INCODIO® - a new Tool for automotive SIL applications

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Overview

ECU Software Development

- Requirements Management
- Design & Prototyping
- Implementation

Calibration
Validation
Integration
Verification

Hardware-in-the-Loop (HIL) Test

ECU Software

Vehicle
HIL – Current Status

- **ECU Validation** with HIL Technology
  - widely used for Validation of a Vehicle (Component)
    - important part of Vehicle Development Process
    - Value Proposition for Customers has been proven
      - i.e. higher Quality of Vehicles and ECU Software

- **ECU Calibration** with HIL Technology
  - still less used due to inappropriate Vehicle Models
HIL – fundamental Disadvantages *)

- **huge effort** for Installation and Operation
- **very expensive**
- **less flexible** due to limited Re-Configuration of Hardware
- separate Validation of ECU Hardware and ECU Software **not possible**
  - indeed we have here a „Hardware & Software - in - the Loop“ Technology

*) see also Hanselmann, dSpace; 11. Euroforum Jahrestagung „Elektronik-Systeme im Automobil“, München, Fachtag Systems Engineering, February, 15th 2007
HIL – Summary

- fundamental Disadvantages of HIL- Technology cannot be removed!
  - due to hardware-based connection to an ECU

- Which Technology can overcome these deficiencies?
  - Software-in-the-Loop Technology!
SIL – an emerging Technology

- **Software-in-the-Loop (SIL)**
  - less effort for Installation
  - less expensive than today’s HIL solution
  - flexible and easily re-configurable
  - Last but not least: better support of Methodology!
SIL – an emerging Technology

- AUTOSAR
  - component based
    Development and Validation of ECUs
    - HIL & SIL for ECU Hardware & Basic Software!
    - SIL for ECU Software Components
SIL – What is this exactly?

- Virtual Validation and Calibration of ECU Software, e.g.
  - C Code and / or Object Code for Production ECU’s!
    - high efficient implementation of Calibration Data
  - Use of special arithmetic Libraries
  - Use of special C Language constructs
    - „Struct“, „Union“, „Pragma“, „Macro“…
  - hand-coded or automatically generated C Code based on Models for ECU Software
SIL – What is this exactly?

- **Virtual Validation** and **Calibration** of ECU Software, e.g.
  - **no** Use of Matlab/Simulink, ASCET Models, …
    - Behavior is different to Production Software!
  - **no** Use of C Code for Prototyping ECU’s
    - Behavior is different to Production Software!
SIL – The Technology in a Nutshell

- Test Tool Calibration Tool
- Integration Tool for C Code, Object Code, Description Files for a Software Component
- Simulation Tool
- Models
  - Vehicle
  - ECU Hardware
  - ECU Basic Software
  - ECU Network
  - remaining ECUs

Production Software!
SIL – Which Models must be available?

- **Vehicle Models**, which allow a Validation and a Calibration in the Lab
  - is as well mandatory for HIL applications!

- **Models** for ECU Network
  - i.e. CAN-Bus Simulation

- **Models** for remaining ECU‘s in the Vehicle
  - i.e. CANoe Models

- **Models** for ECU Hardware & Basic Software
  - i.e. for NVRAM, EEPROM; **will be simplified AUTOSAR**!
SIL – What is the job of the Simulation Tool?

- **Open Interfaces** for Integration of C Code

- Integration of Models from different Tools
  - MATLAB®/Simulink®, ASCET, …

- **PC** (s) as a Simulation platform
  - in Real-time; faster than Real-time

- **Measurement** and **Calibration** of physical Variables
  - i.e. by an open Interface for ASAM-MCD-2MC
SIL – What is the job of the Integration Tool?

- Support of different **Description formats** for Software Components

![Diagram showing software components and integration tools](image)
SIL – What is the job of the Integration Tool?

- **simple Integration** of C-Code
  - Less additional Effort
    - *i.e. no* Definition of Functions and Variables in the Simulation Tool
  - Support of memory optimizing C Language constructs
    - "struct", "union", ...
  - Re-Definition of special C statements
    - *i.e. "CONST" -> "VOLATILE"
    - enables Calibration of Variables during Simulation

![Diagram showing the integration process](attachment:image.png)
SIL – What is the job of the Integration Tool?

- Support of **Measurement & Calibration** during Simulation
  - i.e. by Support of **ASAM-MCD-2MC**
    - enables Measurement of physical Variables of the Production ECU Software
    - enables Calibration of Parameters, Curves and Maps during Simulation
      - arbitrary Record Layouts of Production ECU Software must be supported

**Production Software**

Software Component

Integration Tool

Simulation Tool
SIL – What is the job of the Integration Tool?

- Identification of **Interfaces** and **Real-time behavior** of a Software Component
  - i.e. by Support of the **AUTOSAR** Description
    - enables Stimulation und Input and Output interfaces
    - enables automatic Identification of Processes / Runnables
    - enables Specification of „Priority“, „Trigger Mode“, „Period“, … of Processes / Runnables
SIL – Which Tools are ready for use?

Production Software!

Software Component

Integration Tool for C Code, Object Code, Description Files for Software Components

Simulation Tool

Models

Vehicle
ECU Hardware
ECU Basic Software
ECU Network
remaining ECUs
SIL – Which Tools are ready for use?

Production Software!

INTECRIO

Vehicle
ECU Hardware
ECU Basic Software
ECU Network
remaining ECUs

MatWorks
SIL – Validation of Production Software
SIL – Calibration of Production Software

Automatic Calibration

Production Software!

Software Component

Measurement Data

MDF

Calibration Data

MSR (CDF), DCM

ETAS INTECRIO

Models
SIL – Comparison of Model with Production Software

Design of Software Component

OEM

Supplier

MathWorks

Simulink

ETAS

INTECRIO

Model

ETAS

ASCET

C-Code Editor

Implementation of Software Component

Production Software!

C-Code Object Code

ETAS

INTECRIO

Validation of Software Component
Summary

- **HIL** Technology plays, despite fundamental Disadvantages, an important Role in today’s Vehicle Development Process.

- Importance of **SIL Technology** will steadily increase
  - SIL avoids the Deficits of HIL
  - SIL additionally supports the component based Validation within the AUTOSAR Methodology

- **INCODIO® and INTECRIO** are excellent Tools for SIL applications
Thank you for your Attention

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