Software-in-the-Loop using virtual CAN buses: Current solutions and challenges

5. Tagung Simulation und Test für die Automobilelektronik

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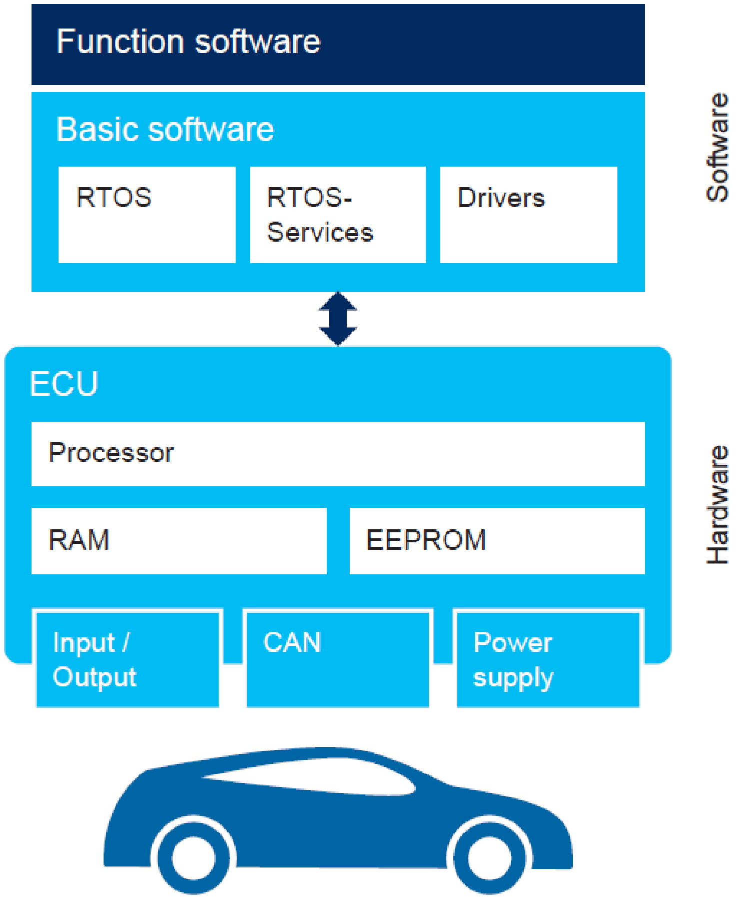
Software-in-the-Loop using virtual CAN buses
Motivation

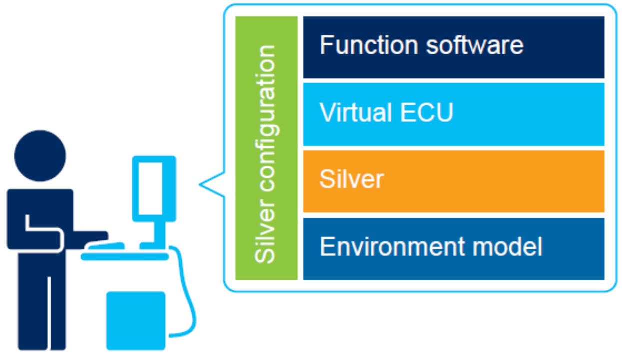
Motivation

- Series Transmission Software development
  - Function software development
  - Basic software from ECU supplier
  - Different software variants
  - C-Code (Hand coded, auto code from TargetLink)
- Frontload development tasks
  - Debugging of series transmission function software
  - Functional behaviour testing
  - Fully utilized HiL systems



Software-in-the-Loop using virtual CAN buses
Motivation

- Software-in-the-Loop (SiL)
  - Integral step in the development process
  - All-time deployable by developer
  - Closed-loop simulation on Developer PC
  - Enables convenient debugging
  - Faster change-analysis-change cycles

