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US tech sanctions on China and effects

Eric Chen, DIGITIMES Research, November 2022

Introduction

DIGITIMES Research believes the US government's Export Administration Regulations (EAR) released on October 7, 2022, which implements controls on transactions of advanced ICs, exports of semiconductor manufacturing items and specific activities of Americans, will prevent China from procuring or independently developing/producing high-performance computing (HPC) chips.

This will set back China's progress in AI and supercomputer research and weaken its technological and military strength which otherwise could be empowered by its semiconductor advances. The EAR will allow the US to maintain its technological and military leadership.

China's semiconductor sector is advancing by leaps and bounds and the US is feeling pressure from China in terms of technology, international status and military strength. The US considers this a threat to its national security and has made several moves to hinder China's progress in semiconductors and other leading-edge technologies. Seeing that the Entity List has generated little effect, the US is stepping up its controls.

The US imposing restrictions on the export of HPC chips, process equipment and human resources to China is an attempt to block China's HPC chip production from the manufacturing side. Having accumulated experiences from its past control policies, the US is able to devise more precise restrictions against China and widen the scope from individual companies to industries.

Although China's semiconductor industry is able to tap its enormous domestic market and advance by leaps and bounds, DIGITIMES Research expects the US government's new export restrictions to grind China's advanced IC and process developments to a halt and set back China's AI and supercomputer research. The restrictions may not affect the development of most HPC chips or automotive chips in the short term but in the long run, they will cripple China's ability to develop HPC chips and advanced processes, leading to a reshuffle of the global semiconductor sector.

Sanction details

Technology

Table 1: US sanctions on China over technologies

Category	Details
Supercomputers	Sanctions cover operable supercomputers sized 41,600 cubic feet or smaller with computing capability of 100petaFLOPS or above for 64bit architecture and 200petaFLOPS or above for 32bit architecture
Chips	Sanctions cover HPC chips with an overall computing capability of 4,800TOPS and above and Chips with two-way transmission speeds totaling 600GB/s or above
Advanced manufacturing nodes	Sanctions cover14/16nm and smaller for logic manufacturing nodes, 18nm and smaller manufacturing nodes for DRAM and 128-layer and above technology for NAND
Applications and users	Sanctions cover applications including supercomputers and military systems and exports to 28 Chinese entities (included in the Entity List)

Source: DIGITIMES Research, November 2022

The US government's latest export restrictions will hinder China's HPC chip development and limit its AI and supercomputer application research.

The export restrictions ban the transactions of HPC chips beyond a specified performance level and cripple China's ability to develop such chips.

As per the restrictions on end uses, HPC chips and supercomputer chips (including components) as well as related semiconductors are also banned from being supplied to China.

Most HPC chips (including CPU, GPU and AI processors) and automotive chips (for ADAS, for example) currently on the market do not have processing performance exceeding the limit imposed by the US government so they are not in the scope of the latest export restrictions. As such, the export restrictions will have a minimum effect on the production or sales of HPC and automotive chips.

The scope of the US government's restrictions has expanded from individual companies to industries.

Instead of targeting individual companies (such as Huawei), the US government now tackles China's HPC ecosystem and supercomputer sector by restricting their design and manufacturing abilities.

Personnel

Table 2: US sanctions on China over personnel

Category	Details	Efforts
Personnel and activities	A permit is required for Americans to provide support to China's development and manufacturing of ICs for specific end uses Americans refer to US citizens, permanent resident aliens holding green cards, foreigners who have been granted temporary residence, and people subject to US law or any jurisdiction within the US Specific end uses include AI, supercomputers, weapons of mass destruction (WMD) and military applications. Supporting activities include shipping, moving, or providing maintenance services.	Setting back China's progress in AI and supercomputer research Crippling China's ability to design and manufacture semiconductors Weakening China's technological and military development energy

Source: DIGITIMES Research, November 2022

The restrictions on Americans will effectively hold back China's semiconductor technology advances.

