Automotive chip shortage: don’t we ever learn?

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Agenda

• Introduction to automotive semiconductor
• Fundamental issues with automotive chips supply management
• What went wrong in 2020
• Why did Toyota manage the chip shortage better than others in Q1 2021?
• Outlook for recovery
• What can be done to avoid another shortage with the next economic cycle?
2.4 million vehicles not produced because of chip shortage to-date in 2021

Q2 2021 will be worse than Q1

Light Vehicle production volume loss to-date due to chip shortage as of April 23rd 2021 by region of production

Note: This is not forecast, the figures represent the scale of disruption identified as of April 23rd 2021
Source: IHS Markit – Light Vehicle Production: Update assessment of semiconductor supply issues - 23 April 2021

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Introduction to semiconductor: from silicon to cars

Silicon Ingots and Raw silicon wafers

Processed wafers

Packaged and tested chips

Electronics Control Units* (ECU)

Manufacturing cycle time: Months

Days

Hours

Car
- 1000 - 1400 chips / car
- $427 chip value / car in 2020

Tier 1:
Bosch, Continental, Aptiv, Valeo, Harman, BorgWarner, Denso…

OEMs:
VW, Toyota, Toyota, GM, RNM…

Foundries (front end):
TSMC, Samsung, GlobalFoundries, UMC, Tower, DB Hitek, SMIC

Packaging & Test (back-end)
Amkor, ASE, UTAC

Material suppliers:
Shin-Etsu, Siltronics, Soitec

Semiconductor Suppliers
NXP, Infineon, Renesas, Texas Instruments, STMicroelectronics, ON Semi, Micron, Samsung...

Service providers
The fundamental issue for managing automotive chip supply chain

12 weeks firm orders

- Tier 1 place 12 weeks firm orders to chip suppliers
- However, it takes typically 14, 16 and up to 24 weeks depending on the chip type to manufacture the chip
- Placing orders shorter than lead-time is risky

95% utilization rate*

- Ideal utilization rate of semiconductor fab
  - Below 90% profitability becomes an issue
  - Above 95% risk of bottleneck, must invest and expand capacity (or outsource)
  - Chip makers must be flexible and react to increase/decrease of demand

* Simplified number. Optimum utilization rate varies by type of semiconductor
Several layers of inventory enable to manage supply/demand in normal conditions

### Automotive semiconductor supply timelines: order – lead time - inventory

- **Start production to fulfil order + replenish inventory**
- **Supply agreement between supplier and customer**
- **Firm order 12 weeks***
- **6-12 months rolling forecast for planning purpose (not committed)**

### Semiconductor Lead times 8-16 weeks lead time for most semi

<table>
<thead>
<tr>
<th>Category</th>
<th>Lead Time</th>
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<tbody>
<tr>
<td>Discretes</td>
<td>6-8 weeks*</td>
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<td>e.g. Diodes</td>
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<tr>
<td>Complex ICs</td>
<td>12-16 weeks*</td>
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<td>e.g. MCU, SoCs</td>
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<tr>
<td>Specialty parts</td>
<td>16-24 weeks*</td>
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<td>e.g. MEMS sensors</td>
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*Lead times are from wafer starts to completed devices.
# Current lead times are >26 weeks.

### Different types of Inventory within supply chain – total 8 to 20 weeks typically

- **Buffer at customer**
- **Finished Goods**
- **Work-in-Process (e.g. die bank)**

Source: IHS Markit

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What went wrong? Automotive industry missed:
1) fast recovery of other industries

- Massive surge of chip (capacity) demand across several industries in 2020 while automotive was cutting its chip orders

- Launch of number of 5G mobile phones and 5G infrastructure

- Gaming: launch of Xbox and Sony PS5

- COVID-19 boost to laptops and data centers

- COVID-19 boost to consumer electronics purchase in general
What went wrong? Automotive industry missed:

1) Hyper reliance on one foundry for car chip production

- Building and maintaining semiconductor fabs is expensive
- Trend to fab-light i.e. more outsourcing to “foundries” for contract manufacturing of wafers
- TSMC is #1 semiconductor foundry with ~56% share
- TSMC fabricates vast majority of processors and modems for mobile phones, processors for gaming, even now Intel’s processors
Microcontrollers (MCU): the weak link of the automotive chip supply chain

- 10s of MCUs per car
- Difficult dual sourcing per ECU because of proprietary architecture of Renesas, NXP…
- 60% to 70% of the production at TSMC
Why does Toyota seem to manage the chip shortage better than others?

- Long term firm orders commitment to Renesas against long-term capacity commitment from Renesas
- 3 months chip inventory held by distributors and suppliers
- Keiretsu structure cements this long-term commitments. Allows prioritizing supply assurance in addition to cost reductions
Fire at Renesas Naka fab on March 19 exposes Toyota... and everyone else

Naka’s 300mm fab (N3 Building) will be down for one month. Not back to full production before 2.5 months after the fire

- Naka was cornerstone of Renesas’ strategy to meet global automotive MCU demand from Q3 2021
- Renesas has started process to increase capacity at Naka fab in Q4 2020
- Renesas was ready to increase significantly internal production from Q2 2021
- Toyota may now be exposed for Q2 2021. So is every OEM

- Renesas MCUs are virtually in every car we analyse
- Renesas MCUs very present in lighting ECUs, power steering ECUs, instrument clusters, Airbag ECU, door ECUs, seat ECUs, 4WD ECUs...
- Renesas #1 microcontroller by far for Volkswagen, GM, Ford, Stellantis, Renault-Nissan-Mitsubishi, Daimler, Honda, Tata, Geely...

