Letting The Chips Fall: India’s Strive for Semiconductor Self-Sufficiency

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Every day, I wake up to the sound of my smartphone's alarm. With a quick gulp of coffee brewed by my coffee machine, I'm ready to start the day. I drive to work in my car, maneuvering through the Mumbai roads with precise braking and acceleration.

Upon reaching office, I am able to effortlessly navigate an environment connected by laptops and internet routers. During my breaks, I like to listen to music with my earphones on.

After work, I usually visit the grocery store, where I pay for my purchases with my credit card. Back home, I prepare dinner using my oven and then, depending on the day, do some chores, like running a load of laundry.

Later, as I relax in the evening, within the comfort of my air-conditioned room, I indulge in my favourite TV shows. I then go to bed, just to start another similar day, blissfully unaware of how absolutely reliant I am on the computing chips that quietly power my daily routine.

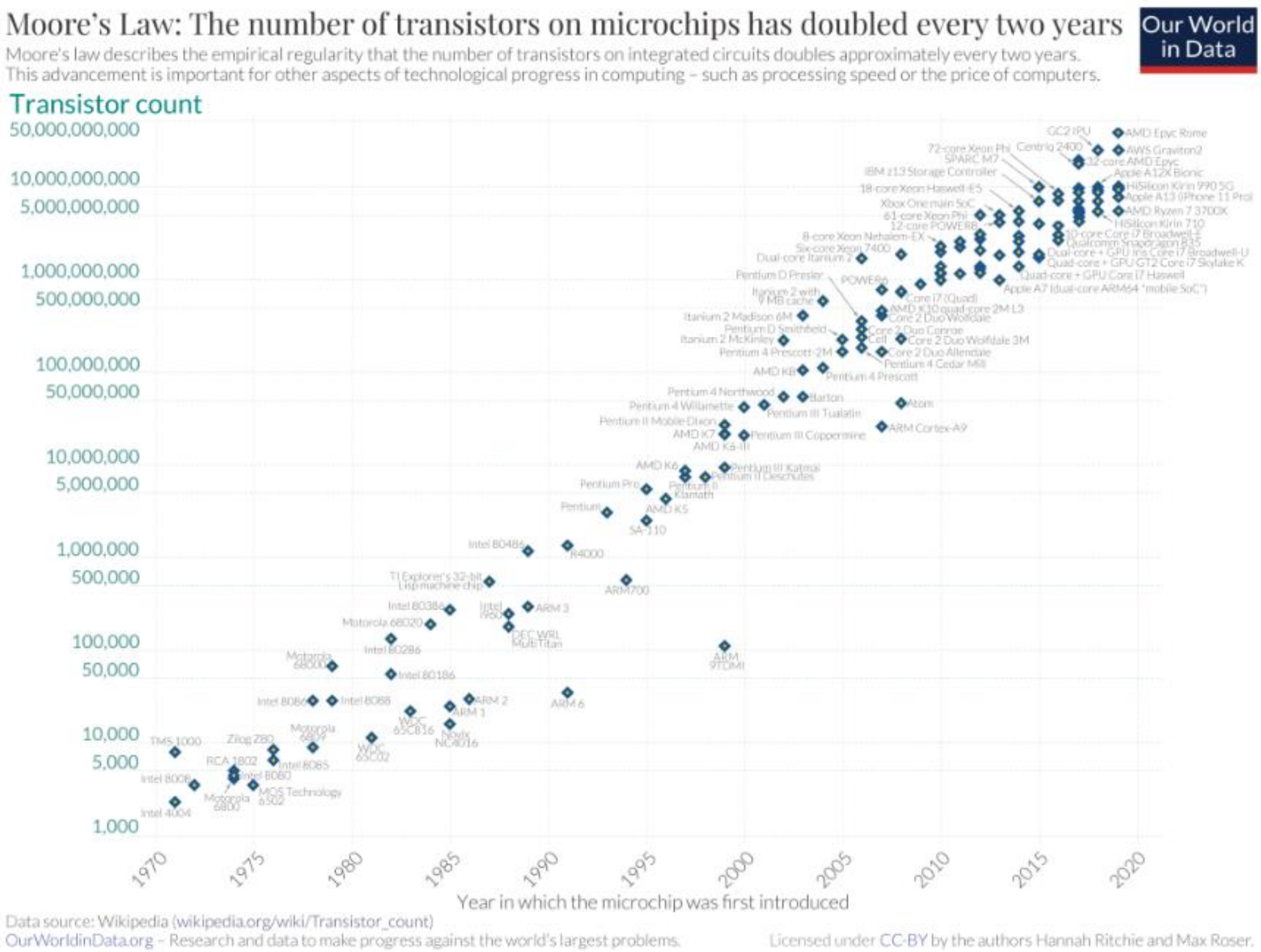
The devices mentioned above, all use chips to process and store information. And the functionality of chips is made possible by the power of transistors, which are made with semiconductors.

