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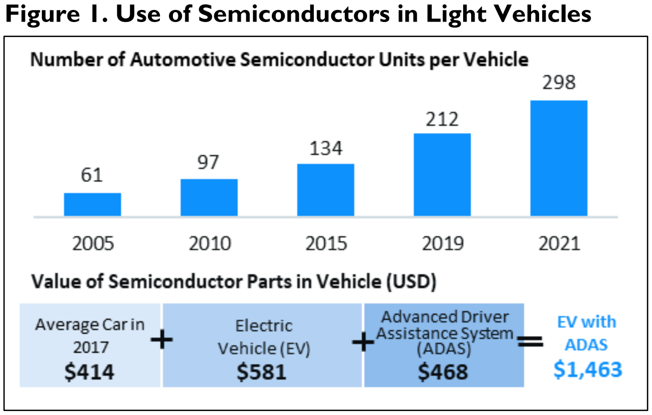
Semiconductor Shortage Constrains Vehicle Production

A shortage of semiconductors has slowed auto production and forced temporary closures of numerous assembly plants around the world. According to data from consulting firm AutoForecast Solutions, North America lost production of 2.3 million vehicles in 2021 due to plant shutdowns. The effects of the semiconductor shortage on automotive supply chains have drawn attention in Congress, at a time when Members are considering a variety of proposals to support domestic semiconductor production.

Semiconductor Use in Vehicles

Recent trends in vehicle design, including vehicle connectivity, electrification, and a growing array of autonomous features, have increased the number and cost of semiconductor components used in the average passenger car, sport utility vehicle, or pickup truck. As shown in the top of **Figure 1**, recent estimates by Goldman Sachs, an investment bank, show today's vehicles employ about 40% more semiconductor devices than those made prior to the COVID-19 pandemic in 2019. The increasing shift toward electric vehicles (EVs) and advanced driver assistance systems (ADAS) is also increasing the cost of semiconductor components used in vehicles. The bottom of **Figure 1** illustrates the additional electronics costs associated with an EV having ADAS features like the Tesla Model 3, which incorporates 3.6 times as much semiconductor value as the average internal combustion vehicle in 2017, according to estimates by Kearney consulting group.

Figure 1. Use of Semiconductors in Light Vehicles



Source: CRS, adapted from Goldman Sachs Investment Research (top) and Kearney analysis (bottom).

Note: Light vehicles include cars, sport utility vehicles, vans, and pickup trucks.

Most semiconductors used in personal vehicles are of the type known as discrete/analog/optoelectronic (DAO) devices, which are typically used in sensors and which can receive and transmit information. The supply shortages that have affected vehicle manufacturers, however, have largely involved a different sort of semiconductor, logic devices called microprocessors. These chips serve as the "brains" of a system calculating and processing information.

In motor vehicles, microprocessors are used for such tasks as gathering information about speed and brake cylinder pressure to manage antilock brake systems. Microprocessors are usually embedded within larger assemblies known as electronic control units, which are central to the functionality of power trains (four-wheel drive, engine, transmission, fuel pump), chassis and safety (antilock braking, airbag, suspension, backup cameras), body and convenience (ventilation, lighting, automatic seats), infotainment (audio and video systems, connectivity), and ADAS applications such as lane departure warnings.

Most microprocessors used for automotive applications are manufactured using older chip designs. For several decades, semiconductor performance has steadily improved as engineers have shrunk the size of core electronic features, characterized in the industry by the term "process node" (measured in metric length, nanometers or nm). Mature technology, also referred to as legacy chips, is generally characterized as having process nodes above 10nm, with bigger numbers indicating older technology (10-180nm+), while leading-edge technology is often regarded as being below 10nm. These legacy chip designs are reliable, effective, and inexpensive. However, automotive chips must meet higher quality standards, and they provide lower margins for chip manufacturers than the leading-edge chips that are critical for many advanced and emerging applications. Hence, chip manufacturers are often hesitant to invest in mature technology, such as by building new facilities to fabricate chips for automotive uses, which accounted for 10% of semiconductor sales in 2019, according to the Semiconductor Industry Association.

Supply-Chain Vulnerabilities

As chip performance has improved with miniaturization, the cost and complexity of the manufacturing process have substantially increased. This trend has driven many chip manufacturers that had previously both designed and produced their own chips (also known as integrated device manufacturers, or IDMs) to outsource the production of their designs to contract manufacturers (often referred to as foundries). Over time, the foundry market has become dominated by a few large companies located primarily in Taiwan and South Korea.