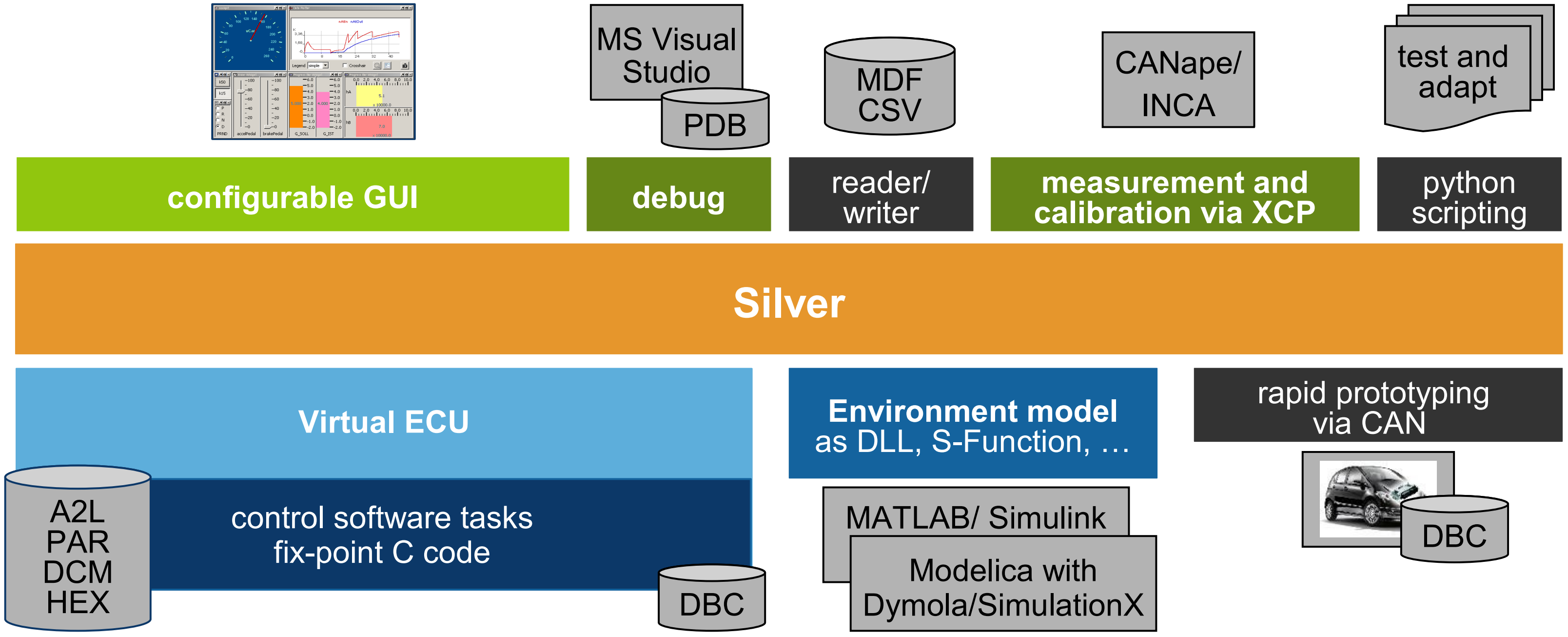


- Controller Area Network (CAN)
  - most commonly used inter-ECU communication

- **Objective**
  - Use CAN in simulation

Software-in-the-Loop using virtual CAN buses
Silver

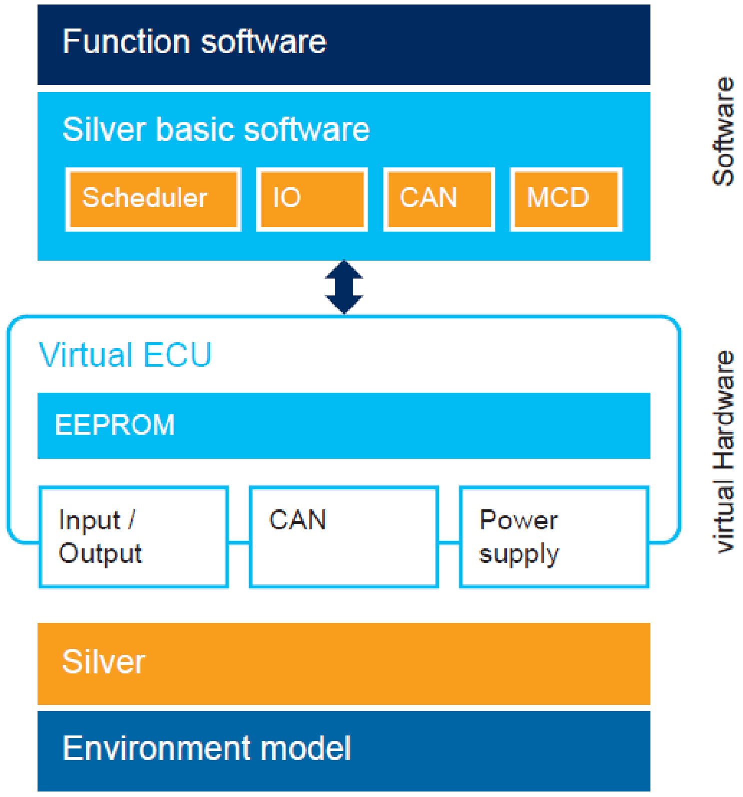
- Silver from QTronic GmbH
  - Software-in-the-Loop (SiL) simulation environment
  - All relevant automotive standard formats supported (A2L, PAR, DBC)
- IAV has already experience with Silver for 2 years



MS Visual Studio
PDB
MDF CSV
CANape/ INCA
test and adapt
configurable GUI
debug
reader/ writer
measurement and calibration via XCP
python scripting
Silver
Virtual ECU
A2L PAR DCM HEX
