Virtual Platform Environment for the Bring Up and Test of a Secure Many-Core RTOS for Automotive Use

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Embedded World conference
28 February 2018

Agenda

- The RTOS challenge for automotive systems
- Virtual platforms for software development
- Building the virtual platform
- eMCOS RTOS
- Debug and test of the RTOS

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Automotive Electronics Is Not Just ADAS and Autonomous Vehicles

- Classic automotive electronics – power train, braking systems, body control – have become more complex
- SoCs for classic automotive applications now have multiple processors
- ECUs for classic automotive applications now have multiple SoCs
- Automotive systems now include multiple ECUs communicating with each other
- Security requirements are now layered on top of the quality, reliability and safety requirements

Today's Automotive Challenge

- How to provide a software environment that enables easy communication and control of the complex automotive systems?
- How to test such an environment?

One Answer

- How to provide a software environment that enables easy communication and control of the complex automotive systems?

- How to test such an environment?

- Develop a many-core RTOS that can support Autosar, including the security requirements, and test that RTOS/Autosar software stack using both virtual platforms (software simulation) and real hardware

This Paper

- eMCOS RTOS / Autosar / RTE software stack
- ECU composed of 1 x RH850F1H
- 2 x ECU in virtual platform
- Testing of the software running on the “pseudo-ECU”

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Current Techniques for Embedded Software Testing

- Hardware based testing
  - Actual production hardware
  - Development boards, FPGA prototypes
  - Hardware emulators
- Cycle accurate simulation
- Instruction accurate simulation

- Hardware based testing is the norm
- Cycle accurate simulation is too slow, too expensive
- Instruction accurate simulation has advantages of controllability, observability, determinism, ease of automation
  - Now starting to move into mainstream as a complementary tool to hardware based testing

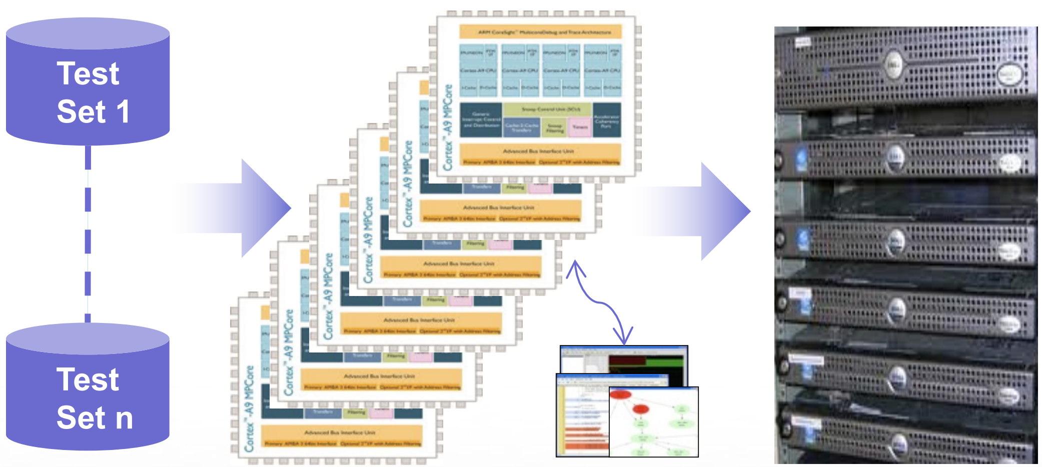
Hardware-Based Software Testing

- Has timing/cycle accuracy
- JTAG-based debug, trace
- Traditional development board / emulation based testing
    - Limited external test access (controllability)
    - Limited internal visibility
    - Limited physical system availability

- To get around these limitations, software is modified
    - printf
    - Debug versions of OS kernels
    - Instrumentation for specific analytical tools, e.g. code coverage, profiling
- Modified software may not have the same behavior as clean source code

