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How Semiconductors Brought the Automotive Industry to its Knees

A SILICONEXPERT WHITEPAPER
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Introduction

It is no secret that the automotive industry is struggling with vehicle deliveries. A prime example is Ford's use of the Kentucky Speedway as a storage facility for incomplete vehicles, awaiting critical components, required to go to market[1]. While semiconductors have been the main reason to blame for these struggles, let's look back to further understand where these issues stemmed from and how a collection of Global Supply Chain disruptions have exacerbated the situation!

Vehicle Electrification

Those who do not eat, sleep, and breathe automotive design or vehicle electrification may not realize how "a few chips" could bring an industry to a crawl. The simple fact is that vehicles do not need "a few chips," they need an enormous number of semiconductors to function at the level of the modern automobile we have grown to expect. Some straight-forward applications that utilize semiconductors include infotainment or your stereo system, key fobs, back-up cameras and sensors, but there are many more that would not come to mind without a deeper understanding of how your car works. Some of these applications that might be overlooked include windows, windshield wipers, mirrors, sunroofs, and seats, all which have motors or actuators that are driven by semiconductors.

For hybrid-electric and electric vehicles (HEV/EVs) there are additional systems that require semiconductor components as shown in Figure 1. Electric vehicles lack a traditional gas internal combustion engine and require systems for charging the vehicle (on-board chargers), converting voltages for various loads (DC/DC converters), driving the AC motor (traction inverter), and even for cooling and heating (E-compressors and PTC heaters). These are just a handful of applications with major semiconductor requirements, in reality there are upwards of **3,000 semiconductors per car** [2].

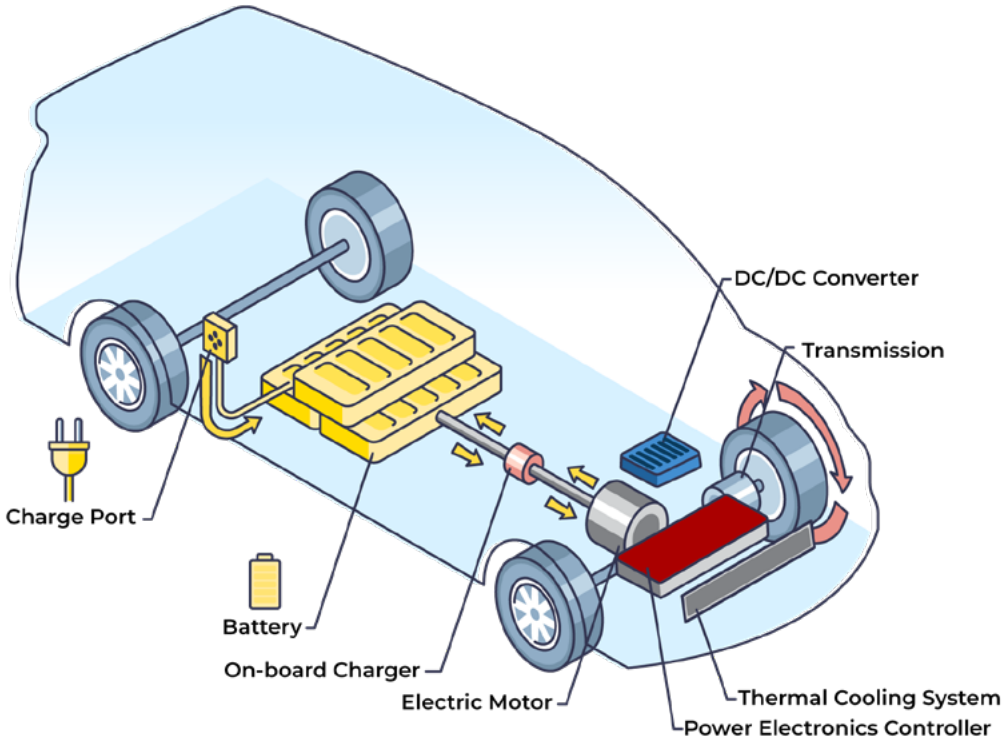

Figure 1: A typical electric vehicle with subsystems that are required for operation[3]

Sourcing Challenges Compared to Other Industries

In an ideal world, automotive manufacturers could increase their semiconductor orders to meet demands within the automotive market. Unfortunately, automotive is not the only industry with a high demand for semiconductors. Many of these industries have just as high or higher semiconductor demand, which places further constraints on inventory availability. As shown in Figure 2, industrial, telecom, and computing and data storage verticals all currently have a larger semiconductor demand than the automotive industry in terms of semiconductor market value, with no plans for a growth downturn. While automotive has the largest anticipated CAGR (compounded annual growth rate), the industry's semiconductor value is still projected to be lower than the 2021 wireless communication valuation.