Overseas Chinese graduates returning to China have played a critical role in driving the country's rapid semiconductor advances in recent years. Most of them hold green cards.

The restrictions will prevent green card holders, US citizens and US company employees from supporting China's advanced semiconductor development.

American equipment suppliers have chosen to pull their advanced process line support engineers out of China.

There have been cases of American IC design firms (Marvell, for example) dismissing their IC design teams based in China.

The US government thinks restricting China's semiconductor development will minimize risks to US national security posed by China's technological and military strength.

China's civil-military integration strategy drives the rapid growth of China's technological and military strength.

AI and supercomputers can be applied in military deployment and exercise as well as missile production and interception calculations.

Semiconductors are key instrumentals in boosting AI and supercomputer power.

Chinese entities

US Entity List

Table 3: Chinese enterprises and organizations in US Entity List

Category	Entities
Academic and research Institutions (7)	Beijing Institute of Technology Harbin Institute of Technology National University of Defense Technology Northwestern Polytechnical University China Aerospace Science and Technology Corporation (CASC) 9th Academy 771 Research Institute Shanghai High-Performance Integrated Circuit Design Center Wuxi Jiangnan Institute of Computing Technology
Supercomputer centers (7)	National Supercomputing Center in Zhengzhou, Changsha, Guangzhou, Jinan, Shenzhen, Tianjin and Wuxi
AI-related developers (6)	Sense Time Iflytek Intellifusion Megvii Technology H3C YITU Technology
IC designer (6)	Jingjia Microelectronics Hygon Information Technology Haiguang Integrated Circuit Design Chengdu Haiguang Microelectronics Technology Sugon Phytium
IoT (2)	Dahua Technology (Surveillance and IoT) Sunway Microelectronics (Radio Frequency)

Source: DIGITIMES Research, November 2022

The US government added 28 organizations to the Entity List. They are subject to export controls under the FDPR to restrict them from using US technologies to independently develop or manufacture products or procure products made with US technologies (including software and hardware). This is aimed to prevent China's use of US technologies to develop AI and supercomputers to engage in military activities, violate human rights or threaten regional security.

The FDPR imposes controls over the trading of US technologies. Products made using US technologies, including ones made outside the US, are subject to the US government's control.

Huawei's 5G business virtually ground to a halt after the US government launched sanctions against Huawei under the FDPR.

Following Russia's invasion of Ukraine, the US government also implemented sanctions against Russia and Belarus to restrict their chip supply.

Chinese entities endeavoring AI and supercomputer-related applications are included in the Entity List, encompassing academic and research institutions, supercomputer centers, AI technology developers and IC design firms.

US Unverified List

Table 4: Chinese enterprises and organizations in US Unverified List

Category	Entities
Academic and research Institutions (6)	ShanghaiTech University University of Shanghai for Science and Technology University of Chinese Academy of Sciences Chinese Academy of Geological Sciences Minerals Resource Institute Institute of Chemistry Chinese Academy of Sciences Wuhan Institute of Biological Products
Semiconductor (2)	YMTC (NAND flash) Nan Jing Gao Hua Technology (sensors)
Optical communication (2)	Wuhan Juhere Photonics Technologies Chongqing Optel Telecom Technology
Materials/equipment (7)	Beijing Naura Magnetoelectric Technology Jin Tan Teng Yuan Machinery Parts DK Laser Company Ningbo III Lasers Technology Wuxi Hengling Technology Guangdong Dongling Carbon Tech Vital Advanced Materials
Testing and inspection (8)	CCIC Southern Testing GRG Metrology & Test Chongqing GRG Metrology & Test Beijing Qingdao Sci-Tech Innovation Quality Testing Beijing PowerMac Company Dandong Nondestructive Electronics Jialin Precision Optics Xian Zhongsheng Shengyuan Technology
Others (6)	Guangxi Yuchai Machinery Suzhou Sen-Chuan Machinery Technology Chongqing Xinyuhang Technology Foshan Huaguo Optical Lishui Zhengyang Electric Power Construction Tianjin Optical Valley Technology

Source: DIGITIMES Research, November 2022

The Unverified List (UVL) includes entities that the US government could not verify the end users and end applications for the products to be exported to these entities.

