Journal of Computer and Communications, 2017, 5, 39-47
http://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

Study on the Development of the Chip Information Industry Based on Moore's Law

Guowang Zeng[1,2], Shihong Zeng[3]

[1]Experimental Project class, High School Department, Xicheng Experimental School of the Second High School Attached to Beijing Normal University, Beijing, China
[2]Experimental Project class, High School Department, The Second High School Attached to Beijing Normal University, Beijing, China
[3]Finance and Economic Development Research Center, College of Economic & Management, Beijing University of Technology, Beijing, China
Email: 3141795267@qq.com, zengshihong2000@aliyun.com

How to cite this paper: Zeng, G.W. and Zeng, S.H. (2017) Study on the Development of the Chip Information Industry Based on Moore's Law. *Journal of Computer and Communications*, **5**, 39-47.
https://doi.org/10.4236/jcc.2017.514004

Received: November 19, 2017
Accepted: December 16, 2017
Published: December 19, 2017

Abstract

Chips are the carriers of ICs (integrated circuits). As a result of design, manufacturing, and packaging and testing processes, chips are typically wholly independent entities intended for immediate use. According to known data, one unit of chip output can drive up to ten units of output in the electronic information industry and 100 units of GDP (Gross Domestic Product). The Chip Information Industry is a strategic industry in most developed countries in Europe and North America. The development of the Chip Information Industry is related to national economies and personal livelihoods. Moore discovered a certain trend after analyzing data: in general, every newly produced chip has twice the capacity of the previous generation, and it takes 18 to 24 months for the next generation to be subsequently invented. This trend has come to be known as Moore's Law. It applies not only to the development of memory chips but also to the evolutionary paths of processor capability and disk drive storage capacity. Moore's Law has become the basis of performance prediction in several industries. However, since 2011, the size of silicon transistors has been approaching its physical limit at the atomic level. Due to the nature of silicon, additional breakthroughs in the running speed and performance of silicon transistors are severely limited. Elevated temperature and leakage are the two main sources that invalidate Moore's Law. To counter these issues, This paper analyzes specific problems challenges in the Chip Information Industry, including the development of carbon nanotube chips and fierce competition in the international Chip Information Industry. In addition, this paper undertakes a critical analysis of the Chinese Chip Information Industry and countermeasures to Chinese Chip Information Industry development.

Keywords

Moore's Law, Chip, Integrated Circuits, Chip Information Industry Development

1. Introduction

Semiconductor component products are generally called chips, and a set of chips is referred to as a chipset. A chip is the carrier of a wafer cut IC (integrated circuit). A silicon wafer is quite small and contains an IC. It is an important component of a computer or other electronic device. The IC consists of specific circuit modules on a silicon board that can achieve certain functions by connecting various electrical components. The IC is the most significant component of electronic devices because it is responsible for calculation and memory functions. IC applications include military and consumer electronic equipment (Villard *et al*., 2015) [1].

A chip is the result of IC design, manufacturing and packaging and testing and is typically an independent entity intended for immediate usage. The two terms, chip and IC, are both similar to and different from each other. ICs typically exist in the form of chips. An IC narrowly emphasizes the circuit itself; for example, we call a simply connected phase-shift oscillator with five elements an IC on blueprint. Such a small integrated circuit must either be an independent entity or embedded into a larger integrated circuit, playing its role by relying on chips. ICs highlight circuit design and "place & route" steps, while chips emphasize the integration, manufacturing and packaging of circuits. However, ICs are broadly related to chips with respect to industry (compared with other industries).

In general, semiconductor wafers are produced by micromachining, regardless of whether the internal circuits can be called chips, *i.e.*, semiconductor illuminant chips, mechanical chips such as MEMS gyroscope chips, or biochips such as DNA chips. In the communication and information technology fields, the intersection of chips and integrated circuits is known as "the circuit on the silicon wafer" if limited to silicon integrated circuits. A chipset is a series of combined correlative chips relying on each other to play a greater role, *i.e.*, CPU and northbridge/southbridge chipsets in computers and radio frequency and baseband and power management chipset in cell phones.

For instance, the performance of a display card master chip determines the performance of a GPU. Graphics chips vary in inner structure and performance; thus, their price differential is vast. Because the graphics chip represents the core of an entire GPU, its position in the GPU is as important as that of the CPU in a computer.

It is estimated that 1 dollar of chip output value can lead to 10 dollars of output value in an IT industry with 100 dollars of GDP. The development of the

Chip Information Industry is closely related to personal livelihoods because western developed countries have considered the Chip Information Industry to be a national strategic industry in succession (Fan and Sun, 2014) [2].