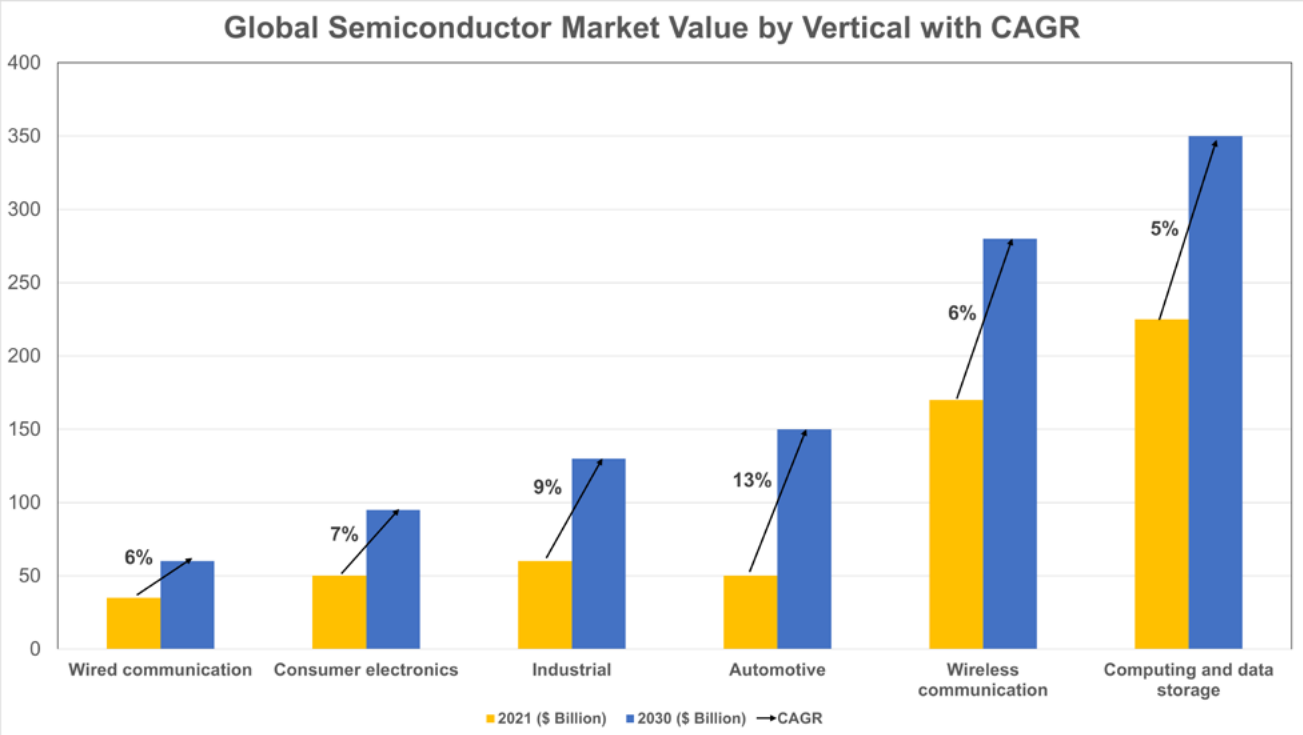

Figure 2: 2021 vs. 2030 (est.) semiconductor value in each industry[4]

Furthermore, while the end applications are different between these industries, the sub-systems can share many of the same components. A MOSFET driver or digital microcontroller that is needed in an automotive DC/DC converter, could also be needed in a server PSU, brick power module, or telecom rectifier. The customers in these industries could be competing for the same ICs.

Additionally, the automotive industry requires that the components they use are AEC-Q100 qualified. AEC-Q100 qualification means a component has passed specified stress tests and meets a level of reliability. AEC-Q100 parts typically go through a different test flow, compared to commercial parts creating a longer cycle time. So, if a component has both a commercial and automotive version, they could share the same die and fabrication process and be used in either commercial or automotive applications, however the automotive, AEC-Q100 marked parts will need to be more rigorously qualified and tested.