control software tasks fix-point C code
DBC
Environment model as DLL, S-Function, …
MATLAB/ Simulink
Modelica with Dymola/SimulationX
rapid prototyping via CAN
DBC

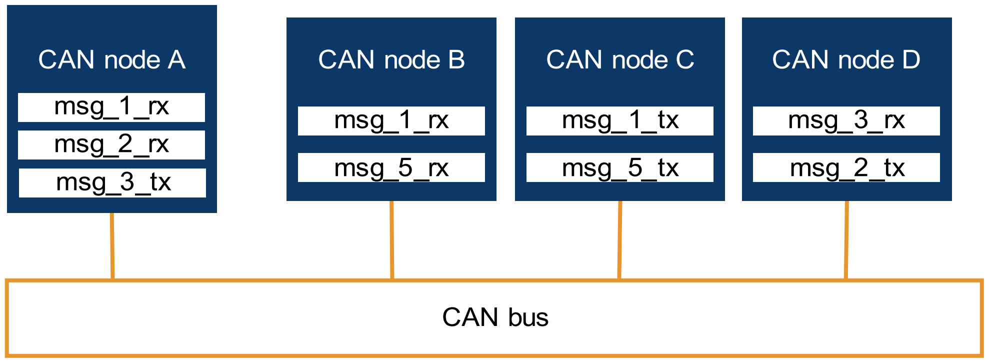
Software-in-the-Loop using virtual CAN buses
IAV Software-in-the-Loop setup

- **Virtual ECU**
  - Hardware and BIOS software
    - IO interface
    - Timing of tasks
    - BIOS functionality
    - Non-volatile memory
  - uses C-Silver-API
- **Environment model**
  - Longitudinal vehicle dynamics, detailed transmission model, and CAN rest bus
  - Reuse of HiL models
- **Silver configuration**
  - Graphical user interface
  - PAR file flashing, Access A2L variables



