Virtual Hardware ECU – How to Significantly Increase Your Testing Throughput!

Elektrobit Tech Day

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Agenda

• Automotive electronic evolution and the testing challenges

• What are Virtual Prototypes and Virtual Hardware ECU

• Increasing automotive systems testing throughput

• Requirements and experiences deploying Virtual Hardware ECUs
E/E Vehicle Architecture is Changing

Cars are Becoming Computers on Wheels

From modular/integration to DCU centralization and fusion to vehicle computer/cloud computing

Source: (R)Evolution of E/E Architectures SAE Paper 2015-01-0196 Robert Bosch
## New Technologies & MCUs/SoCs

- **In vehicle Networks:** Ethernet & CAN-FD
- **Domain ECU – High Computing power**
- **Basic System ECU – Embedded controllers**
- **Integration Platforms – SW Virtualization**
- **Central gateways – advanced routing**
- **Connected cars – Multi-points, QoS**
- **Multi-layer security**
- **Power Networks – 12V & 48V**
- **Safety mechanisms**

### MCU and SoC targeted at ADAS, EV/HEV, Powertrain, Chassis, ….
- Multicore
- Complex programmable subsystems
- Multiple connectivity interfaces (Ethernet AVD, CAN-FD)
- ISO 26262 safety mechanisms

<table>
<thead>
<tr>
<th>Infineon AURIX 2nd Gen</th>
<th>NXP S32V234</th>
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<tbody>
<tr>
<td>6 cores</td>
<td>Quad ARM Cortex-A53</td>
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<tr>
<td>Gigabit Ethernet</td>
<td>Dual Apex-2 Image Cognition Processor cores</td>
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<tr>
<td>12 CAN-FD</td>
<td>Image signal processing</td>
</tr>
<tr>
<td>24 LIN</td>
<td>3D GPU</td>
</tr>
<tr>
<td>HW Security Module</td>
<td>Hardware Security Encryption</td>
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Verification and Validation Effort is Dramatically Increasing

“There will be as many as 10 design revisions in the electrical and electronics area, where consumer expectations and the rate of development are both rapidly increasing”

“Every part of the vehicle has been impacted by electronics in the past 30 years, and today it accounts for more than 40% of a vehicle’s cost, up from 20% just 10 years ago”
Introducing Virtual Prototypes
What is a Virtual Prototype?

A Virtual Prototype is a fast model of a microcontroller (MCU) or system-on-chip (SoC) that can execute an unmodified binary executable. It is used in the development process to simulate the behavior of the actual hardware before the physical device is built.
More than Hardware
Available Earlier, Easier to use for Debug!

Software
MCU Hardware

Software Developer’s View in Virtual Prototype
No change of habits required

With VDKs, all debugging becomes non-intrusive, deterministic=repeateable!

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Start HW/SW Development Early

Before Silicon or Boards are Available

SW development 9-12 months earlier

Experience from Automotive Semi and Tier1/OEM SW Teams

• Pre-silicon Dual OS (AUTOSAR & Linux) + Hypervisor bring up.

• Complex driver and communication
  – GTM, CAN, Ethernet communication, vision accelerators/sub-systems, …

• Algorithm flow from Matlab/Simulink to embedded software

• Faster Debug
• Non Intrusive
• Deterministic
• HW/SW Correlation
• OS aware
Moving to Virtual Hardware ECU
What is a Virtual Hardware ECU?

Fast model of the ECU Hardware with the benefits of virtual prototypes

- Infotainment ECU
- ADAS ECU
- Powertrain ECU
Example: ADAS Development

Virtual Prototype Available 9 Months Before ADAS ECU HW

ECU SW:
- Communication Networks
- ECU Board Support Package
- Multicore software

SoC SW:
- Linux
- Hypervisor
- Image processing
- AUTOSAR
- Complex drivers
- Communication

Networks: AVB, CAN-FD, FlexRay

Sensor Fusion SoC ASIL-B
Control SoC ASIL-D
Today’s Leader’s Start Early!

**Why Virtual Prototypes?**
- Early availability
- Better for debugging
- Easier to deploy

**Virtual Prototype Use Cases**
- Functional accurate software development
- Interactive day-in-day-out debugging
- Multicore SW, complex drivers, algorithm, AUTOSAR, hypervisor, communication protocols, … to applications

| SW starts 18 months before silicon at semi |
| SW starts 12 months before silicon at lead Tier1/OEM |

| SW starts 9-12 before ECU HW at Tier1/OEM |

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Establishing a virtual Hardware-in-the-Loop test bench (vHIL)
Hardware-in-the-Loop

Development Gap

MIL
Plant Model
Control Model
PC Target (.exe)

SIL
Plant Model
Control SW

HIL Limitations:
- Access due to limited number of HIL systems (cost and access)
- Limited visibility and controllability
- Hard to deploy in regression
- Complex to set up, share, maintain and archive

Project Timeline

EFFORT & TIME GAP
Virtual Hardware-in-the-Loop
Start Before Test Benches are Available

Project Timeline

MIL
Plant Model → Control Model

SIL
Plant Model → Control SW

PC Target (.exe)

Software Development Tools
Embedded Software
Virtual HW & Environment

MCU Virtual Prototype (Synopsys VDK)
Embedded Software
Plant Model and Analog
Debug, Analysis and Test Tools

Automotive tool ecosystem support includes Matlab/Simulink, SABER, Vector CANoe, ...