Semiconductors, as the name suggests are, well, semi-conductors. They allow for the fine-tuning of conductivity as they can combine the electrical properties of a conductor (like metals) with that of an insulator (like rubber). This ability to precisely control the flow of electricity makes semiconductors integral to creating components and circuits within a chip.

Semiconductor chips are manufactured in specialized facilities called fabrication units, or simply fabs. These fabs prepare silicon wafers made of 99. 999% pure silicon, and then, using a process called photolithography, transfer intricate patterns onto the wafers. This step defines the circuitry and features of the microchip. Chemically, impurities are deposited onto or etched out from the surface of the wafers to create a chip as per the specifications.

As complex as the process sounds (and is!), semiconductor companies have made unbelievable progress in the last few decades. The industry has been able to continuously shrink the size of a transistor, thereby increasing the number of transistors on a chip, leading to a tremendous rise in the computing power of chips. Currently, the most advanced chips have a diameter of less than 10 nanometer, which would make it 1/100th the size of a single hair strand.

This is largely in line with Moore's Law, coined by Gordon Moore, the co-founder of Intel. Moore's Law is an empirical relationship that states that the number of transistors in a circuit will double every two years, while costs will reduce.



Source – Our World in Data (Wikipedia)

However, all these advancements are quite concentrated. For context, 75% of the intellectual property rights are registered in the USA. Further, 50% of the world's semiconductor manufacturing and 92% of the world's most advanced semiconductor manufacturing happens in Taiwan, in a single company, TSMC[1]. The production of these advanced semiconductors requires a specific machine, and these machines are also manufactured by a single company in Netherlands – ASML.

The increasing demand for electronic devices and the global shortage due to covid-19 supply chain disruptions made nations reconsider this reliance on single companies or nations, and look inwards to secure a foothold in the semiconductor industry. The geopolitical implications of such high reliance on Taiwan coupled with the importance of chips for military and defense purposes added another layer of strategic vulnerability.

This led to numerous initiatives by various nations to bolster their domestic semiconductor manufacturing capabilities. The European Union, United States, and China launched initiatives worth $50 bn, $46 bn, $143 bn respectively.

India too, launched the India Semiconductor Mission (ISM) as part of its "Make in India" scheme. The ISM includes a $10 bn outlay for semiconductor manufacturing which provides 50% of the project cost back as a rebate. There is also the design-linked incentive (DLI) scheme, which provides up to 50% of eligible expenditure as incentive to 100 domestic semiconductor design companies for integrated circuits[2].

This initiative facilitated the Vedanta-FoxConn joint venture which will be setting up a $15 bn fab unit in Gujarat. Vedanta expects to start producing 40 nanometer and 28 nanometer wafers by 2027, with a goal to reach a monthly manufacturing capability of 40,000 wafers[3]. These chips will find uses in ICT devices, automobiles and certain smartphones as well.