As an example, Figure 3 highlights the qualification differences between the UCC27201ADDAR (commercial version) on the bottom versus the UCC27201AQDDARQ1 (automotive version) on the right. *Please note this is just one example.*

Qualification summary

Type	AEC Q100 test #	Test spec	Min lot qty	SS / lot	Test name	Condition	Result
Test group A - accelerated environment stress test							
THB/HAST	A2	JESD22-A101/JESD22-A110	3	77	Temperature humidity-bias or biased HAST	THB 85C/85%RH for 1000 hours or HAST 110C/85%RH for 264 hours or equivalent	Pass
AC/UHAST	A3	JESD22-A102/JESD22-A118	3	77	Autoclave or unbiased HAST	AC 121C for 96 hours or UHAST 110C/85%RH for 264 hours or equivalent	Pass
TC	A4	JESD22-A104	3	77	Temperature cycle	Per grade requirements. See data sheet.	Pass
TC-WBP	A4	MIL-STD883 method 2011	1	30	Post temp cycle bond pull	Per requirements	Pass
HTSL	A6	JESD22-A103	1	45	High temp storage bake	Per grade requirements. See data sheet.	Pass
Test group B - accelerated lifetime simulation test							
HTOL	B1	JESD22-A108	3	77	High temperature operating life	Per grade requirements. See data sheet.	Pass
ELFR	B2	AEC Q100-008	3	800	Early life failure rate	Per grade requirements. See data sheet.	Pass
Test group C - package assembly integrity tests							
WBS	C1	AEC Q100-001	1	30	Wire bond shear	Cpk > 1.67	Pass
WBP	C2	MIL-STD883 method 2011	1	30	Wire bond pull	Cpk > 1.67	Pass
SD	C3	JEDEC J-STD-002D	1	15	Solderability	>95% lead coverage	Pass
PD	C4	JESD22-B100 and B108	3	10	Physical dimensions	Cpk > 1.67	Pass
Test group D - die fabrication reliability tests							
EM	D1	–	–	–	Electromigration	Per technology requirements	Pass
TDDB	D2	–	–	–	Time dependent dielectric breakdown	Per technology requirements	Pass
HCI	D3	–	–	–	Hot carrier injection	Per technology requirements	Pass
NBTI	D4	–	–	–	Negative bias temperature instability	Per technology requirements	Pass
Test group E - electrical verification							
HBM	E2	AEC Q100-002	1	3	Electrostatic discharge - human body model	Per AEC Q100-002	See data sheet
CDM	E3	AEC Q100-011	1	3	Electrostatic discharge - charged device model	Per AEC Q100-011	See data sheet
LU	E4	AEC Q100-004	1	6	Latch-up	Per AEC Q100-004	Pass
ED	E5	AEC Q100-009	3	30	Electrical distributions	Per AEC Q100-009	Pass

Figure 3: UCC27201ADDAR (Commercial) below vs. UCC27201AQDDARQ1 (Automotive) above

Qualification summary

Stress	Reference	Min Lot Qty	Sample Size / Lot	Condition	Duration	Result
TC	JESD22-A104	3	25	Temperature Cycle -65/150C	500 Cycles	PASS
AC/UHAST	JESD22-A102/JESD22-A118	3	25	Autoclave 121C or Unbiased HAST 130C / 85% RH	96 Hours	PASS
HTSL	JESD22-A103	3	25	High Temp Storage Bake 150C	1000 Hours	PASS
THB/HAST	JESD22-A101/JESD22-A110	3	25	THB 85C/85%RH or HAST 130C/110C/85%RH	1000 Hours or 96 Hours	PASS
CDM	JESD22-C101	1	3	ESD - CDM	Classification	See datasheet
HBM	JS-001	1	3	ESD - HBM	Classification	See datasheet
HTOL	JESD22-A108	3	77	Life Test, 125C	1000 Hours	PASS
LU	JESD78	1	3	Latch-up	Per JESD78	PASS
MSL	JEDEC J-STD-020E	–	–	Per JEDEC J-STD-020E	Classification	See datasheet

Design With Flexibility

To decrease the risk of going line-down designers, component engineers, and procurement managers have increased scrutiny on using components that do not have a multi-source alternative or a dual-fabrication process. Sourcing components that have pin-to-pin (“P2P”) alternatives allows automotive manufacturers to qualify multiple components and designs to hedge against a single component disrupting production. Figure 4 highlights some components needed in a DC/DC converter application, including a microcontroller, gate drivers, PMIC, and sensing. Immediately, an engineer can see which components pose sourcing issues. The NCV51561DADWR2G does not have any P2P crosses, so the engineer would be better off sourcing a different isolated gate driver.