Unlike the Entity List, US suppliers are not banned from transacting with the entities in the UVL.

The entities listed in the UVL are required to cooperate with the US government for checks and approval. Those who failed to comply will be added to the Entity List.

The US government added 31 Chinese entities including academic and research institutions as well as biotech, laser equipment, photonics, semiconductor material and testing companies to the UVL, with YMTC being the center of attention.

Effect on semiconductors and companies

Effect on China IC design industry

HPC chips

Table 5: Sanctions on Chinese and non-Chinese HPC chip

Company	Chip model	Peak performance (TOPS)	Peak transmission speed (GB/s)	Foundry/node
AMD	MI250X	3,064	800*	TSMC (6nm)
	MI250	2,897	800*	TSMC (6nm)
	MI210	1,448	800*	TSMC (6nm)
Nvidia	H100	24,208*	600*	TSMC (4nm)
	A100	4,992*	600*	TSMC (7nm)
T-Head	HanGuang 800	6,600*	Undisclosed	TSMC (12nm)
Cambricon	MLU290	4,096	600*	TSMC (7nm)
Biren	BR100	15,360*	448	TSMC (7nm)
	BR104	8,192*	192	TSMC (7nm)

**Note: Figures with * are numbers that surpassed US's tech sanction baselines.*
Source: DIGITIMES Research, November 2022

The US government's export controls not only restrict US IC design firms from supplying chips to China but also limit China's ability to independently develop and produce HPC chips.

AMD and Nvidia have been prohibited from providing AI processors and GPUs with performance exceeding the specified limit to China.

Foreign companies based in China are given a one-year grace period.

Chips that currently fall under the restriction scope are mainly manufactured on TSMC's 12nm to 4nm nodes. TSMC has indicated that the restrictions will make little impact on its revenue.

It is likely that the US will raise the limit on chip processing performance and tighten the control on China's ability to procure or develop HPC chips.

IC designers

Table 6: Effect of sanctions on chips and China's IC design industry

Chip type	Sanction target	Sanction details	Effects
Chips under sanctions	International/ Taiwanese companies	Can't sell the chips to the China market	China market: Businesses shrinking for the high-end HPC market Non-China market: No effect
	Chinese companies	Can't design or in-house produce the chips	The US is putting a halt to Chinese chips' computing ability and will disrupt China's development of HPC chips such as those for high-end AI and GPUs.
Chips not under sanctions	International/ Taiwanese companies	None, only need to ensure that the chips' end buyers and applications did not violate the sanctions	No effect
	Chinese companies		Mid-range to low-end: No effect High-end: To be monitored. The effect on the segment will depend on foundries' attitudes toward accepting orders from Chinese chip designers, how the US defines its sanction rules, and whether the US will impose more new sanctions on Chinese IC designers.

Source: DIGITIMES Research, November 2022

The US restricts the supply of EDA tools, process equipment and human resources, aiming to block China from developing and producing the chips under the US government's control. This will cripple China's ability to design and manufacture HPC chips and its volume production of non-restricted HPC chips will also be hindered.

The US has put a cap on China's computing power and set back its long-term development.

The production of non-restricted chips on advanced processes can be outsourced to foreign or Taiwan-based foundries but the US still places controls over their end users and applications as well as product destinations, uses and development progress.

China's IC design firms are set to increase their use of mature processes, which will drive China's semiconductor manufacturers to step up their investments toward mature processes. This will exacerbate the intense competition among global foundries in the mature process segment.

