Complexity Challenges for Global E/E Architectures

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Introduction

• In order to significantly reduce the global work share complexity, GM has decided to limit the amount of electrical architectures applied in GM vehicles

• In 2012 around **70% of all GM vehicles** will be based on the same global E/E architecture (Global A)

• Global A has been designed to reduce development time leveraging the global company footprint
  – Global A enables efficient information exchange between the GM tech centers around the globe ("speaking the same technical language")
  – Global A development is based on a globally synchronized architecture development and release timings (release cadence)

• Global A is also a critical element in achieving the continuously increasing quality targets in the context of vehicle electronics
  – Leveraging of globally distributed man power in all development centers around the world
  – Significantly increased number of development vehicles and build options/combination to identify and remedy development issues
Global Architecture Development (1)

- **Global A is a superset architecture**, i.e. defines the maximum possible set of features that can be deployed on any vehicle program.
- **The vehicle electrical architecture level should be selected based on the requested vehicle content**, in particular the requested E/E features:
  - New features can be introduced with any major Global A release.
  - All subsystems must be compatible with the respective architecture release.
- Consequently, Global A does not only specify the technical aspects but also defines the organizational framework for the globally distributed E/E development by GM (development methodology).
- GM has formed **Global Subsystem Leadership Teams (GSSLTs)** in each of the center of expertise:
  - These teams include representatives from every other region.
  - They ensure that the global requirements meet all regional regulations.
  - Reducing non-value added variation by harmonizing regional requirements.
Global Architecture Development (2)

- A Global A Architecture release consists of various work products and specifications tailored to each other
  - The various work products of Global A need to be synchronized (Global A release cadence)
  - A mixture between different Global A releases may lead to significant compatibility mismatches and consequently functional failures
  - For example, all ECUs in a vehicle need to be compatible with the same data dictionary
- Global architecture release cadence defines the overall Global A project timing incl. requirements freeze, release dates for work products (e.g. data dictionary), in-house software availability
  - Ensure consistent and synchronized architecture development
  - Establish link between E/E Architecture development and vehicle program execution
  - Strong linkage between Global A and all target vehicle projects around the globe
Development Methodology Overview

- Feature Technical Specifications are HW independent and defined the desired features

- Subsystem Technical Specification describes logic of subsystem independent of hardware and platform

- Component Technical Specifications (CTS) is used to specific the components that implement the requirements stated in the respective SSTs
Example – Global E/E Quality

Architecture Releases Cadence for one Software Plateau

<table>
<thead>
<tr>
<th>Release</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR x.0</td>
<td>~12 weeks</td>
</tr>
<tr>
<td>AR x.1</td>
<td>~10 weeks</td>
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<tr>
<td>AR x.2</td>
<td></td>
</tr>
<tr>
<td>AR x.3</td>
<td></td>
</tr>
<tr>
<td>AR x.4</td>
<td></td>
</tr>
</tbody>
</table>

Minor release (x.4.z) are possible until PPV with each MRD

Leading Vehicle Project

IVER 

-100

PPV 

-50

SORP 

0

Vehicle Projects of the Same Model Year

IVER

-100

PPV

-50

SORP

0

• Development issues detected in the lead vehicles will automatically be fixed for all following vehicle projects of the same model year (and vice versa)
• Leveraging of global development footprint to increase quality of all vehicles of General Motors

IER | Integration Vehicle Engineering Release
PPV | Product/Process Validation Vehicle
SORP | Start Of Regular Production

GM General Motors Company

THE WORLD'S BEST VEHICLES
Global Architecture Lifetime Analysis

- E/E vehicle systems will always have an inherent complexity, i.e. there exists a minimal achievable level of complexity.
- It is of critical importance for success of the company to keep the gap between the theoretical complexity limit and the real level of complexity of the E/E vehicle system to its minimum.

The graph illustrates the complexity over time, with peaks due to the introduction of new architectures and decreases due to improved optimized solutions in the next generation architecture.

- Complexity control
- Complexity design

Early introduction of next E/E Architecture can help minimize the gap, with changes in functionality driven by market/customer requirements.
Global A Program Execution

• Comparison of three different programs that have implemented Global A architecture
  – Global A version 2.x in MY10: Opel Astra
  – Global A version 4.x in MY12: Opel Zafira
  – Global A version 5.x in MY13: Opel Adam
Program Comparison Overview

Opel Astra (MY10)

- Description:
  - Compact segment
  - 5 seats
- Architecture Facts:
  - #Networks: 4
  - #Gateways: 3
  - #Grid links: 2
  - #ECUs: 23

Opel Zafira (MY12)

- Description:
  - Compact segment
  - 7 seats
- Architecture Facts:
  - #Networks: 4
  - #Gateways: 3
  - #Grid links: 3
  - #ECUs: 28

Opel Adam (13)

- Description:
  - Mini segment
  - 4 seats
- Architecture Facts:
  - #Networks: 3
  - #Gateways: 2
  - #Grid links: 3
  - #ECUs: 13
Example – Zafira Tourer (MY12)

**Vehicle complexity**
- 402 regular production options (RPOs) with three trim levels
- Application of Global A E/E version 4.x architecture (approx. 30 control units) in MY12
- More than 550 different calibration file releases

**Calibration file complexity examples**
- AFL (~400 calibration parameters)
- EBCM (~1200 calibration parameters)
- BCM (~5800 calibration parameters)
- IPC (~1700 calibration parameters)
- UPA/APA (~150 calibration parameters)
- HVAC (~5000 calibration parameters)
Global A Complexity Analysis

Global A - Network Complexity

- Comparison between Astra MY10 (100%), Zafira MY12 (117%) and Adam MY13 (95%) shows realistic complexity figures that correlate with the engineering efforts.
- The mini segment Opel Adam has a considerable complexity due to the reuse of Global A components that are similar to compact and midsize projects.

Global A - Architecture Complexity

Complexity value is proportional to the required engineering resources for program execution.

General Motors Company
Global A Complexity Increase

- Typical deployment strategy is based on MY
  - MY09: Global A 1.x
  - ...
  - MY13: Global A 5.x
  - MY14: Global A 6.x
  - ...
- Comparison of all Global A releases shows significant increase in the number of overall signals (distributed nature of today’s automotive systems)
  - Feature increase from 2.x to 3.x primarily driven by electrification (Chevy Volt)
  - Feature increase from 4.x to 5.x primarily driven by active safety systems
- Private communication systems have not been included in analysis, e.g., infotainment communication system
Architecture Design Challenges

• Beside the traditional (and predominant) engineering challenges like cost and weight, the **design and control of architecture complexity** is key for success

• For each E/E feature transparency on piece cost and engineering cost is required

• Development of **suitable complexity metrics** for architecture development

• In case of global architecture development the **optimum at enterprise level** is relevant

• Strong differentiation between feature complexity and physical architecture complexity (e.g., topology variants) necessary to determine implementation cost for a given vehicle project