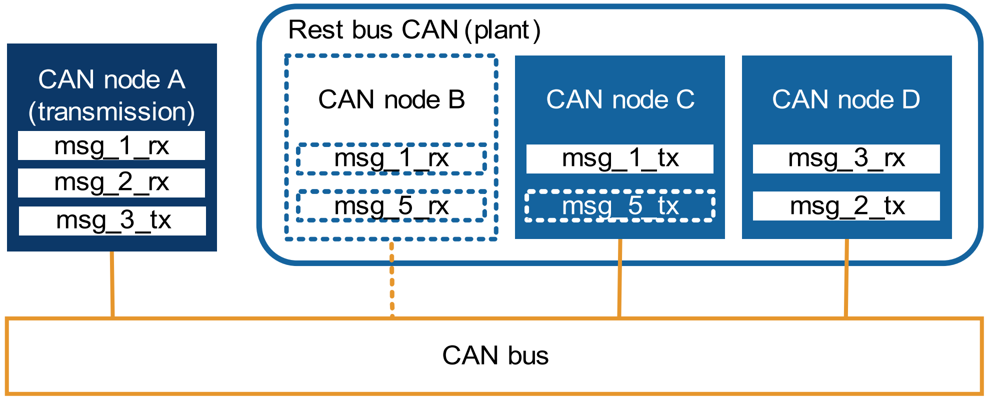
Software-in-the-Loop using virtual CAN buses
CAN Basics

- Bus: One transmitter - multiple receivers
- Node: typically one ECU, transmits or receives messages
- Message: up-to 8 Byte data, cyclic or event-based, priority
- Signal: packed into a message, scaled by gain/offset (1-64 bit)
- DBC File: specifies CAN bus, especially message structure and timing



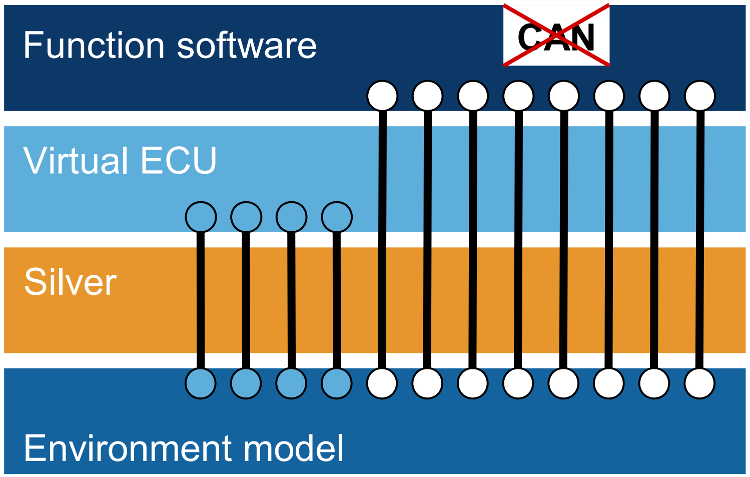
Software-in-the-Loop using virtual CAN buses
CAN Basics: rest bus

- SiL simulation focused on one ECU
  - DBC defines whole bus
  - Not all nodes/ messages are needed in simulation
  - Emulation filters by
    - node names
    - black listing or white listing of messages



Software-in-the-Loop using virtual CAN buses
Signals in common SiL

- Common SiL signal rooting (without CAN)
  - Virtual ECU/ Function software (Silver C API)
    - Remove CAN code
    - define **Silver I/O** for code variable (gain and offset manually)
  - Model (Silver Simulink block set)
    - define **Silver I/O** for Simulink signal
- Silver
  - detects Silver I/O signals by name
  - copies information automatically at begin/ end of simulation step
  - connection data type: double
- Summary
  - Function software CAN code is bypassed
  - Typically many signals to be set up