Advantages of Virtual Platform Based Software Development

- Earlier system availability
- Full controllability of platform both from external ports and internal nodes
  - Corner cases can be tested
  - Errors can be made to happen
- Full visibility into platform: if an error occurs, it will be observed by the test environment
- Fully deterministic testing
- Easy to replicate platform and test environment to support automated CI and regression testing on compute farms



Virtual Platforms Complement Hardware-Based Software Development

- Current methodology employs testing on hardware
  - Proven methodology
  - Has significant limitations
- Virtual platform based methodology delivers controllability, visibility, repeatability, automation

Application Layer: Customer Differentiation

Middleware: TCP/IP, DHCP, LCD, …

OS: Linux, FreeRTOS, µC/OS-III, ThreadX, …

Drivers: USB, SPI, ethernet, …

Actual Hardware or **Virtual Platform**

Virtual platforms – software simulation – provide a complementary technology to the current methodology

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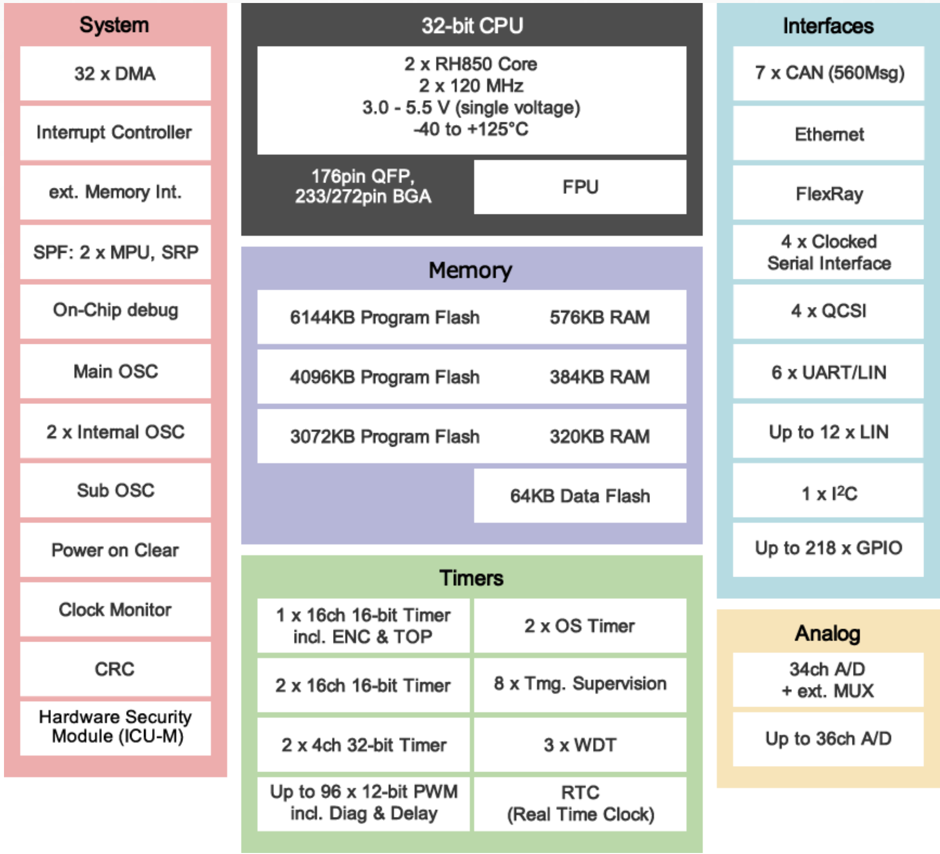
Virtual Platforms Provide a Simulation Environment Such That the Software Does Not Know That It Is Not Running On Hardware