2. Methods: Moore's Law

This Gordon Moore (1929-) is one of the founders of Intel. After graduating from high school, he attended the University of California at Berkeley (UCB) and studied chemistry. After receiving his bachelor's degree in 1950, he pursued a higher educational degree and received his doctoral degree in physical chemistry in 1954.

In 1965, he served as the director of the Fairchild Semiconductor Research and Development Laboratory. Moore was invited to write a review for Electronics magazine's 35th anniversary entitled "Cramming more components onto integrated circuits" [3]. Moore found that a new chip has approximately two times the capacity of the previous generation's chip. Furthermore, each new chip is produced 18 - 24 months after the previous generation [4] [5]. This discovery is called Moore's law [6] [7], which not only applies to the development of memory chips but also illustrates the development of processor competence and disk drive storage capacity. Moore's law has become the industrial foundation of performance prediction in several fields.

2015 marked the 50th anniversary of Moore's law proposed by Gordon Moore, one of founders of Intel. Over the past 50 years, the integration of semiconductor chips mirrored Moore's predictions, promoting the development of the IT industry. Currently, a progressive integrated circuit contains 1.7 billion transistors. In 1975, a new type of memory chip surfaced with nearly 65,000 components, which is consistent with Moore's prediction in 1965. According to statistics published by Intel, the number of transistors on a single chip increased from 2300 in the 4004 CPU in 1971 to 7.5 million in the Pentium II CPU in 1997, rising 3200 times in 26 years. If we accept the forecasting of "doubling every two years", there should have been 13 doubling cycles in 26 years. After each cycle, the number of chip integration elements should have improved 2n times ($0 \le n \le 12$). Thus, 13 cycles and 26 years later, the number of components was fairly close to 3200 times the actual growth. The 24 core Xeon Broadwell-WS with over 5.7 billion transistors is available processor in 2016.

Moore's law is not a mathematical or physical law but rather a development trend prediction. Therefore, its expression and quantitative calculation should be allowed a certain degree of tolerance. Because Moore's prediction has consistently shown a high degree of accuracy, it is accepted as a Chip Information Industry standard (Dai and Liao, 2014) [8].

Because of the uniqueness of high purity silicon, higher integration levels are associated with cheaper selling prices. This can be analyzed from the viewpoint of economic benefit. In early 1960, a transistor cost approximately $10. As transistors became increasingly smaller in size, *i.e.*, 1000 transistors fitting on a single hair, the price of each transistor was only one thousandth of a cent. According to known statistics calculating the prices as 100 thousand multiplications, the cost of the IBM 704 is $1, and the cost of the IBM 709 has been reduced to 20 cents. In addition, the IBM 360 system that cost 5 billion dollars in 1965 currently costs 3.5 cents. The costs of chip fabrication plant are exponential curve. This is called Moore's Second Law [9] [10].

3. The Development of Chip Information Industry

3.1. Development of the Carbon Nanotube Chip

Michio Kaku is a professor of theoretical physics and physicist at the City University of New York. In 2012, he claimed that, after being popular for the past 47 years, the utilization of Moore's Law in the Chip Information Industry would collapse in the next ten years. Computing capability cannot maintain a fast rate of exponential growth relying exclusively on standard silicon material technology. High temperature and leakage are the two main sources of Moore's Law failure.

On October 28th, 2012, US Institute of IBM scientists announced that the latest development of the carbon nanotube chip adhered to the "Moore's Law" cycle. Every 18 months, the degree of integration of the computer chip doubled, and its price was halved. Although a traditional transistor is made of silicon, in 2011, silicon transistors approached the atomic level and reached their physical limit. Due to the natural properties of silicon, breakthroughs in the running speed and performance of silicon transistors are becoming difficult to produce. Because carbon nanotube devices can run faster than siliceous devices, scientists at IBM have posited the placement of greater than 10,000 carbon nanotube transistors on a silicon chip. Carbon nanotubes are the ideal structure for transistors, which contributes to why they are replacing silicon transistors. Combined with novel chip design, this exceptional property will enable micro-level chips to drive innovation. Carbon nanometer chips not only improve the performance of mobile phones and tablets but also have low energy consumption. Papers published in Nature confirm that computing power can be increased up to 1000 times via a nanometer chip. Carbon nanometer chips can not only be used in mobile phones, tablets and personal computers but also in other applications, such as nano-robots that kill cancer cells in the human body (Dai and Liao, 2014) [8].