**MCU process technologies at Renesas**

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<th>28 nm</th>
<th>40 nm</th>
<th>130 nm</th>
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<tbody>
<tr>
<td>100% outsourced to TSMC from 2016</td>
<td>90% outsourced to TSMC in 2012. 10% at Naka fab</td>
<td>100% in house</td>
<td></td>
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<tr>
<td>Most advanced technology</td>
<td>Majority of volume includes MCUs and Gen 1 SoCs and Power Management IC</td>
<td>Old technology. Minority of volumes</td>
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- 23 machines must be replaced
  - Plant down for a month
  - Restarted at 10% capacity on April 17th
  - Return to 50% capacity by end April
  - Return to 100% capacity by end of May
It is going to get worse before it gets better

Chip demand remain strong for laptops etc
Mobile phones place large chip orders for 5G phones
Nintendo and Microsoft place large chip orders for new video consoles
TSMC’s order book is getting full outside automotive

Car OEM cut their orders
Chip vendors cut orders to TSMC
Tier 1 cut their chip orders

Car chip demand increases significantly
Chip vendors struggle to keep-up with demand

TSMC fully booked
Lead time for MCU increase to 6 months and more
Orders to TSMC placed in Nov 2020 result in wafer delivery in Sept 2021!
MCU vendors increase in-house capacity where possible or accelerate building of new fabs

Constraints on other semiconductor types even though MCU remain main issue
Earthquake hits Renesas fab in Japan
Cold wave hits NXP, Cypress and Samsung fabs in Texas
Draught in Taiwan threaten TSMC
Fire in Renesas fab

1.4 M cars not produced in Q1

12

Q1 2020  Q2 2020  Q3 2020  Q4 2020  Q1 2021  Q2 2021  Q3 2021  Q4 2021  Q1/Q2 2022

Car OEM increase demand to Tier 1
First car plant shutdown in China
Car plant shut down in all regions

Tier 1 increase orders to chip vendors
(Some Tier 1 think orders from OEMs are inflated and don’t place full orders)

MCU suppliers meet on-going demand but no extra volume to recover for missed vehicle of early 2021
MCU suppliers meet on-going demand plus some extra volume to recover for missed vehicle of early 2021 (not all)

Peak of crisis Still shortage, but slightly better than Q2

MCU suppliers meet on-going demand plus some extra volume to recover for missed vehicle of early 2021 (not all)

Toilet paper syndrome
OEM and Tier 1 inflate orders to get parts. It prolongs artificially chip shortage
Automotive chip capacity crunch on old chip technologies beyond 2022

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Deployment in


Semiconductor manufacturing process nodes (the smallest, the most advanced, the most expensive)

180 nm 130 nm 110 nm 90 nm 65 nm 40 nm 28 nm 14 nm 10 nm 7 nm 5 nm 3 nm

Microcontrollers for Powertrain, Chassis & Safety, Infotainment, Body & Convenience, ADAS/Autonomy
15 to 80 per cars

Memory for Infotainment, ADAS/Autonomy
2 to 6 per cars

AI chips for Autonomy and advanced cockpit
0 to 2 per car

Image sensors
0 to 10 per cars

Analog for power management, RF, radar, motor drivers etc
10s to >> 100 per car

Power discrete for xEV, chassis, power train
10s per car

Display drivers for Infotainment
2 to 5 per car

Booming demand for all other functions of phones for RF front end (increases with number of bands), cameras (now 4 per phone), high-end audio, contactless payment… and IoT

Application processors for mobile phones

90% of investment of TSMC
Investment of Intel
Subsidies from governments

Capacity crunch in next years for automotive on old technologies
Need to completely rethink the automotive chip supply chain

Prioritize supply assurance and share associated cost across supply chain

- Revisit foundry policy. Reduce reliance of industry on 1 foundry. Maintain some level of in-house chip prod
- MCU dual sourcing with 2 designs for each ECU?
- More tripartite transparency from OEM to Tier 1 to chip
- Increasing OEM direct buy model?
- Capacity and demand commitments
  - Secure supply by extending commitments
  - Firm commitments from OEMs to chip vendors for 12 months rather than 12 weeks
- Prioritize supply assurance to keep 2-4 months of inventory for critical chips

Can OEMs push Tier 1s to implement 2 designs for each ECU with 2 BOMS and 2 different MCU suppliers? Who pays for additional design and supply chain management?

Currently “manual” alignment from OEMs to Tier 1s to chip vendor. OK in crisis mode, not in long run. EDI (Electronic Data Information) and Part Number systems does not allow Tier 2 to see OEM demand. Cost to change system, who pays?

Who is responsible for the product within an extended firm window? Is the OEM responsible for a year's worth of product in order to give the supply longer visibility? Are long-term commitments possible without Keiretsu?

Where is this inventory stored? Is the inventory paid for by OEM? By Tier 1? By chip supplier? Is a 2-4 months inventory possible without Keiretsu?
Conclusion: history repeats itself. Will we ever learn?

• Automotive industry learned from 2010 allocation crisis to some extent, but it has missed:
  • Perfect storm of chip demand outside of automotive (5G phones, gaming, …) highly reliant on TSMC
  • Excessive dependence of automotive microcontrollers production on TSMC

• Uncertainty increases about recovery outlook
  • Natural disasters and fab fires are the straw which break the camel’s back. Push out recovery by a quarter
  • Car chip demand bubble builds up in H2 2021 as OEMs and Tier 1s race to get parts. Muddies the water about magnitude of chip shortage in second half of 2021 and early 2022

• Need to completely rethink the automotive chip supply chain to prioritize supply assurance
  • Who pays?
  • Can Toyota’s best practice be applied outside financial ties of a Keiretsu?

• Structural capacity issues for automotive chip on old semiconductor nodes. Investment should not be aimed only at leading edge semiconductor process nodes but also on older process nodes