- The virtual platform is a set of instruction accurate models that reflect the hardware on which the software will execute
  - Could be 1 SoC, multiple SoCs, board, system; no physical limitations
- Run the executables compiled for the target hardware
- Models are typically written in C or SystemC
- Models for individual components – interrupt controller, UART, ethernet, … – are connected just like in the hardware
- Peripheral components can be connected to the real world by using the host workstation resources: keyboard, mouse, screen, ethernet, USB, …
- High performance: 200 – 500 million instructions per second typical, or boots Linux in <5 sec

Renesas RH850F1H

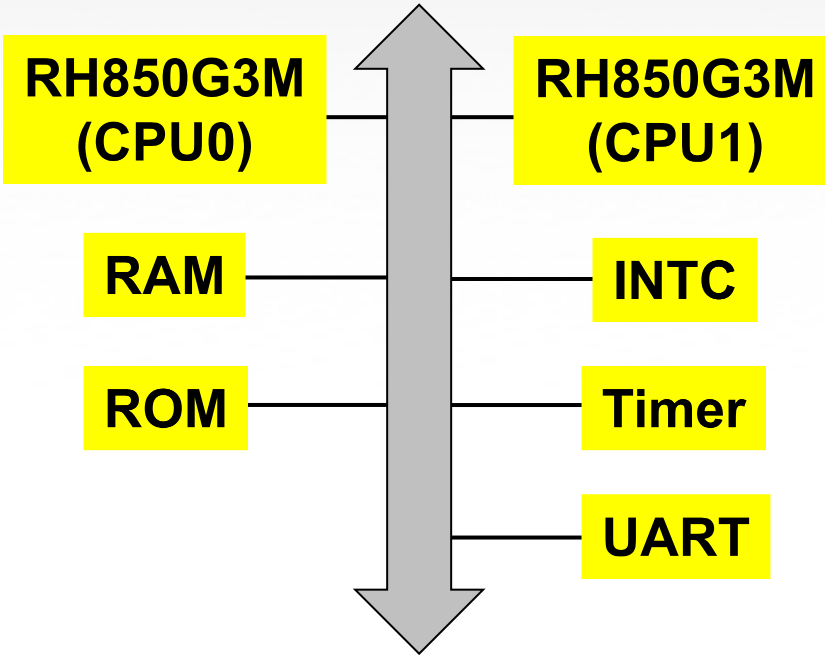
- 2 x RH850G3M processors
- Lots of peripherals

- Have a test plan: what will be tested using the virtual platform, what with hardware based testing
- Only build the peripheral models that are needed for the virtual platform testing tasks



