DENSO's Model-Based Design Capability
to Contribute OEMs’ Success

Beyond All Expectations!

DENSO CORPORATION
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Overview

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2. MBD Process Development in DENSO
3. KSF (Key Success Factors) for Introducing MBD
   3-1. “Advanced”
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   3-3. “Reinforce”
4. Practical Example
   Increase Productivity by Using ACG (Auto-Code Generator)
5. How Suppliers should be in MBD
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MBD Process Development in DENSO

1996: Start MBD Project in R&D.
1998: Start Project Meeting to Share MBD Knowledge in DENSO.
2000: Build a Task Force Team with Key Engineers from Production Department.
2003: Key Engineers Start MBD Projects in Each Production Departments
KSF (Key success factors) for Introducing MBD

1. “Advanced”
   - Global Standard Conformance
   - Research/Evaluate/Introduce state-of-art Technology and Tools
2. “Initiative”
   - In-house Tools Development/Deployment
   - Support for OEMs’ and Internal Users
3. “Reinforce”
   - Develop Managers’/Engineers’ MBD Skills
   - Build MBD Environment Infrastructure

DENSO Joined ASAM in 2000

DENSO Joined ASAM in February 2000 as 63rd member, and 1st member from Japanese Companies. Our Calibration/Measurement Tool (“Meister”) Supports ASAM-MCD-2MC and –3MC.
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**In-house RP* Tools and Calibration/Measuring Tools**

- Matlab/Simulink
- RP software (RDS-Fit)
- Calibration/measuring software (Meister)

PC card 32-bit ECU interface

*RP: Rapid Prototyping
RDS-Fit Ver.4.2 (1/2)

- Measurement data display (timeline)
- Calibration constant display & input
- 2D calibration map display & input
- Project management

RDS-Fit Ver.4.2 (2/2)

- Measurement data display (trend graph)
- Digital data
- Tachometer
- LED display
- Thermometer display
- Bar graph display
- **KSF (Key success factors) for Introducing MBD**

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- Develop Managers’/Engineers’ MBD Skills

- Point
  Provide Appropriate Training Materials for Managers/Engineers

- Skills Required for Managers/Engineers
  1. Managers
     - Basic Knowledge about Modeling
     - Skills for Understanding and Editing Existing Models
  2. Engineers
     - Basic Knowledge about Modeling
     - Skills for Developing Models Based on Requirement Specifications

- Training Material for Managers (eLearning)

- Training Program Top Page
- Hands-on Simulation for Basic Operations (Flash)
- Electronic Text (PDF)
- Easy Way to Learn about Operation
- Training Material for Engineers (Mathcad)

**Text (Paper/PDF)**

**Executable Worksheet**

- Hands-on Learning by Real Simulink Models
- Easy graphing and documenting
- Good for Parameter Study in Early Design Phase
- Design Standard can be also Defined in Mathcad Worksheet

**Launch Simulink**

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**MBD Environment Infrastructure : ecVERSIM**

Building Basic MBD Environment by This Kind of Utilities are also very Important

- Modify the model, then I should check it out
- Let's see the history of modification…
- I'll check out this version…
- Oops! User1 locked this block….
- Practical Example

**Quality Improvement by Introducing ACG for Production**

(ACG: Auto Code Generator)

- Simulink-based Specification and ACG* application

  - MBD application in powertrain ECU for Toyota Motor Corporation
    - 2000: Introduce Simulink Model (executable specification) as Production I/F
    - 2001: CAMRY/AIR. Use Simulink Specification, but Hand-Coded ECU implementation
    - Currently, Simulink and ACG are applied in several production development projects.

<table>
<thead>
<tr>
<th>Year</th>
<th>Model Based Development Method</th>
<th>Hand Coding</th>
<th>Automatic Code Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Developed</td>
<td>Started</td>
<td>Started</td>
</tr>
<tr>
<td>2001</td>
<td>Developed</td>
<td>Started</td>
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<td>2002</td>
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<td>2003</td>
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<td>2004</td>
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<tr>
<td>2005</td>
<td>Developed</td>
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*ACG: Auto Code Generator*
**Motivation for Introducing ACG in Production Projects**

- Introduction of Automatic Code Generator (ACG) Leads
  "Letting Software Engineers Free from Coding"

- Development Efficiency Improvement in Upper Stream Process
  (e.g. Specification Development by RP)
  → Coding Process might be the Bottleneck Process through whole Development Cycle.