An estimated 70% of all the microprocessors needed for vehicle electronic control units come from a single chipmaker, Taiwan Semiconductor Manufacturing Company (TSMC). Nevertheless, the automotive industry accounts for only 3% of TSMC's total revenue, as estimated by IHS Markit, an analytics firm. Even though vehicle manufacturers have many suppliers of electronic control units, those supplier networks rely mainly on one producer of microprocessors. This exposes the entire network to disruption if that manufacturer encounters production issues. Further, suppliers of automotive components and systems face cross-industry competition as foundries weigh how to allocate manufacturing capacity among various types of chips, including some with greater demand and some which offer greater profit potential.

These supply chain vulnerabilities became apparent during the global coronavirus pandemic. Initially, anticipated declining consumer demand led suppliers of automotive systems to reduce orders with chip makers. Accordingly, chip manufacturers allocated capacity and inventory to industries experiencing rising demand due to the increasing use of telework and online learning. As vehicle demand recovered in the latter half of 2020, automotive suppliers were confronted with long lead times in acquiring semiconductors as chip makers tried to keep up with demand across many industries. The situation was exacerbated in early 2021 by severe winter weather in Texas affecting two major semiconductor component suppliers, NXP and Samsung, and a fire at another important supplier, Renesas, in Japan.

Expanding Legacy Chip Capacity

In response to recent shortage-induced impacts and increasing demand across industries, IDMs and foundries have committed $382 billion to expanding capacity and diversifying regionally. However, IHS Markit estimates that only 6% of the new expenditure will be relevant for the legacy chips needed in the automotive industry. Many such chips are produced in facilities employing older equipment able to process only 200mm (8-inch) silicon wafers rather than the larger 300mm (12-inch) wafers processed in newer plants. Equipment to make 200mm chips is no longer readily available.

Another big risk facing chip manufacturers is choosing the wrong technology and process to invest in, especially as mature technology comes with the risk of earlier obsolescence. Typically, building a semiconductor fabrication plant takes two years or longer. Mindful of their industry's traditional boom-and-bust cycles and concerned that what appears to be a long-term increase in demand could be suppliers of automotive components and systems placing multiple orders to build inventory, foundries are hesitant to invest in capacity expansion to manufacture chips for automotive applications without commitment from their customers.

New Relationships and Buying Strategies

Traditionally, auto manufacturers have had little visibility into the operational risks in their supply chains beyond the "first tier" suppliers of assembled electronics where semiconductor manufacturers usually reside. Recent shortages have led many automakers to form partnerships directly with chip suppliers. In October 2021, General Motors reached an agreement with semiconductor device supplier Wolfspeed to secure a supply of chips needed for EVs. In November 2021, Ford Motor Company and GlobalFoundries announced a "strategic collaboration" to advance domestic manufacturing of chips for Ford.

Additionally, many automotive companies are changing their buying strategies. Formerly, they typically ordered electronic components using just-in-time buying strategies to avoid holding stock. New long-term contracts are being requested from chip suppliers to allow them to increase investment in research and expansion with greater confidence. For example, semiconductor supplier Microchip began prioritizing shipments for customers who committed to 12 months of non-cancellable orders versus the historical 90-day cancel period for such orders.

Legislation

At the start of 2021, the Creating Helpful Incentives for the Production of Semiconductors (CHIPS) for America Act was included in the National Defense Authorization Act (P.L. 116-283). The CHIPS Act authorizes incentives for the construction, expansion, and modernization of domestic semiconductor facilities and equipment. In June 2021, the Senate passed the U.S. Innovation and Competition Act (S. 1260), which would appropriate $39 billion over the period FY2022-FY2026 for a fund to expand semiconductor capacity authorized in the CHIPS Act. Of the $19 billion that would be available in FY2022, the bill would allocate $2 billion specifically for the production of "mature technology nodes." The bill would direct the Secretary of Commerce to classify which process nodes qualify as "mature."

Considerations for Congress

As Congress considers additional legislation to promote domestic semiconductor production, considerations related to automotive supply chains include the following:

- Is future automotive demand for semiconductors sufficiently clear for the federal government to be able to allocate investment appropriately to particular technology nodes?
- How will the definition of "mature technology node," as determined by the Secretary of Commerce pursuant to the CHIPS Act, impact industries reliant on mature semiconductors, including the automotive sector?
- After the definition of "mature technology nodes" is established, will federal support for such technologies be limited to the allotted $2 billion, or may a portion of the additional $37 billion authorized in the CHIPS Act be used for this purpose?
- Is there a risk that automotive technology will migrate to advanced semiconductor nodes, which could make new facilities to produce legacy chips obsolete?

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