Complexity, quality and robustness - the challenges of tomorrow's automotive electronics

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Abstract— **Developing a state-of-the-art premium car means implementing one of the most complex electronic systems mankind is using in daily life. About 100 ECU's with more than 7.000 semiconductor components realize safety, comfort and powertrain functions. These numbers will increase drastically when going the step from the conventional vehicle to the e-car, where a lot more functions have to be realized just by electronics. Finally the functionality has to be guaranteed in one of the harshest environments where electronics are used with a target of 0 ppm concerning the subcomponents for the 15 years lifetime of the car.**

We give an overview of the challenges on the way to reach this target. The task of getting to a high level of robustness and quality within short maturing periods of new technologies and semiconductor products are discussed.

Using state-of-the-art semiconductor process technologies for devices in a car is necessary to fulfill today's performance requirements and even more future requirements with respect to the e-car. But it leads to a mission which seems to be a paradoxon: combining more robustness of the complete system and quality of its subcomponents with less mature technologies. A way out of this dilemma can only be found by reviewing carefully today's qualification and validation processes and understand their strengths, weaknesses and capabilities. This must be the starting point for an evolution to a qualification strategy which is suitable for this fundamentally changed situation.
Therefore the limits of today's qualification methods will be discussed as well as some suggestions for future strategies will be made to bring complexity, quality and robustness in an early phase of product lifetime together. The roles of the parties in the supply chain shall be highlighted in these strategies as well.

Keywords-automotive, semiconductor, robustness, qualification

I. Introduction

Today's car manufacturers developed their core competences from a mechanical engineering dominated domain to a broad interaction of several engineering disciplines. The customer's experience is realized by a perfect co-work of mechanical and electrical engineers, chemists, physicist and designers.

Semiconductor technology became a major gearwheel in this machinery. Around 90 % of the innovations brought into the car during the last decade were directly or indirectly linked to semiconductors. This might in some cases be very obvious, like for example bringing a night vision system with pedestrian recognition on the road. But even some innovation which on the first look seems to be very close to the original core competence are not possible without the appropriate use of semiconductors. Examples can be found in the field of powertrain and engine application like active chassis. This trend will obviously increase during the electrification.

Now the big task is combining this functionality realized by semiconductors with high requirements concerning quality and robustness which must be fulfilled for the complete system "car". We will outline the major boundary conditions for this mission and highlight some approaches to overcome significant hurdles.

II. Complextiy

From complexity point of view, a modern premium class vehicle is one of the most complicated systems mankind has ever developed. The reason for this development is the increase in functionality in a car which took place over the last years. Mainly infotainment and driver assistance applications pushed this trend but all other fields of application contributed as well.

The total number of ECUs (electronic control unit, e. g. a electronic subsystem of the car) increased approximately by a factor of 1.45 over the last 5 years. This reflects mainly the trend of bringing new functionality into the car.

The total amount of application software in MByte per car increased with a factor of 4.5 within the same timeframe. This is a strong hint towards the rising complexity of the subsystems themselves. This is of course also due to new functions but also related to improved performance of existing subsystems like in the infotainment sector. 3D graphics, speech recognition and Google Earth integration have significantly increased demands in hardware performance compared to the last generation of navigation systems.

This trend is also visible when looking into the semiconductor technologies available on the market compared to those used in cars. Figure 1 shows the trend in CMOS technology, commonly known as Moore's Law [1], compared

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to the trend of technology used for automotive applications. Until 2002 these trends went quite in parallel with the automotive curve following the consumer trend with a delay of about 5 years. This comfort-zone brought mature technologies in the car. Accelerated by rapidly increased performance requirements the trend for automotive changed around 2002 and the comfort-zone has begun continuously shrinking.

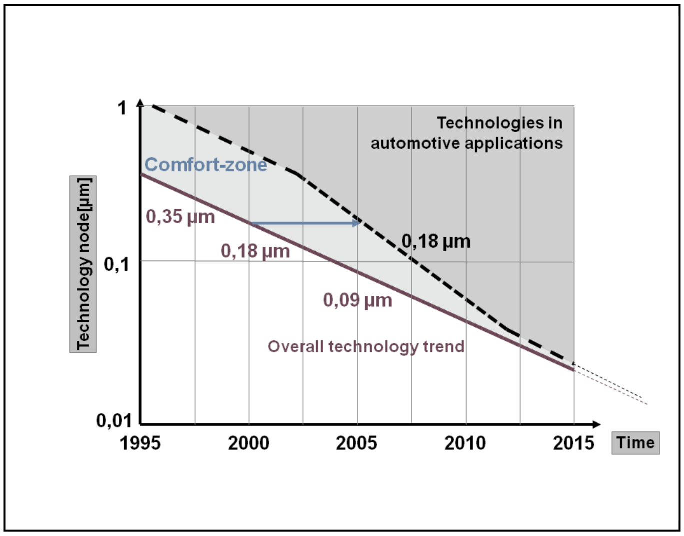

Figure 1. Overall CMOS technology trend compared to CMOS technology trend used for automoitve applications

III. QUALITY AND RELIABILTY

Quality and reliability are two aspects of the target “0 ppm” which are often used as synonyms. From a technological point of view this is not quite correct. However from an OEM point of view from the system down to the semiconductor we can reduce these aspects to a quality issue only by using different abstraction levels. First the level of the devices, which is within the responsibility of the semiconductor manufacturer, and second the level of the ECU, which is in responsibility of Tier1.

When talking about the quality of such complex systems one should take two aspects into account:

- Intrinsic quality of the subcomponents. This includes quality manufacturing, design and test of subcomponents. The target is to ensure that subcomponents work as they are intended to work.
- System quality. This includes the interaction of all subcomponents and their application. The target is to ensure that all subcomponents are used as they are intended to be used.

Both levels of abstraction have to achieve high quality targets to bring the quality level of the system “car” on the intended performance level.

Now the main task is to communicate requirements and specifications along the supply chain. The link between the capabilities of the device and the requirements of the system is obviously the most curcial point in this model as it correlates strongly with the borderline of responsibilities between semiconductor manufacturer and Tier1. The same aspect is valid between Tier1 and OEM when integrating the ECU in the final system “car”.

A way out of this dilemma is a early interaction between all three parties on an equal base (OEM, Tier1 and semiconductor manufacturer) with more transparency in all directions. This includes for example a formalized but detailed description of application requirements by the OEM [2] and the breakdown of this requirements und device level by the Tier1 to close the feedback loop regarding device capabilities by the semiconductor manufacturer.

This triangular shaped interaction is a must for risk controlled innovations in future automotive electronics.

IV. QUALIFICATION

Automotive qualification strategies in the past benefitted significantly from the fact of the existing comfort-zone described in Fig. 1. A technology became mature in non-automotive applications and was then moved to a automotive level with a one-size-fits-all AEC-Q100 qualification as final proof of robustness. A standard for making a technology automotive does not exist.

As this comfort zone has vanished our qualification approach will have to change essentially. The efforts of automotive semiconductors manufacturers today are already tremendous when bringing the manufacturing technology to automotive grade.

A useful approach to canalize these efforts could be a three parts qualification scenario:

- A technology qualification integrating stress test driven lifetime testing of basic structures of the technology.
- A stress oriented device qualification with respect to the results of the technology qualification and application requirements.
- A strongly application related functional qualification.

A definition of such an approach as a joint work of the whole supply chain must be the target for the next few years to keep the trends in functionality and quality for automotive electronics.

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