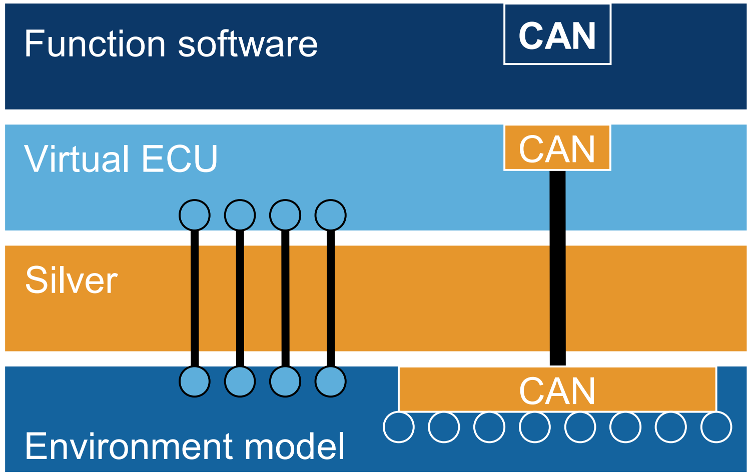


Legend:

●	Pin Silver I/O
○	CAN Silver I/O

Software-in-the-Loop using virtual CAN buses
Signals in SiL with CAN (1)

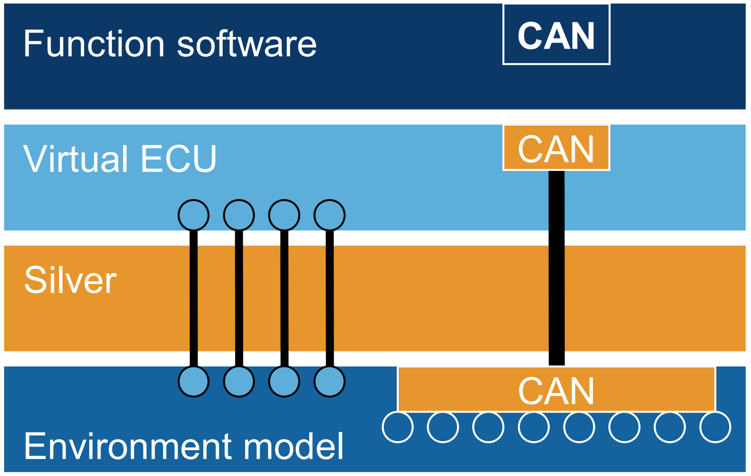
- SiL with CAN
  - Virtual ECU (Silver C API)
    - define **Silver I/O** for ECU pins
    - define **CAN emulation** (by DBC node) to access message data
  - Model (Silver Simulink block set)
    - define **Silver I/O** for ECU pins
    - define **CAN emulation** (by DBC nodes) and connect signals to CAN blocks
- Silver
  - Silver I/O are handled as before
  - CAN emulation (by DBC usage)
    - messages are identified by ID, multiple buses possible
    - Silver copies information automatically with DBC timing
    - connection data type: from DBC, automatically scaled



Software-in-the-Loop using virtual CAN buses

Signals in SiL with CAN (2)

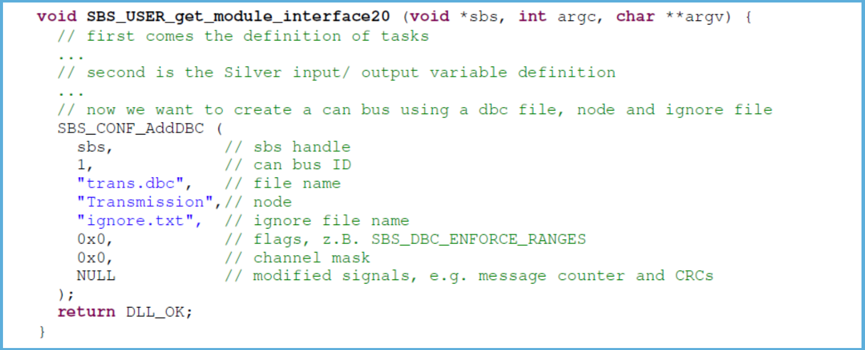
- Summary
  - Function software CAN code in simulation, can be debugged and tested
  - Reduced communication setup effort
    - Less manual definitions
    - Automatic scaling from/ to CAN message
  - Use of DBC work product
  - Car comparable communication behaviour



