

Intro

Semiconductors are not one industry, but thousands. They range from ultra-high value advanced logic chips like H100s to bulk discrete electronic components and basic integrated circuits (IC). Leading-edge chips are the advanced logic, memory, and interconnect devices manufactured in cutting-edge facilities requiring production processes at awe-inspiring precision. Leading-edge chips confer differential capabilities, and “advanced process nodes¹” enable the highest performance computation and the most compact and energy-efficient devices. This bleeding edge performance is derived from the efficiencies enabled by more densely packing circuit elements in a computer chip. Smaller transistors require lower voltages and more finely packed ones can compute faster.

Devices manufactured with older process nodes, 65nm and above, form the bulk by volume of devices we use. These include discrete electrical components like diodes or transistors, power semiconductors, and low-value integrated circuits such as bulk microcontrollers (MCU). These inexpensive logic chips like MCUs, memory controllers, and clock setters I term “commodity ICs”. While the keystone components in advanced applications are manufactured at the leading edge, older nodes are the table stakes of electrical systems. These devices supply power, switch voltages, transform currents, command actuators, and sense the environment. These devices we’ll collectively term foundational chips, as they provide the platform upon which all electronics rest. And their supply can be a point of failure. The automotive MCU shortage provides a bitter lesson that even the humblest device can throttle production.

Foundational devices themselves do not typically enable differentiating capabilities. In many applications, such as computing or automotive, they simply enable basic functions. These devices are low-cost, low-margin goods, made with a comparatively simpler production process. Unfortunately, a straightforward supply does not equate to a secure one. Foundational chips are manufactured by a small quantity of firms concentrated in China. This is in part due long running industrial policy efforts by the Chinese government, with significant production subsidies. The Chips and Science Act was mainly about innovation and international competitiveness. Reshoring a significant fraction of leading edge production to the United States in the hope of returning valuable communities of engineering practice (Fuchs & Kirchain, 2010). While these policy goals are vital, foundational chip supply represents a different challenge, and must be addressed by other interventions.

The main problem posed by existing foundational chip supply is resilience. They are manufactured by a few geographically clustered firms and are thus vulnerable to disruption, from geopolitical conflicts (e.g. export controls on these devices) or more quotidian outages such as natural disasters or shipping disruptions.

There is also concern that foreign governments may install hardware backdoors in chips manufactured in their borders, enabling them to deactivate the deployed stock of chips. While this meaningful security consideration, it is less applicable in foundational devices, as their low complexity makes such backdoors more challenging. A DoD analysis found mask and wafer production to be the manufacturing process steps most resilient to adversarial interference (Coleman, 2023, p. 36). There already exist [“trusted](#)

¹ The specific manufacturing process, material base, design rules, and machine tools required to build an individual chip is known as a *technology node* or *process node*. Nodes were historically named for the smallest circuit element it could resolve (e.g. 26 nm). While the relationship between node name and physical feature size has ceased to be meaningful, the naming convention remains.

[foundry” electronics manufacturers](#) for critical U.S. defense applications concerned about confidentiality; my policy interventions seek to address the vulnerability to a conventional supply disruption. I will first outline the technical and economic features of foundational chip supply which are barriers to a resilient supply, and then propose policy to address these barriers.

Foundational Chip Challenges

Technical characteristics of the manufacture and end-use of foundational microelectronics make supply especially vulnerable to disruption. Commodity logic ICs such as MCUs or memory controllers vary in their clock speed, architecture, number of pins, number of inputs/outputs (I/O), mapping of I/O to pins, package material, circuit board connection, and other design features. Some of these features, like operating temperature range, are key drivers of performance in particular applications. However most custom features in commodity ICs do not confer differential capability or performance advantages to the final product, the pin-count of a microcontroller does not determine the safety or performance of a vehicle. Design lock-in combined with this feature variability results in dramatically reduced short-run substitutability of these devices; while MCUs exist in a commodity style market, they are not interchangeable without significant redesign efforts. This phenomenon, designs based on specialized components which are not required in the application, is known as over-specification (Smith & Eggert, 2018). This means that while there are numerous semiconductor manufacturing firms, in practice there may only be a single supplier for a specified foundational component.

These over-specification risks are exacerbated by a lack of value chain visibility. Firms possess little knowledge of their tier 2+ suppliers. The fractal symmetry of this knowledge gap means that even if an individual firm secures robust access to the components they directly use, they may still be exposed to disruption through their suppliers. Value chains are only as strong as their weakest link. Physical characteristics of foundational devices also uncouple them from the leading edge. Many commodity ICs just don’t benefit from classical feature shrinkage; bulk MCUs or low-end PMICs don’t improve in performance with transistor density as their outputs are essentially fixed. Analog devices experience performance penalties at too small a feature scale, with physically larger transistors able to process higher voltages and produce lower sympathetic capacitance. Manufacturing commodity logic ICs using leading edge logic fabs would be prohibitively expensive, and would be actively detrimental to analog device performance. These factors, design over-specification, supply chain opacity, and insulation from leading edge production, combine to functionally decrease the already narrow supply of legacy chips.

Industrial dynamics impede this supply from becoming more robust without policy intervention. Foundational chips, whether power devices or memory controllers, are low-margin commodity style products sold in volume. The extreme capital intensity of the industry combined with the low margin for these makes supply expansion unattractive for producers, with short term capital discipline a common argument against supply buildout (Connatser, 2024). The premium firms pay for performance results in significant investment in leading-edge design and production capacity as firms compete for this demand. The commodity environment of foundational devices in contrast is challenging to pencil out as even trailing edge fabs are highly capital intensive (Reinhardt, 2022). Chinese production subsidies also impede expansion of foundational fabs, as they further narrow already low margins. Semiconductor demand is historically cyclical, and producers don’t make investment decisions based on short run demand signals. These factors make foundational device supply challenging to expand: firms manufacture commodity style products manufactured in capital intensive facilities, competing with

subsidized producers, to meet widely varying demand. Finally, foundational chip supply resilience is a classic positive externality good. No individual firm captures all or even most of the benefit of a more robust supply ecosystem.