Effect on foundries and memory makers

Foundries and memory makers

Table 7: Effect of sanctions on foundries and memory makers

Company type	Sanction target	Sanction details	Effects
Wafer foundries/ memory makers	US/non-US companies	Non-China production lines: No effect, but need to verify the chips' final customers and applications	Advanced nodes under sanctions: Cannot accept orders from Chinese IC designers
		China production lines: Need permission from the US for acquiring advanced manufacturing equipment and need to verify the chip's final customers and applications	Advanced nodes not under sanctions: No effect as of the moment, but will affect the foundries' willingness to accept orders from Chinese IC designers Some foundries may benefit from orders shifted away from Chinese foundries Whether the US will impose more sanctions rules will need to be monitored
	Chinese companies	Advanced nodes will halt Logic chip manufacturing: 14/16nm and more advanced nodes are banned DRAM: 18nm and more advanced nodes are banned NAND: 128-layer and higher manufacturing processes are banned	Can only produce non-advanced node semiconductors
			Geopolitical risks may push clients to shift their orders to non-China foundries
			How does the US change or adjust its definitions for advanced nodes will need to be monitored

Source: DIGITIMES Research, November 2022

Foreign or Chinese firms are prohibited from fulfilling orders for chips destined for AI, supercomputer or military uses within the scope of the restrictions.

Foreign firms can decide on whether to accept orders for non-restricted chips, which are not for AI, supercomputer or military uses.

Foundries will have to verify the end users and applications if they decide to accept the orders. However, this may be too challenging to do, thus deterring foundries from taking such orders.

The US government's controls will block China's semiconductor sector from producing chips on advanced processes.

To achieve chip self-sufficiency, China's semiconductor sector will aggressively invest in non-advanced processes.

The US government's definition of advanced processes on a rolling basis is something to watch.

In view of the risks arising from the US-China standoff, even the production of chips on mature processes may be relocated outside of China.

Technology ability

Table 8: Technology ability of key foundries worldwide

Company	16/14nm	7nm	5nm	3nm
TSMC	V	V	V	V
Samsung	V	V	V	V
Intel	V	V	V	
SMIC	V	^	^	
HLMC	^			

**Note: V indicates that the node is already in volume production, while ^ indicates that the node is still being developed.*
Source: DIGITIMES Research, November 2022

Table 9: Technology ability of key DRAM makers worldwide

Company	1x	1y	1z	1α	1β
Samsung	V	V	V	V	
SK Hynix	V	V	V	V	
Micron	V	V	V	V	V
CXMT	V	^			

**Note: V indicates that the node is already in volume production, while ^ indicates that the node is still being developed.*
Source: DIGITIMES Research, November 2022

Table 10: Technology ability of key NAND flash makers worldwide

Company	96L	128L	176L	2xxL
Samsung	V	V	V	^
SK Hynix	V	V	V	^
Micron	V	V	V	V
YMTC	Skip	V	^	^

**Note: V indicates that the node is already in volume production, while ^ indicates that the node is still being developed.*
Source: DIGITIMES Research, November 2022

With China encountering setbacks in semiconductor fabrication and memory technology development, foreign firms can expect to maintain their competitive edge.

China's process technology advances will stop at the 7nm node while its most advanced production capability will stay at the 28nm node.

ChangXin Memory Technologies (CXMT) has entered 19nm DRAM volume production (1xnm) and was on course to move toward the 17nm node before the progress ground to a halt due to the US government's sanctions.

Yangtze Memory Technologies (YMTC) has unveiled a NAND flash featuring 232 layers of memory cells but will not be able to keep pressing forward in the midst of the US government's sanctions.

Taiwan-based chipmakers manufacturing memory on mature processes may face competition from their Chinese rivals.

The manufacturing equipment that European, American and Japanese suppliers can provide to China will determine the process by which China-based chipmakers can maintain a normal operation.