Software-in-the-Loop using virtual CAN buses
Using Silver CAN emulation: Code

- Silver API 2.0 defines C functions for:
  - Configure CAN bus or busses by DBC file or by single messages
  - Start/ stop CAN emulation
  - Check new message received
  - Transmit/ receive message (8 byte data)
  - Transmit/ receive signal/ variable (from a message, raw or scaled)
  - Manipulate messages for counter/ CRC (call-back dll)

Virtual ECU

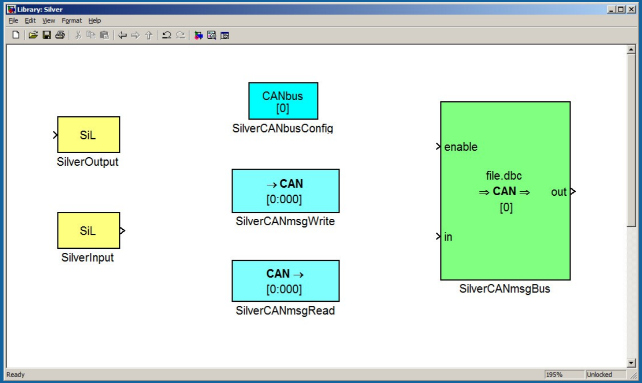


```c
void SBS_USER_get_module_interface20 (void *sbs, int argc, char **argv) {
  // first comes the definition of tasks
  ...
  // second is the Silver input/ output variable definition
  ...
  // now we want to create a can bus using a dbc file, node and ignore file
  SBS_CONF_AddDBC (
    sbs,             // sbs handle
    1,               // can bus ID
    "trans.dbc",     // file name
    "Transmission",// node
    "ignore.txt",    // ignore file name
    0x0,             // flags, z.B. SBS_DBC_ENFORCE_RANGES
    0x0,             // channel mask
    NULL             // modified signals, e.g. message counter and CRCs
  );
  return DLL_OK;
}
```

Software-in-the-Loop using virtual CAN buses
Using Silver CAN emulation: Simulink

- Silver CAN block set
  - Bus message setup (SilverCANmsgBus)
    - Configure one CAN bus by DBC and node names
    - Enable/ disable node by Simulink input bus
    - Transmit messages from Simulink input bus
    - Output received messages to Simulink output bus
  - Single message setup (SilverCANbusConfig, SilverCANbusRead, SilverCANbusWrite)