3.2. Fierce Competition in the International Chip Information Industry

Foxconn's bid for Toshiba's flash memory business was greater than 2 trillion yen ($18.4 billion), according to people familiar with the deal. This price was slightly higher than the other two bidders, according to a consortium led by American West Data Co. and a consortium including private equity firm Bain Capital (Wu, 2017) [11].

Patent fee litigation between Apple Inc. and chip maker Qualcomm has recently intensified. In an attempt to alter Qualcomm's existing cost model, Apple proposed to a US court that their patent license agreement with Qualcomm was invalid on June 20, 2017. Apple believes that it should only be required to pay for Qualcomm's chip technology. However, Qualcomm claims that it is entitled to a wider range of royalties in addition to those for its single chip technology. In the lawsuit, Apple stressed that assessing costs based on a whole machine's price is unreasonable and likened it to a tax that impinged upon Apple's potential for innovation. For example, although Apple's revolutionary innovations Touch ID, Retina Display, etc., are unrelated to Qualcomm patent technology, Apple is required to pay higher licensing fees due to the rising price of whole machines. Apple reasons that Qualcomm's cost model violates the FRAND requirement (Fair, Reasonable And Non-Discrimination), and Qualcomm's business model, in accordance with the recent court decision, is also in violation of United States patent law. Qualcomm's executive vice President Rothenberg says that "Qualcomm's innovation is at the heart of Apple's products, making these devices playing the most important role and function." Qualcomm is not attempting to collect royalties for Apple innovations unrelated to Qualcomm's technology. Qualcomm has several global mobile chip core patents, and its main revenue comes from technology licensing fees, which is also Qualcomm's core business model, since most Android smart phones in the market adopt its chips. In accordance with Qualcomm's patent fee model, every manufacturer who uses its chip must pay Qualcomm a chip fee for each cell phone shipment in addition to extra patent license fees of 5% to 6% of the whole machine costs, which varies from 2% to 3% based on the vendor's specific situation. Moreover, smart phone manufacturers unwillingly pay the "Qualcomm tax" because of the high level of competitiveness of Qualcomm's chip in the smart phone market, particularly in baseband support. Smartphone manufacturers must opt for Qualcomm or receive permission from Qualcomm to support CDMA or CDMA2000 or design a mobile phone (Liu, 2017) [12].

In the second quarter of 2017, Samsung Electronics Co., a leading South Korean company, surpassed Intel in the semiconductor industry, establishing itself as a new leader in the global Chip Information Industry. In the second quarter of 2017, Samsung's electronic semiconductor business sales reached 17.6 trillion ($15.8 billion), which surpassed Intel's chip sales of $14.8 billion during the same period. The strong growth in Samsung's electronics chip business stemmed from the rapid expansion of mobile devices and data services. As mobile devices and cloud computing services are used by a growing number of customers, the memory chip market experiences a rapid growth in demand as well as rising prices. Thus, Samsung Electronics is in a leading position in memory chips.

With respect to sales, Intel has been the world's largest chip manufacturer since 1992. Over the past ten years, Intel and Samsung Electronics ruled their own domains in the semiconductor industry. Intel is currently the world's largest supplier of personal computer processors, whereas as a result of the rapid spread of mobile phones and tablets, Samsung is the world's largest supplier of memory chips. The market demand for memory chips will boost global semiconductor industry revenues by 52% in 2017, which will reach $400 billion for the first time in history. Data from the US Financial Data Software Corporation cited by the Associated Press show that Intel sales are expected to reach $60 billion this year, and Samsung's electronic semiconductor business is expected to be greater than $62 billion (Xin, 2017) [13].

At the September 19, 2017 "Intel top manufacturing date" held for the first time in Beijing, Intel EVP and President of Manufacturing, Operations and Sales Stacy Smith said that the answer to the question of "whether or not Moore's law would fail" is: "NO!" Today, for the first time ever, Intel introduced its 10-nanometer wafer via a live broadcast from Beijing. Intel's 10-nanometer technology represents the technological progress of an entire generation. It has fully proven that Moore's law stands and maintains momentum. With respect to the market, the density of our rival companies' ten-nanometer chips is identical to that of Intel's 14-nanometer chips, although they were released three years later. All in all, Moore's law still holds.

3.3. Analysis of China's Current Chip Information Industry

The equations China's Chip Information Industry encompasses chip design, manufacturing and packaging and testing.

