To master dynamic behavior
Challenges in ECU development for OEM and Tier 1

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Overview

1. How to visualize dynamics

2. Dynamic event chains in driver assistance systems

3. Processes and methodologies to master dynamics

4. Robust and scalable architectures – The earlier the better

5. Conclusion
1. How to visualize dynamics

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New Perspectives ➔ New Insights ➔ Better Results
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Levels in E/E-Systems

Vehicle

Domain

ECU

CPU

Software
E/E-System for a Driver Assistance System
E/E-System – Multiple Suppliers
Function Network

Timing Requirement: $\Delta t \leq 300$ ms
Mapping of Function Network to HW

- Signal detection
- Pre-processing
- Object Verification
- Tracking
- Vehicle Movement
- Decision
- Braking

Timing Requirement: $\Delta t \leq 300$ ms
Event Chain in E/E-System

Signal detection → Pre-processing → Object Verification → Tracking → Decision → Braking → Vehicle Movement

Timing Requirement: $\Delta t \leq 300$ ms
Limited System View of Tier 1

\[ \Delta t \leq 250 \text{ ms} \]

\[ \Delta t \leq 50 \text{ ms} \]
Multiple Suppliers of SW Components
Event Chain on Time Axis
Event Chain on Time Axis
Tier 1: Event Chain Evaluation
Tier 1: Event Chain Evaluation
Tier 1: Event Chain Evaluation

Timing Requirement: $\Delta t \leq 250$ ms – Failed!

Event chain broken
Data lost
Tier 1: Event Chain Evaluation

- Preemption by other task
- Clock drift and delayed by other task
Event Chain Evaluation – End-to-End
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Timing Model of Dynamic System Behavior
System Architecture and Requirements

Real-Time Data Sheet

- CPU and Bus Load
- Event Chain Latencies
- Event Chain Synchronization
- Signal Rate, Loss or Age
- Runnable’s Response Time
- Runnable’s Execution Rate and Order
- Runnable’s Activation Condition
- IRQ’s Loss or Blocking

Timing-Model

Real-Time Data Sheet

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Real-Time Data Sheet in Early Design Phase

- CPU and Bus Load
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Real-Time Timing-Model

OEM

Tier 1

Tier 2

Tier 1
Continuous Integration and Test
Continuous Integration and Test

Real-Time Data Sheet

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Timing-Model
It Doesn’t Take Much to Frontload Dynamic Challenges

Time to create initial dynamic behavior model

- **Body**: 40 man hours
- **Chassis**: 60 man hours
- **Powertrain**: 80 man hours
- **DAS**: 120 man hours
- **Infotainment**: 300 man hours

Very little time to get first valuable insights!
It Takes Very Little Time to do What-if Analysis in Model

Time to model and evaluate changes for DAS

- Synchronisation of CPU Clocks: 0.25
- Execution order of runnable in Task: 0.25
- Task Priority: 0.25
- Offset time triggered tasks: 0.30
- Mapping runnable on different Task (same CPU): 0.30
- Splitting of tasks: 1.00
- Mapping runnable on different CPU: 2.00
- Inter-CPU communication: 18.00
- Extending ECU with CPU and mapping of runnable on new CPU: 24.00

How much time does it take to do the equivalent on your HW? – If that’s possible!
Awareness Grows with Insights

Average number of real-time criteria per project

You can specify, what you can see and measure!

+75% awareness

Conventional Methods vs. Model based with R-T Data Sheets

- Activation Limit
- Buffer overflow
- Event chains
- Load
- Start-to-start jitter
- Response Time ISRs
- Response time task
- Data consistency
If You Can See and Measure, You Can Specify

Categories of real-time errors

- Event chain: 53%
- Load: 60%
- Activation limit: 60%
- Response time of tasks: 67%

Event chain errors are show stoppers!
Increasingly connected and integrated functions.
OEM View: Causes for Event Chain Errors

- Incomplete / wrong specification of r-t requirements: 40%
- Drifting clocks (ECU, bus, gateway): 23%
- Bad mapping (of steps on ECU): 20%

% of projects with causes for errors in event chains
Tier-1 View: Causes for Event Chain Errors

- Incomplete / wrong specification of r-t requirements: 40%
- Unknown interaction HW / SW: 20%
- Bad execution order of steps: 20%
- Unknown order of steps: 23%

% of causes for errors with event chain relevance
End-to-End View OEM: From Radar to Brake

OEM view: Event chain errors in subsystems

- Gateway: 10%
- Bus: 10%
- ECU: 30%
- End-to-End: 67%

% of projects with causes for errors in event chains
End-to-End View Tier-1: From Radar to CAN

Tier-1 view: Event chain errors (ECU perspective)

- Peripheral: 10%
- Application SW: 23%
- Basic SW: 27%
- End-to-End: 50%

% of projects with causes for errors in event chains
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4. Outlook

- Description of event chains in complex systems is required at an early stage
  - Integral part of the design phase: Feasibility analysis
  - Important criteria in the bid phase: Competence of the supplier

- Clear specification of the roles and responsibilities
  - Who is responsible for the real-time capability
  - Who delivers which contribution to the overall system analysis

- How is real-time capability continuously verified?
  - Model-based approach from project start
  - Ongoing verification of current task-models during development

"Problem only identified during project" ⇔ "next time systematically from the start"
Robustness analysis

- Stress with stimuli
- Load with net execution times
- Drifting, asynchronous clocks
- Increased bus load

Net execution times of all processes were incremented in steps of 10% up to 50%
Feature Ramp Up / Error Ramp Down

Graph based on presentation from
Dr. Karl Fuchs, Continental, BU Infotainment & Connectivity
Frontloading Reduces Risk and Cost

„We have found errors already in simulation, that we would have found 12 months later in testing.“

Undisclosed Tier 1

Level of risk from dynamic behavior errors

Real errors found model based

Real errors found in conventional testing

Project timeline
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… Even More Perspectives
Conclusion

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Function

Developer

Management

Project Leader

Architect