China's domestically produced process equipment and materials can hardly support the initiative of a home-grown semiconductor supply chain. It has to rely on process equipment (such as lithography machines) from non-US sources.

Effect on equipment suppliers

Equipment suppliers

Table 11: Effect of sanctions on semiconductor equipment suppliers

Node type	Sanction target	Sanction details	Effects
Equipment with nodes under sanctions	US and non-US suppliers including Taiwanese ones	Permission from the US is required for exporting the related equipment to China	US suppliers: halting shipments and pulling personnel out of Chinese foundries' production lines to avoid violating US sanctions Non-US supplies: shipping equipment based on non-US technologies at a higher priority
	Chinese suppliers		They can only provide equipment not subject to the US restrictions
Equipment with nodes not under sanctions	US and non-US suppliers including Taiwanese ones	No effect as of the moment	There may be implications for equipment that can be used across different processes. The US Department of Commerce's actual implementation of the restrictions will provide clarification The US government's sanction rules going forward are to be monitored.
	Chinese suppliers		

Source: DIGITIMES Research, November 2022

Although the US government provides a specific definition for advanced processes, some equipment can be used across different processes. This makes the restriction scope unclear and forces US equipment suppliers to halt equipment exports and pull staff out of Chinese foundries' production lines to avoid violating the restrictions.

Due to the issue of shared use of equipment across processes, China's chipmakers may have to retreat to making chips on even more mature processes.

Non-US suppliers can provide equipment for non-advanced processes and based on non-US technologies to China's semiconductor sector.

The US is seeking an alliance with Europe and Japan to jointly impose advanced process equipment sanctions against China, which may further affect equipment exports by non-US suppliers.

Short- and long-term effect

Table 12: Short- and long-term effect of sanctions on equipment suppliers

Supplier		Effect	Detail
Non-China suppliers	US suppliers	Short-term: To be impacted	Equipment for processes subject to the restrictions sustains a direct impact.
		Mid- to long-term: To be monitored	Export of non-restricted equipment will resume but the influence will depend on whether China's chipmakers are willing to make purchases.
	Non-US suppliers	Short-term: To benefit	They can take over the position of US suppliers but their equipment will be required to be de-Americanized.
		Mid- to long-term: To be monitored	The US may call on other countries' supply chains to jointly impose restrictions on process equipment exports to China.
Chinese suppliers		Short-term: To benefit	Some of them stand to benefit from the initiative to replace imported parts with homemade ones and fill the gap resulting from the restrictions placed on US suppliers.
		Mid- to long-term: To benefit	They can benefit from China's chip self-sufficiency initiative but the US government's future export control policies will play an influential role.

Source: DIGITIMES Research, November 2022

US foundry equipment suppliers are prohibited from exporting products to Chinese firms. They will sustain the most significant impact from the US government's restrictions in the short term. The actual extent of the impact will become clearer when the scope of the controls is ascertained. In the long run, whether US suppliers can recapture foundry equipment

opportunities in China will depend on Chinese chipmakers' willingness to make purchases going forward.

Non-US suppliers (including Taiwan-based ones) and China-based suppliers stand a chance to fill the foundry equipment supply gap left open by US suppliers.

Non-US suppliers will reap the biggest benefit but future restrictions to be imposed by the US may narrow the benefit.

The US is seeking an alliance with Europe and Japan to jointly impose restrictions against China.

Taiwan-based suppliers mostly act as distributors or sell used equipment. They may have a chance to benefit from the US government's sanctions but US equipment will be banned from being exported to China.

China-based equipment suppliers may reap the benefit of the country's chip self-sufficiency drive as well as the initiative to replace imported parts with homemade ones. However, they are not as competitive as non-US suppliers so they will only benefit to a limited extent.

China-based suppliers of advanced process equipment are likely the potential target that the US government attempts to strike to cripple their mid- to long-term planning for advanced processes.

China-based etching equipment supplier AMEC has been added to the Military End User (MEU) List.