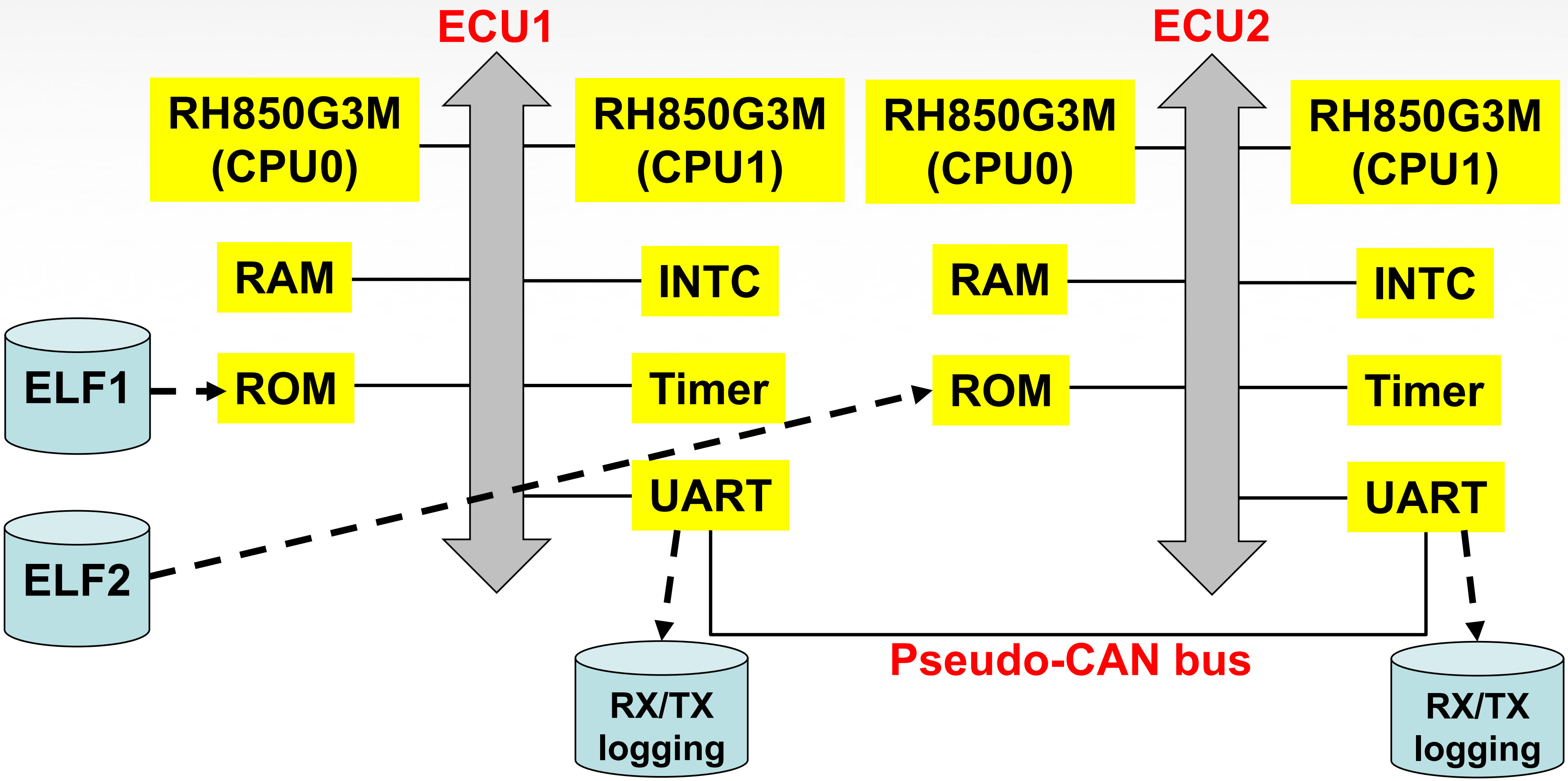
RH850F1H Virtual Platform: A Virtual, or Pseudo, ECU

- 2 x RH850G3M processor models
- UART
- INTC
- Timer
- Memory



- Processor models are from the Open Virtual Platforms (OVP) Library (www.OVPworld.org)
- Peripherals models and platforms built using OVP APIs
- ✓ Building peripheral models and RH850F1H virtual platform, and initial bring up of eMCOS RTOS, took about 1 week

Multi-ECU Virtual Platform



- True CAN model is not needed
- Test objective is to have communication between ECUs, not to test specific protocol