The two core technologies of the chip design industry are the DSP (digital signal processing) and CPU (Central Processing Unit) microprocessors. A DSP—a type of integrated computer chip called a digital signal processor—is approximately the size of a coin. DSP refers to the theory and techniques of how a signal is expressed and processed digitally, that is, DSP is the theory and techniques of signal processing via numerical calculation. A CPU is a very large-scale integrated circuit that comprises a computer's computing and control cores. It includes an ALU (Arithmetic and Logic Unit) and a Control Unit (CU) as well as a number of registers, memory caches and buses enabling the linking, control and status of data. The main function of a CPU is to interpret computer instructions and process data in computer software. The highest level of domestic CPU product research is known as "Longxin", and that of DSP product research is referred to as "Hanxin". Datang Microelectronics, Hangzhou Shilan Microelectronics, Wuxi China Resources Silicon Microelectronics, China Huada, Shanghai Huahong, Jiangsu Yiyuan Technology and 10 additional design companies represent the chip design industry with domestic sales exceeding 100 million yuan.

In terms of chip manufacturing, a group of IC companies represented by SMIC have been successively established, providing the necessary basic conditions for the rapid development of ICs in our country and further driving the overall development of all the links in the IC industry chain in China. The main chip manufacturing representatives are SMIC (Beijing), SMIC (Shanghai), SMIC (Tianjin), Wuhan Xinxin (SMIC), Shanghai Hongli, Hejian Technology (Suzhou), Songjiangtai SMC, Shanghai Xinjin (Metallurgy), Zhongwei Zhiti (Ningbo), Wuxi Huarun, Jilin Huawei (Shenyang), Hangzhou Shilan Electronics, Chongqing Maode, Dalian Intel, Zhangjiang Tech, Shanghai Belling, Fangda, and China Microelectronics.

In the chip packaging and testing industry, there are approximately 70 large IC packaging and testing enterprises in China, of which 22 are local or locally controlled. The remaining 48 are wholly owned, Taiwan-funded or foreign-controlled enterprises, and nearly 60% of the enterprises are concentrated in the Yangtze River Delta region. With respect to packaging technology, the diversification of packaging products and demand for high-end packaging products have driven progress in new technology development and production, which is gradually altering the original middle-to-low level plastic packaging landscape. Chinese chip packaging companies include Tong Fu Microelectronics, Changdian Technology, Huatian Technology, Tai Chi Industrial, and Suzhou solid technetium, among which Changdian Technology is the largest semiconductor manufacturer in China—a well-known, leading edge domestic transistor and integrated circuit manufacturer. Changdian Technology already has three core technology R&D platforms synchronized with international advanced technology ICs to achieve an annual output of 7.5 billion integrated circuits, 25 billion medium and small power transistors, and a discrete device chip production capacity of 1.2 million, which is among the top five in the world. Some of their products, designated as military products by the Commission of Science, Technology and Industry for National Defense, are widely used in the fields of aviation, aerospace engineering, military engineering, electronic information and automatic control. Suzhou Solid Tech, the first enterprise to engage in QFN (Quad Flat No-lead Package) package research and industrialization, can produce a variety of QFN/DFN (Dual (Double) Flat No-lead Double, flat bilateral, pinless) packages of integrated circuit products and is the largest QFN/DFN integrated circuit packaging companies in China worldwide.

3.4. China's Core Chip Information Industry Relies Heavily on Imports

According to the "2016-2017 Annual Report on China's Internet of Things Development", China's newly developed sensor products, which have lagged behind those of developed countries for nearly 10 years, currently rely approximately 60% on imports. Moreover, China's micro-electromechanical system sensors rely almost entirely on imports, and 80% or more its core chips rely on imports (Zhu *et al.*, 2017) [14]. In 2013, ICs surpassed crude oil as the largest importers of goods in China, with a total import volume of 231.3 billion US dollars, which represents a 20.5% increase over the same period a year ago. Accelerating the development of the integrated circuit industry has become a top priority in China (Niu, 2015) [15].

3.5. China's Chip Information Industry Development Strategy

The 8.9 nm integrated circuits manufacturing technology will reach by the year 2024, the number of transistors per square millimeter integration will reach 9 billion.

Advanced networks-on-chip (NoC) is very promising [16].

India has stepped up its collaboration with international chip companies, which makes the technology level of Indian chips higher than that of Chinese chips (Fuller, 2014) [17]. China should continue to increase its capital investment to attract worldwide talent to join the research and development of China's Chip Information Industry and create a chip design, manufacturing, and packaging and testing industry of international influence.

