semiconductor innovation.

Owning the Companies Necessary to Power AI, 5G, and IoT

A second part of our investment thesis focuses on the firms that design and market the high-performance chips made possible by the linchpin production companies. In short, we want

to own the companies that have the best product portfolio and are in the right place for the next horizons in technology. Our holdings potentially provide the chips necessary to power AI, 5G, and the so-called internet of things (IoT), or the proliferation of internet connectivity into everyday devices.

NXP Semiconductors, also based in the Netherlands, is a world leader in the design and manufacturing of mixed-signal semiconductors, which enable the conversion of analog signals, such as temperature and light, into digital ones. This technology is particularly important in the automotive market, where sensor-driven chips have proliferated rapidly. NXP also recently announced a new "ultra-wide band" chip that the company has been working on for automotive, IoT, and smart home applications. The chip will enable devices to sense the location of nearby objects, allowing doors to open as a trusted car or person approaches, for example.

T. ROWE PRICE BEYOND THE NUMBERS

Getting a Firsthand Look at EUV

We visit the factory floor and talk with customers and suppliers.

When it comes to the promise of ASML's EUV lithography equipment, we don't just take the company's word for it. We travel to ASML's facilities to get a firsthand look at the machines being assembled and have consulted with ASML's customers and suppliers. These efforts are aided by our analysts all over the globe who maintain coverage of many of ASML's partners and competitors, giving us a holistic view on how EUV is set to change the industry.

“...we are willing to wait out the periodic downcycles in the global memory market and focus on the long-term trends that should drive growth for the best-positioned suppliers.”

Arizona-based Microchip Technology is a leader in microcontrollers—essentially, computers shrunk down to a single chip—as well as other types of devices used for specialized purposes. Demand for these chips should balloon as computers find their way into a growing range of devices, from toys to appliances. The company's management team has proved adept at acquiring undermanaged assets and integrating a range of products into its already diversified portfolio, making it a one-stop shop for customers.

As computing processes and data continue to migrate to the cloud, demand is rapidly growing for high-grade memory chips. This explosion of “big data” and the tremendous computing needs of AI are fueling almost insatiable levels of memory demand.

For this reason, we are willing to wait out the periodic downcycles in the global memory market and focus on the long-term trends that should drive growth for the best-positioned suppliers. Samsung and Micron Technology (headquartered in Boise, Idaho) have recently been our two favored holdings in the memory industry. The two are the largest and third-largest suppliers, respectively, of dynamic random-access memory (DRAM) chips, the fastest-growing segment of the semiconductor market in terms of volume.

Trade and Global Slowdown Create Uncertainty

To be sure, many uncertainties hang over the semiconductor industry. The slowing global economy has weighed on industrial demand, particularly in the automotive sector. The PC market has generally been shrinking over the past decade as consumers turn to smartphones to access the internet and as cloud-based computing makes regular upgrades less necessary. Demand for mobile chips continues to grow, but at a slower pace. These factors have made us more selective, and we ended June 2019 with a modest underweight in the sector relative to our benchmark, the MSCI All Country World Index Information Technology Net.

The trade conflict between the U.S. and China and the specter of a technological “cold war” add another layer of opacity. A ban on U.S. semiconductor firms doing business with major Chinese buyers—as the Trump administration has partially imposed on sales to telecommunications giant Huawei—would clearly disrupt the industry.

For their part, Chinese officials have made developing a homegrown supply of advanced chips a key part of their Made in China 2025 plan, with the aim of producing 70% of the chips it uses domestically, up from roughly 16% currently. Signs are that China's move away from U.S.-based suppliers has already started. Crucially, however,

“The trade conflict between the U.S. and China and the specter of a technological ‘cold war’ add another layer of opacity.

we believe China cannot succeed in building its own high-performance chips without purchasing equipment and services provided by the global linchpins.

As Designs Evolve, Linchpins Will Remain Vital to Production

As companies that are less well positioned than the linchpins fall victim to China’s fading demand, others are likely to lose ground to new application-specific designs. Nvidia has seen rapid growth in recent years, for example, thanks to the use of its graphics processing units (GPUs), which were originally developed for video gaming but have proved especially adept at handling the algorithms used in machine learning. However, companies

are trying to get around Nvidia’s lock on machine learning technology. For example, Alphabet, Google’s parent company, is currently developing tensor processing units (TPUs), a type of application-specific integrated circuit (ASIC), to power the advanced neural networks that enable machine learning and AI.

Such uncertainties are yet another reason to focus on the industry’s linchpins, in our view. Regardless of whether CPUs, GPUs, or TPUs dominate the future, and whether they are sold by companies in China, the U.S., or Europe, we are confident that this small group of global companies will remain vital to their production.

WHAT WE’RE WATCHING NEXT

Chip advances are playing a key role in the development of next-generation automobiles. Chips will power the sensors that alert self-driving cars to the presence of other vehicles as well as pedestrians and obstacles, and they will also be crucial to further advances in the electric vehicle (EV) drivetrain. Silicon Valley’s Tesla, Google, and Uber are current leaders in both autonomous driving and EV, but we are keeping a close eye on opportunities in global competitors. With the encouragement of regulators, European and Chinese automakers are increasingly incorporating leading-edge technologies in their designs.

As of June 30, 2019, the Global Technology Fund’s top 10 holdings were as follows: Facebook, 10.4%; Alibaba Group Holding, 10.3%; Intuit, 6.0%; Amazon.com, 5.4%; Tencent Holdings, 5.4%; Salesforce.com, 4.8%; Netflix, 4.7%; Microchip Technology, 4.6%; Workday, 4.6%; ASML Holding, 4.1%. Among other stocks mentioned above, Samsung Electronics represented 3.6%; Alphabet, 3.4%; NXP Semiconductors, 2.1%; Taiwan Semiconductor Manufacturing, 1.6%; and Micron Technology, 1.1%. Apple, Intel, and Nvidia were not held in the portfolio.

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