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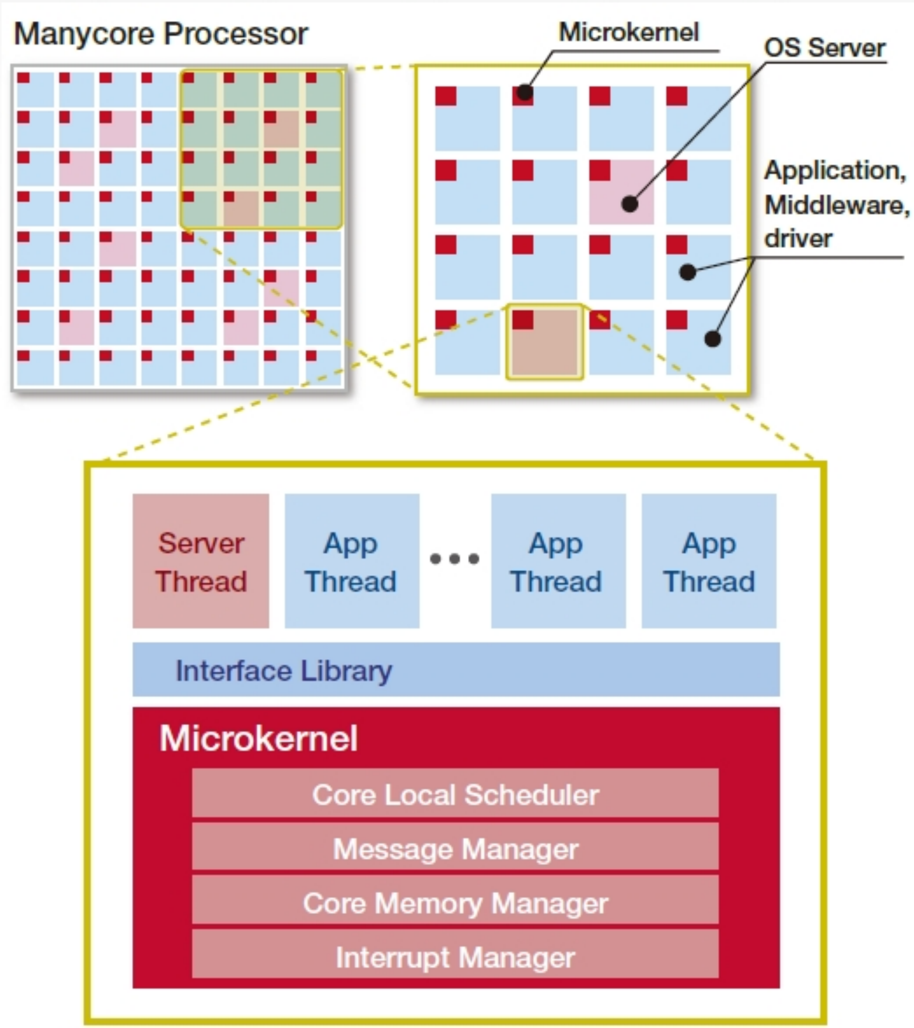
eMCOS RTOS

- Distributed microkernel architecture
- Optimized for many-core hardware – does not depend on cache coherency
- Uses MPUs in target hardware to enable users to designate secure regions



eMCOS / Autosar / RTE

- eMCOS AUTOSAR: eMCOS supporting AUTOSAR Classic Platform (CP) AUTOSAR OS specification
- RTE: The Run Time Environment module compliant to AUTOSAR Classic Platform RTE specification
  - RTE provides API to AUTOSAR CP application called SW-C (Software Components)
  - RTE provides communication between SW-Cs on the same ECU, and also between SW-Cs that resides in different ECUs via CAN, for example