HIL
Plant Model → ECU

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SW Development Early & Increased Testing Throughput
From Virtual SoCs to Virtual Hardware ECU(s) with Virtualizer and Automotive VDKs

Start early & accelerate development
• When SoC evaluation boards or ECU HW boards are not available
• 12-18 months earlier
• Easier and more efficient debug

Start earlier, test faster and better
• Frontload test development
• System SW testing
• Fault & coverage testing
• Regression

Early Software Development
Increase Testing Throughput

Developers & Test Teams
Debug, Analysis and Test Tools
Software
Virtual HW ECU
Plant Model & Analog
Establishing a vHIL Test Bench

1. Virtual prototypes of MCU/SoC and modeling environment

2. Integration with software debuggers

3. Co-simulation interface with other simulators (example: Simulink, SABER, CANoe, …)

4. Tools to drive testing

5. Tools to analyze and report
Integrating with Automotive Flows

Model-based Testing

Control Algorithm

Engine model

Model-based Design

Code Generation

Co-simulation

Control Algorithm SW

Synopsys VDK

AUTOSAR OS

System under Test (SUT)

Test Execution

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Support of ISO 26262
Testing Earlier and Faster – Evaluating Corner Cases

Inject fault anywhere
- Anywhere in hardware
- Anywhere in software
- Modify the state of the complete system
- Permanent fault

Control & Analyze better
- Control triggered by SW, HW or time events
- Record and correlate all HW/SW events
- Non Intrusive

Repeat deterministic
- Deterministic execution
- Overnight execution in regression
- Fast execution w/ complete SW stacks
Accelerate Testing Productivity through Regression

Evaluate the Impact of Software Changes More Efficiently!

Vehicle SW Stack #1
Base Software
MCAL, Drivers, OS, …

Vehicle SW Stack #2

Vehicle SW Stack #3

Test scenarios

Automated test regression on server farm

PASS
FAIL
Significantly Increase Test Throughput
Test More and Faster – Higher Software Quality Earlier, at Every Development Milestone

Using HIL

Using vHIL

Further Acceleration through Parallelization

80% reduction
Application Example to vFMEA

Actual Results

- Increased test coverage 200 to 900 tests
- Testing effort reduced from 3 man/months to 2 man weeks
- Reusable, safer and distributed access
- Faster analysis of result and change iteration
The most comprehensive Virtual Hardware ECU Solution

Synopsys Solution from Modeling to Test Bench Deployment

Models
- CoE VDKs
- Semi VDKs
- IP Models

VDKs
- Software Tool Interfaces
  - Scripting
  - HW/SW Debug and Analysis
  - Virtual Prototype
  - Co-Simulation & External Connectivity

Virtualizer
- VDK Extension

Development Deployment

Methodology & services

Developers & Test Teams

Virtual Hardware ECU Test Bench

- Debug, Analysis and Test Tools
- Software
- Virtual HW ECU
- Plant Model & Analog

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Synopsys & the Automotive Ecosystem

Automotive Centers of Excellence
Partnering with Tier 1 Automotive Semiconductors for Software Development

“The Virtual MCU Center of Excellence brings together the unique expertise of both companies to extend and optimize proven virtual prototyping technology for users of Renesas microcontrollers.”

“The VDK for Freescale S32V200, delivered through our Center of Excellence collaboration with Synopsys, helps our customers accelerate automotive system development and rapidly deliver high quality software to market.”

“With access to virtual prototypes as part of the AURIX development tool suite, our customers can now rapidly integrate this technology into their current software development and testing processes.”
Software & System Development, Integration & Test

Virtual Platforms: Breaking New Grounds - IEEE

System design
Executable spec

SW-development
Bring-up of HW and tooling

Integration & Verification
Variant handling

Tier2 Models
HW specification available

Tier2 OEM Models
HW available

OEM Models
Timeline not to scale

MODELS: Complexity, Simulation Speed & Abstraction, Maturity & Reliability


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The success rate for the introduction of virtual prototyping over the last couple of years is quite high. About 70% percent of my internal customers are repeat customers after their first serious pilot engagement. Virtual prototypes are of great help to support software developers to find issues in their software when it comes to reacting to faulty hardware.

Over time we found that the use of virtual prototypes is not only applicable for the design and implementation of software, but for the entire system-level testing and validation of the product dependability.

We observed 100% functional accuracy in the results, that is, the same test that would pass/fail on the board would also pass/fail on the virtual board. In addition, in terms of simulation fidelity of execution timing, we gathered very promising results, in the range of 2% to 11% error. This means that the same test that would run functionally equivalent on the board and on the virtual board, would take say 1 second to run on the target and between 1.02 and 1.11 seconds on the virtual prototype.
Virtual Hardware ECU Accelerate System Testing

Proven and Deployed Today

Synopsys is the right partner in automotive virtual prototyping – technology, expertise and support

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Virtual Hardware ECUs w/ VDKs

Improving SW quality with better testing earlier

Software-in-the-Loop (SiL)

Virtual Hardware-in-the-Loop (vHiL)

Model-in-the-Loop (MiL)

Hardware-in-the-Loop (HiL)

ECU/Network (Tier1/OEM)

MCU/SoC (Semi)

Better SW Earlier

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