- "Coding-less" Production Development by ACG is the Key Issue to Deal with Large-scale, Quick-delivery Development Projects

- Certain Level of Quality can be Available in a Short Term by Using ACG Regardless of Complexity and Changes of Specifications.\(^1\)

\(^1\): This fully depends on the quality of the model.

**Barriers to Introducing ACG into Production Projects**

- Barriers to Introduce ACG to Production Projects
  - Insufficient Capability of ACG itself
    ACG cannot win the race against production software engineers, who produce highly hand-optimized code!?

- Concerning in Quality Issues
  - Confusion in the Production Development Work due to Process Change

- ACG for Production Use must Solve These Problems
## Requirements for ACG

### Main requirements for ACG for Production Use:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Quality of Generated Code</td>
<td>Models and Codes must be Logically Coherent.</td>
</tr>
<tr>
<td>Reliability of Code Generation Engine</td>
<td>Generated Codes must have Full Reproducibility.</td>
</tr>
<tr>
<td>Code Efficiency &amp; Performance</td>
<td>Generated Codes never Consume CPU Resources.</td>
</tr>
<tr>
<td>Compatibility with legacy Software</td>
<td>Consistent with Production ECU Software Architecture.</td>
</tr>
<tr>
<td>Compatibility with Legacy Processes</td>
<td>Consistent with Production ECU Development Process and Tools</td>
</tr>
<tr>
<td>Continuous Support &amp; Compatibility</td>
<td>Both “Version Fix” and “Update to the Latest Version” must be Supported</td>
</tr>
</tbody>
</table>

### ACG Customization/ Special Technical Support

Will give solutions for these issues.

## ACG Customization for Production Use

**Customization with RTW-EC**

Use Real-Time Workshop Embedded Coder as Base for Customization. Provide Flexible Support for OEMs' Requirements.

- Support for Target Processor-, Compiler-Dependent parts
- DENSO-unique Code Optimization
- Implementation of Knowledge from Production ECU Programming
- File Format has Compatibility with Legacy One
- I/F Codes for Legacy Code Integration are also Generated
- Compliance with Toyota Standard Coding Rules
- Compatibility with Toyota In-house Tools

**Basic architecture of Auto-Code Generator**

![Model Compiler Engine (RTW-EC)](Custom Fcn#1 Custom Fcn#2 Custom Fcn#3 Custom Fcn#4)
- **Special Support Contract with MathWorks/Cybernet System**

  - Official Continuous Support & Compatibility
  - Tool Version Used in Production Projects must be Fixed for a Long Term
  - Use Common Versions both in Toyota and DENSO
  - We Agreed a Special Relationship with MathWorks/Cybernet Systems to Provide Technical Support during Using Fixed Version for Production Projects

  ![Graph](image)

- **How Suppliers should be in MBD**

  In MBD Process, Overall Development Efficiency Depends on Interface between OEM and Supplier, more and more than Legacy Process.

  - **Key Supplier Capabilities**
    1. Flexible Task Sharing with OEM (Component – System Level)
    2. Flexibility to Meet OEM’s Unique Development Environment
    3. Ability to Manage Larger, more Complex Development Projects
    4. Technology Development Capability in Areas where Supplier should Take the Lead, such as Software Implementation and ECU Testing
    5. System Development Capability with Vehicle System View like OEM
### Conclusion

- Since 1996, DENSO has been Promoting MBD Implementation, Deployment and Penetration. Currently, Each Production Departments Operate MBD Activities Independently.

- KFS (Key Success Factors) for MBD Promotion/Implementation are AIR (“Advanced,” “Initiative,” and “Reinforce”).

- Productions Departments are Trying to Investigate Effective Use of ACG, Managing Large-Scale MBD and so on.

- DENSO Moves forward from "Matlab Based Development" to Real “Model Base Development”, and Continue to Accelerate MBD through Tight Collaboration of R&D Team and Production Departments. (Of Course, Using Matlab as a Core Tool, and Trying to Use Other Peripheral Tools to Leverage Total Environment)

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Danke für Ihre Aufmerksamkeit

Thank you for your attention

ご清聴ありがとうございました