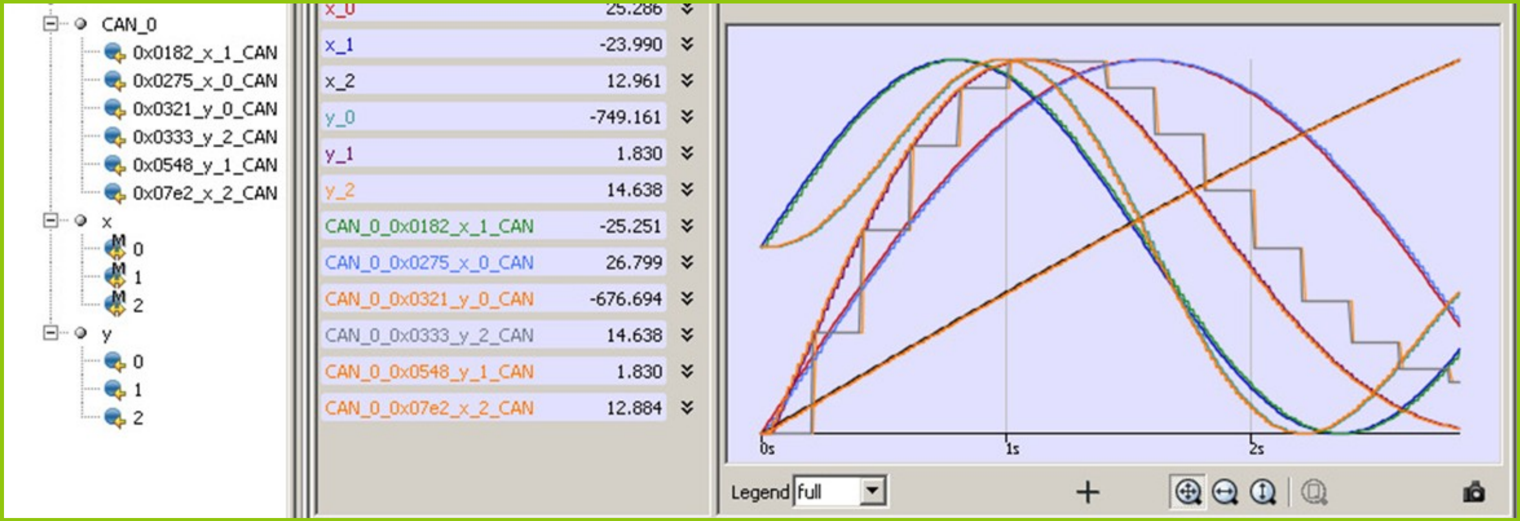
Environment model



Software-in-the-Loop using virtual CAN buses
Using Silver CAN emulation: User GUI

- See connection state of CAN messages
- Easy access to CAN signals for plotting/ debugging

Silver GUI

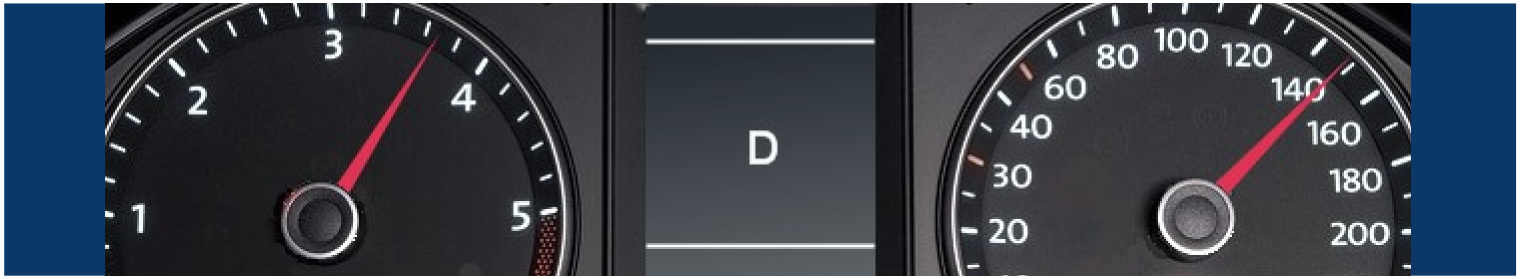


```
CAN_0
  0x0182_x_1_CAN
  0x0275_x_0_CAN
  0x0321_y_0_CAN
  0x0333_y_2_CAN
  0x0548_y_1_CAN
  0x07e2_x_2_CAN
x
  0
  1
  2
y
  0
  1
  2
```

x_0	25.286
x_1	-23.990
x_2	12.961
y_0	-749.161
y_1	1.830
y_2	14.638
CAN_0_0x0182_x_1_CAN	-25.251
CAN_0_0x0275_x_0_CAN	26.799
CAN_0_0x0321_y_0_CAN	-676.694
CAN_0_0x0333_y_2_CAN	14.638
CAN_0_0x0548_y_1_CAN	1.830
CAN_0_0x07e2_x_2_CAN	12.884

Software-in-the-Loop using virtual CAN buses
Summary

- Network communication is an important part of system design
- Using CAN emulation in SiL simulations
  - drastically reduces the effort for defining SiL communication setup
  - improving the consistency of definitions
  - adds additional simulation aspects (signal scale, communication timing)
  - enables tests of the CAN-related software parts (which are up to now bypassed)



Thank you!

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