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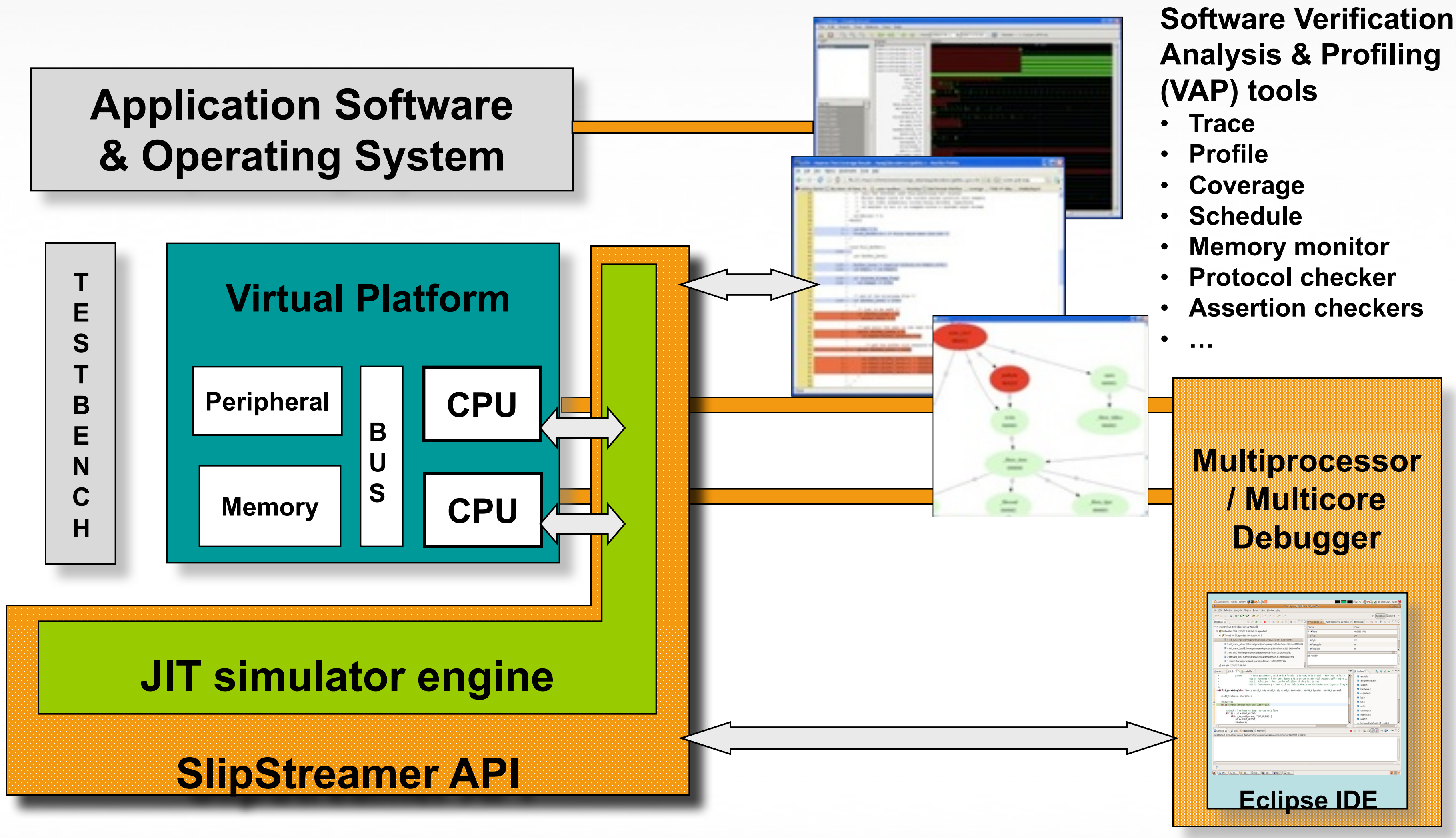
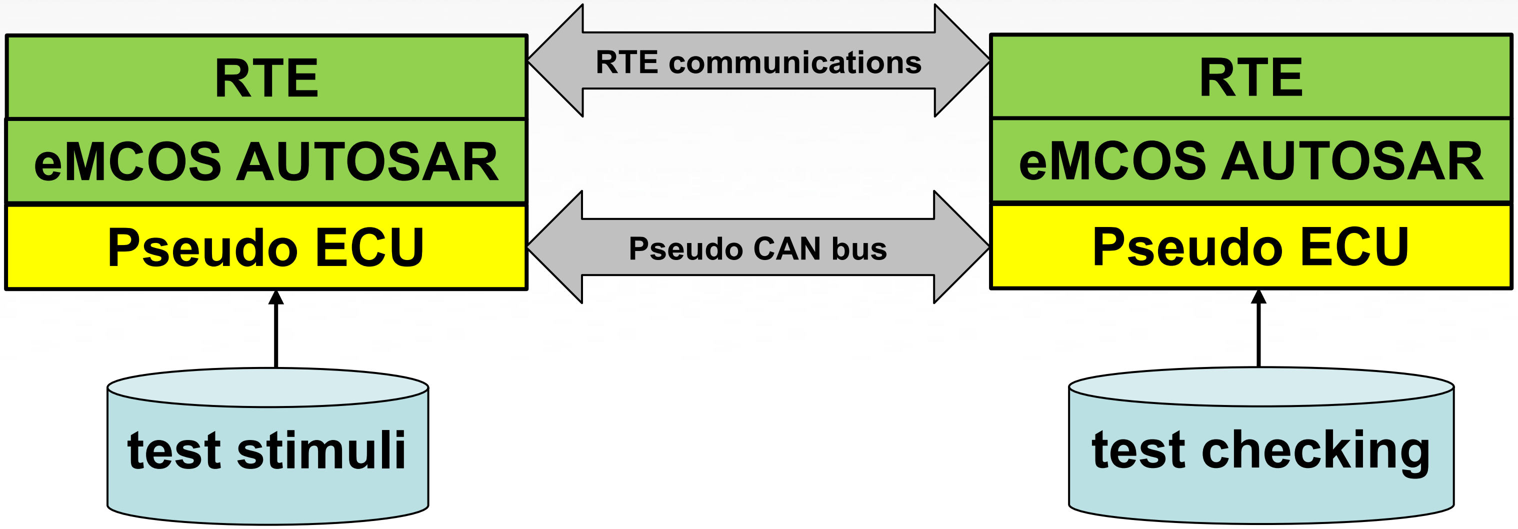
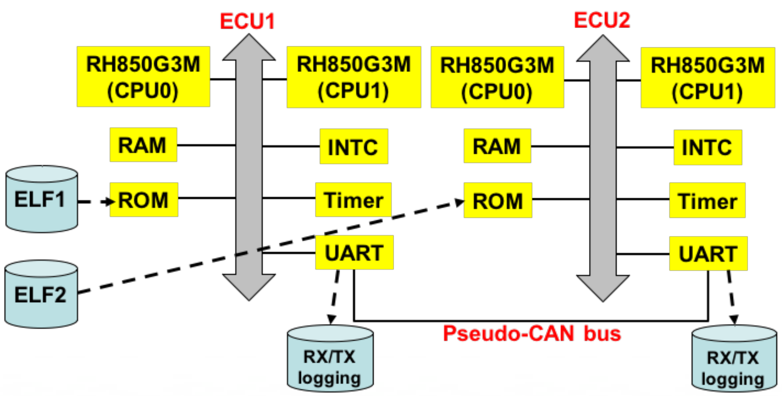
Imperas Environment for Embedded Software Development, Debug & Test



Test Block Diagram



- Same cross-compiler with same compiler options as for target hardware is used to build software
- *The software should not know that it is not running on hardware*



Test Objectives for the Virtual Platform Environment

- Verification of eMCOS/Autosar/RTE
- Enable Continuous Integration (CI) flow
- Enable multiple teams to use the same test environment

Test Results

- Virtual platform performance was > 200 MIPS
  - Performance of > 200 MIPS critical because of large test cases
- Virtual platform environment easy to replicate and deliver to additional engineering teams
- Visibility of virtual platform enabled debug of secure elements of software stack
- Easy to set up simulation in CI flow

Conclusions

- Using the virtual platform accelerated software testing
- Using the virtual platform caught bugs that would have been found much later in the test cycle, if at all
- Virtual platforms are a complementary technology to hardware based testing
  - Use the virtual platform where significant ROI can be achieved

- Further work: start using the virtual platform environment for code coverage, fault injection

- See eSOL at Hall 4, booth 4-634
- See Imperas at the RISC-V Foundation booth, Hall 3A, booth 3A-419

- Any questions?

- Thank you!