	DS	Part	Manufac	Crosses	Description	Lifecycle	RoHS	AEC Qualified	Product Line	Y-to-EOL
1		STB12N60DM2AG	STMicroelect	227	Trans MOSFET N-CH 600V 10A Au Pin(2+Tab) D2PAK T/R	Active	2011/65/EU, 2015/863	Yes	MOSFETs	9.5 years
2		F28386DZWTQR	Texas Instruments	--	MCU 32-bit C28x RISC 1MB Flash Automotive 337-Pin NFBGA T/R	Active	2011/65/EU, 2015/863	Yes	Microcontrollers - MCUs	10.0 years
3		UCC27282QDRCRQ1	Texas Instruments	19	Driver 3.5A 2-OUT High and Low Automotive 10-Pin VSON EP T/R	Active	2011/65/EU, 2015/863	Yes	Gate and Power Drivers	10.0 years
4		TLF30682QVS01XUMA1	Infineon Technologies AG	--	Power Management IC 5V to 35V	Active	2011/65/EU, 2015/863	Yes	PMIC Solutions	8.5 years
5		MCP9808-E/MS	Microchip Technology	418	Temp Sensor Digital Serial (2-Wi Automotive 8-Pin MSOP Tube	Active	2011/65/EU, 2015/863	Yes	Temperature and Humidity Sensors	4.3 years
6		TSC211IYCT	STMicroelect	486	SP Amp Current Sense Amp Sing Automotive 6-Pin SC-70 T/R	Active	2011/65/EU, 2015/863	Yes	Special Purpose Amplifiers	8.0 years
7		NCV51561DADWR2G	onsemi	--	Isolated Dual Channel Gate Drive	Active	2011/65/EU, 2015/863	Yes	Gate and Power Drivers	8.0 years

Figure 4: Partial BOM for an Automotive DC/DC Converter

Like the component qualification process, automotive Tier-1s and original equipment manufacturers (OEMs) also need to test and qualify their PCBs to ensure the boards are safe for production. The qualification process can be rigorous and lengthy, which is why it is best to qualify multiple sources at the beginning of a design to avoid potential delays later in the process.

Since alternatives are not available for all components, especially those that are high performance or innovative, using parts with dual-fab setups is the next best option. Components with multiple fabrication sites can output more wafers and more silicon to meet the growing demand from the market. Unfortunately, this information is typically not publicly available to customers. In SiliconExpert’s Supply Chain Risk Management (SCRM) tool, we can display fab statuses as shown in Figure 5. In this example UCC27282QDRCRQ1 is shown to have only 1 fab site, whereas the UCC21540QDWKRQ1 lists multiple sites, with different geographical locations helping to increase throughput, while mitigating risk.

Part Number	Manufacturer	PL Name	Fab Site Status	Fab Site Company
UCC27282QDRCRQ1	Texas Instruments	Gate and Power Drivers	Single Site	Texas Instruments
UCC21540QDWKRQ1	Texas Instruments	Gate and Power Drivers	Multiple Sites, Different Geo	Texas Instruments

Figure 5: GeoRisk Fab Site Data from SiliconExpert's SCRM Solution

An added layer of complexity in the automotive market is the relationship between the Tier-1 suppliers and the OEMs . Figure 6 is an example of the semiconductor, Tier-1, OEM relationship. In this liner setup the OEMs may not have direct access to their component suppliers if they are relying completely on their Tier-1s. This lack of visibility can mean the OEMs are in the dark on what components are causing shortages, why they are causing shortages, and what solution the supplier can provide as an alternative. Without visibility or control of their supply chain OEMs cannot be proactive and are forced to be reactive.

Figure 6: The Relationships Between Semiconductor Suppliers, Tier-1s, and OEMs[5]

Why SiliconExpert

SiliconExpert's p5 platform is the foremost data-driven solution for manufacturers.

SiliconExpert's platform is not only a database of 1+ Billion parts, but also a platform that enables effective supply chain and product lifecycle management. For engineers, the platform can find multi-sourced automotive ICs that have inventory, that meet their specs, and can evaluated and qualified for their design.

A supply chain manager can see where their components are sourced from, what environmental regulations they are compliant with, what global events could disrupt their production, or even which components are showing up on the secondary market, signifying potential shortages.

These benefits have enabled SiliconExpert customers to reduce time-to-market, mitigate risk, and stay ahead of their competition.

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References

1. https://www.fox19.com/2022/09/28/unsellable-ford-trucks-fill-kentucky-motor-speedway-parking-lot/
2. https://www.autocar.co.uk/car-news/industry-news-tech%2C-development-and-manufacturing/stock-take-experts-drill-motor-industrys
3. https://evreporter.com/ev-powertrain-components/
4. https://www.mckinsey.com/featured-insights/coronavirus-leading-through-the-crisis/charting-the-path-to-the-next-normal/whats-driving-the-semiconductor-market
5. https://www.eetimes.com/auto-oems-tier-ones-think-soc-designs/