Chip manufacturing however, is an excruciatingly complex task. It's one of the things that experts say is the toughest to manufacture. The drive for miniaturization requires manipulation of materials at an atomic and molecular level. The path of light also has to be precisely controlled with lenses and mirrors to ensure that accurate patterns are transferred onto the wafer.

Each component of a chip requires specific raw materials with precise properties. Variations that could arise due to properties of the raw material also have to be minimized. Fabs, thus, can need up to 1200 different raw materials that have to be sourced from different parts of the world.

Further, a typical fab consumes more than 10 million liters of ultra-pure water per day. What's more? Manufacturing these 10 million liters of ultra-pure water requires 30 million liters of regular water.

Another key requirement is uninterrupted power supply as they run 24×7. Fabs use up to 100 megawatt-hours of power each and every hour and even a flicker in power supply could affect the integrity of the entire lot of chips being produced.

Chip manufacturing also requires very clean rooms. A single particle of dust can ruin a chip. Hence, the manufacturing rooms have to be constructed in such a way that air flows from ducts in the ceiling to floor vents, ensuring that particles don't linger.

Lastly, it requires an extremely trained employee force that is able to operate sophisticated machinery, conduct quality checks, and troubleshoot issues that may arise during production. They also need to follow strict protocol and safety parameters including wearing glasses, masks, gloves, and boots, and having an "air wash" before entering the factory unit.

Even after somehow getting all the above right, it takes about three months to transform a silicon wafer into a semiconductor. And then there's the rapid rollout of new technologies which means that by the time a new entrant is able to come up to speed to current specifications, the industry has already moved on. For example, TSMC has already committed to investing $100 bn in its fabrication units over the next three years[4].

While the most cutting-edge technologies will be used in new smartphones and self-driving cars, there are numerous use cases for larger, less advanced chips in various areas – from home appliances to industrial machinery. Such chips would be a more pragmatic fit with India's current capabilities and would enable India to steadily make its own position in the value chain.

For example, India's Shakti microprocessor program achieved a significant milestone by delivering the country's first indigenous microprocessor. With manufacturing options in 180 nanometer and 22 nanometer, this marks an important step towards building a processor infrastructure in India[5].

Further, India already designs around 20% of semiconductors[6], but mostly for foreign companies who own the intellectual property. Almost all the top international chip design companies have a presence in India. In fact, Intel's largest design and engineering center outside the US is in India.

However, a few small homegrown companies with a marquee clientele have been challenging the convention – They own the intellectual property rights for the chips they make, in areas from communication systems to radar technologies.

Another ancillary area that India could build capabilities in is outsourced semiconductor assembly and testing (OSAT). An OSAT plant packages, assembles and tests silicon wafers. Leading players like Micron have shown interest in setting up the same in India. On the domestic front, HCL and Tata Group have added their names to the mix.

While undertaking OSAT work does not necessarily translate into manufacturing capabilities, it can, overtime, enable moving up the value chain. For instance, the Tata Group chairman has already said that they will be considering building a full-fledged fab in India, in partnership with a foreign firm[7].

Entry by such large local players, with patient capital, can play a crucial role in this cash-hungry business. Further, international partnerships with companies from like-minded nations will help build the technological know-how. Government initiatives should try to promote the same.

And such initiatives are underway. Just recently, the US Semiconductor Industry Association, in partnership with the Indian Electronics and Semiconductor Association, hosted a private-sector task force. The task force will undertake a "readiness assessment," to identify opportunities in India to accelerate investment. The meetings were attended by top American companies such as Lockheed Martin and Micron. India and USA also signed a memorandum of understanding (MoU) which will look to create a semiconductor sub-committee on establishing a semiconductor supply chain.

India's semiconductor demand is expected to more than double to $64 bn by 2026, and continued dependency on imports to meet this demand is a clear risk. Catching up is not going to be easy – but India has to start somewhere. After all, India has, over the years, lagged in sectors such as auto and electronics, but is a relevant player in both those industries today. Now, onto merely replicating this with semiconductors.

This article is written by Soumya Turakhia.

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