4. Conclusions

Based on Moore's Law, since the Chip Information Industry is growing rapidly, chip and integrated circuit industries are developing at a rapid rate, reducing power consumption. Since 1960, the cost of a transistor has been reduced to one part per million. This has greatly reduced resource consumption, allowing energy savings and emission reduction. In the era of big data and artificial intelligence, there is a great demand for the Chip Information Industry.

This paper also found that the competition in the international chip information industry is furious. China's core chip information industry relies heavily on imports. China should increase capital investment to develop China's chip information industry.

Acknowledgements

This research study was funded by the National Natural Science Foundation of China (71473010). Humanities and social science excellent results breeding project in Beijing University of technology.

References

[1] Villard, A., Lelah, A. and Brissaud, D. (2015) Drawing a Chip Environmental Profile: Environmental Indicators for the Semiconductor Industry. *Journal of Cleaner Production*, **86**, 98-109. https://doi.org/10.1016/j.jclepro.2014.08.061

[2] Fan, A. and Sun, Q. (2014) Market Structure, Government Intervention and Mobile Phone Chips Industrial Development—Based on Game Theory Perspective. *Review of Industrial Economics*, **6**, 17-32.

[3] Dean, E. (2014) Moore's Law: How Long Will It Last? http://www.techradar.com/news/computing/moore-s-law-how-long-will-it-last-1226772

[4] Moore, G.E. (1975) Progress in Digital Integrated Electronics. *International Electron Devices Meeting, IEEE*, 11-13. http://www.eng.auburn.edu/~agrawvd/COURSE/E7770_Spr07/READ/Gordon_Moore_1975_Speech.pdf

[5] Bradley, D. (2017) Single-Atom Memory Maintains Moore's Law. *Materials Today*,

20, 225. https://doi.org/10.1016/j.mattod.2017.04.021

[6] Moore, G.E. (2006) Understanding Moore's Law: Four Decades of Innovation. In: Brock, D.C., Ed., *Chemical Heritage Foundation*, Philadelphia, PA, 67-84.

[7] Robison, R.A. (2012) Moore's Law: Predictor and Driver of the Silicon Era. *World Neurosurgery*, **78**, 399-403. https://doi.org/10.1016/j.wneu.2012.08.019

[8] Dai, J. and Liao, X. (2015) The Past, Present and Future of Moore's Law, Electronics and Encapsulation. *Electronics & Packaging*, **6**, 30-34.

[9] Schaller, B. (1996) The Origin, Nature, and Implications of "Moore's Law". http://www.welchco.com/02/14/01/60/96/09/2601.HTM

[10] Ross, P.E. (1995) Moore's Second Law. *Forbes*, March 25, 116-117.

[11] Wu, K. (2017) A Part of the Toshiba Director, Foxconn to Toshiba Chip Bid More than $18.4 Billion. *The First Finance and Economics: Ke Chuang*, 11 September 2017. http://www.chinesechip.com/documents/c58f53e7614740f38d22c10e2a409e8e.html

[12] Liu, Y. (2017) Apple and Qualcomm Patent War End Height: There Is No Suspense. *Science and Technology Daily*, 2 August 2017. http://www.chinesechip.com/documents/8b2a22508a9646fca6dbca9e5b2c09e0.html

[13] Xinhua News Agency. (2017) Samsung Replace Intel as Global Chip Industry Leader. *Xinhua News Agency*, 28 July 2017. http://www.chinesechip.com/documents/f622884cdc444662baffe81e6a93902b.html

[14] Zhu, G., Yang, S. and Zhu, C. (2017) The Internet of Things New Era Were the Core Technology Bottleneck: Chip Rely on Imports. *Economic Information Daily*, 18 September 2017. http://www.chinesechip.com/documents/b19d395d3773464e9c7eea5767be1375.html

[15] Niu, L. (2015) China's Chip Industry Rise. *New Economy Weekly*, No. Z1, 36-39.

[16] Achballah, A.B., Othman, S.B. and Saoud, S.B. (2017) Problems and Challenges of Emerging Technology Networks—on—Chip: A Review. *Microprocessors and Microsystems*, **53**, 1-20. https://doi.org/10.1016/j.micpro.2017.07.004

[17] Fuller, D.B. (2014) Chip Design in China and India: Multinationals, Industry Structure and Development Outcomes in the Integrated Circuit Industry. *Technological Forecasting & Social Change*, **81**, 1-10. https://doi.org/10.1016/j.techfore.2012.10.025