Forging Foundational Chips for the Future

To secure supply of foundational chips, I recommend development of an “Open Foundational” design standard and buyers’ group. One participant in that buyer’s group will be the U.S. federal government, which would establish a strategic microelectronics reserve to ensure access to critical chips. This reserve would be initially stocked through a multi-year advanced market commitment for Open Foundational devices.

The foundational standard would be a voluntary consortium of microelectronics users in critical sectors, inspired by the Open Compute Project. It would ideally contain firms from critical sectors such as enterprise computation, automotive manufacturing, communications infrastructure, and others. The group would initially convene to identify a set of foundational devices which are necessary to their sectors (i.e. system architecture commodity ICs and power devices for computing) and identify design features which don’t significantly impact performance, and thus could be standardized. From these, a design standard could be developed. Firms are typically locked-in to existing devices for their current design; one can’t place a 12 pin MCU into a board built for 8. Steering committee firms will thus be asked to commit some fraction of *future* designs to use Open Foundational microelectronics, ideally on a ramping up basis. The goal of the standard is not to mandate away from valuable features, unique application needs should still be met by specialized devices, such as rad hardened components in satellites. By adopting a standard platform of commodity chips in future designs, the buyers’ group would represent demand of sufficient scale to motivate investment, and that supply would be more robust to disruptions once mature.

Government should adopt the standard where feasible, to build greater resilience in critical systems if nothing else. This should be accompanied by a diplomatic effort for key democratic allies to partner in adopting these design practices in their defense applications. The foundational standard should seek geographic diversity in suppliers, as manufacturing concentrated anywhere represents a point of failure. The foundational standard also allows firms to de-risk their suppliers as well as themselves. They can stipulate in contracts that their tier one suppliers need to adopt Foundational Standards in their designs, and OEMs who do so can market the associated resilience advantage.

Having developed the open standard through the buyers’ group, congress should authorize the purchase through the Department of Commerce a strategic microelectronics reserve (SMR). Inspired by the strategic petroleum reserve, the microelectronics reserve is intended to provide the backstop foundational hardware for key government and societal operations during a crisis. The composition of the SMR will likely evolve as technologies and applications develop, but at launch the purchasing authority should commit to a long-term high-volume purchase of Foundational Standard devices, a policy structure known as an advanced market commitment. Advanced market commitments are effective tools to develop supply when there is initial demand uncertainty, clear product specification, and a requirement for market demand to mature (Ransohoff, 2024). The foundational standard provides the product specification, and the advanced government commitment provides demand at a duration which should exceed both the product development and fab construction lifecycle, on the order of 5

years or more. This demand should be steady, with regular annual purchases at scale, ensuring producers consistent demand through the ebbs and flows of a volatile industry. If these efforts are successful, the U.S. government will cultivate a more robust and resilient supply ecosystem both for its own core services, and for firms and citizens. The SMR could also serve as a backstop when supply fluctuations do occur, as with the strategic petroleum reserve. The goal of the SMR is not to fully substitute for existing stockpiling efforts, either by firms or by government for defense applications. Through the expanded supply base for foundational chips enabled by the SMR, and through the increase in substitutability driven by the Foundational Standard, users can concentrate their stockpiling efforts on the chips which confer differentiated capabilities. As resources can be concentrated in more application specific chips, stockpiling becomes more efficient, enabling more production for the same investment. In the long run, the SMR should likely diversify to include more advanced components such as high-capacity memory, and field programmable processors. This would ensure government access to core computational capabilities in a disaster or conflict scenario. But as all systems are built on a foundation, the SMR should begin with Foundational Standard devices.

There are potential risks to this approach. The most significant is that this model of foundational chips does not accurately reflect physical reality. Interfirm cooperation in setting and adhering to the standards is conditional on these devices not determining performance. If firms perceive foundational chips providing competitive advantage to their system or products, they shall not crucify capability on a cross of standards. Alternatively, each sector may have a basket of foundational devices as we describe, but there may be little to no overlap sector-to-sector. In this case, the sectors representing the largest demand, such as enterprise compute, may be able to develop their own standard, but without resilience spillovers into other applications. These scenarios should be identifiable early in the standard setting process before significant physical investment is made. In such cases, government should explore using fab lines in the national prototyping facility to flexibly manufacture a variety of foundational chips when needed, by developing adaptive production lines and processes. This functionally shifts the policy goal up the value chain, achieving resilience through flexible manufacture of devices rather than flexible end-use.

Value chains may be so opaque that the buyers' group might fail to identify a vulnerable chip. The department of commerce developing an office of supply mapping, and applying a tax penalty to firms who fail to report component flows are potential mitigation strategies. Existing subsidized foundational chip supply by China may make virtually any greenfield production uncompetitive. In this case trade restrictions or a counter-subsidy may be required until the network effects of the Foundational Standard enable long-term viability. We do not want the Foundational standard to lock in technological stagnation, in fact the opposite. Accordingly, there should be a periodic and iterative review of the devices within the standard and their features. The problems of legacy chips are distinct from those at the technical frontier. Foundational chips are necessary but not sufficient for modern electronic systems. It was not the hundreds of dollar System-on-a-Chip components which brought automotive production to a halt, but the sixteen cent microcontroller. The technical advances fueled by leading edge nodes are vital to our long term competitiveness, but they too rely on legacy devices. We must in parallel fortify the foundation on which our security and dynamism rests

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