Multi Chip Simulation of Battery Management System with Synopsys Virtualizer Studio

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Outline

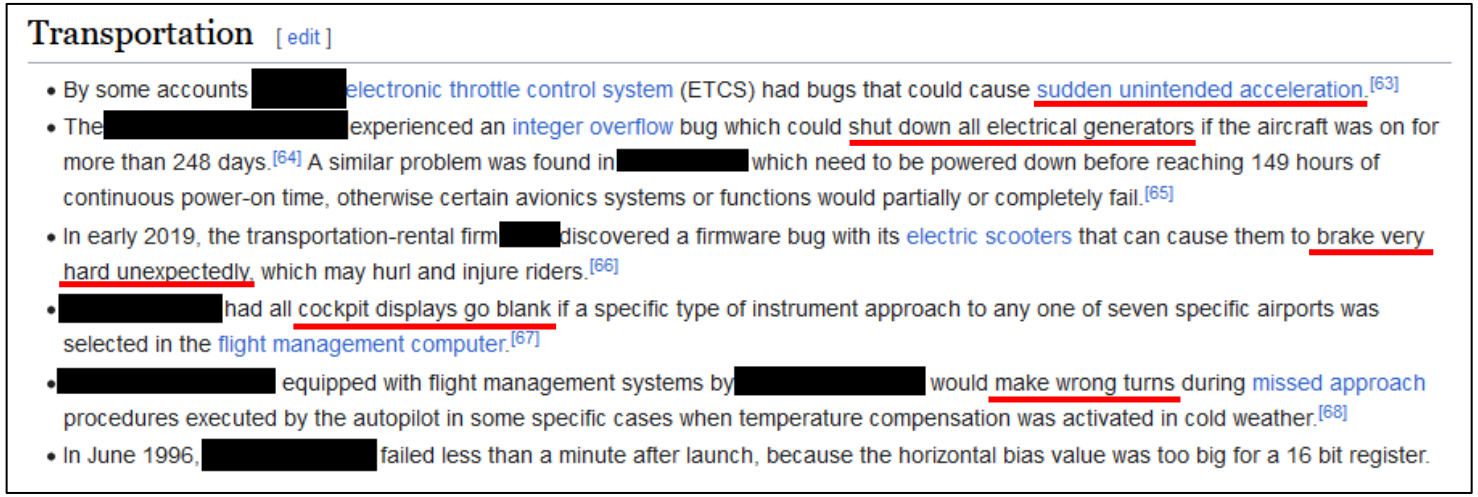
- Motivation
- High Voltage Battery Management System
- Full System Simulation Setup
- Issue with TLM-SPI
- Complete SW Stack Execution
- Conclusions and Future Work

Motivation

Motivation

- Automotive Microelectronic Systems
  - high complexity
  - high degree of interaction inside them
  - high degree of interaction between them
- Strong Requirements
  - functional safety
  - reliability
  - cost
  - time to market

https://en.wikipedia.org/wiki/List_of_software_bugs



Transportation [edit]

- By some accounts [redacted] electronic throttle control system (ETCS) had bugs that could cause sudden unintended acceleration.[63]
- The [redacted] experienced an integer overflow bug which could shut down all electrical generators if the aircraft was on for more than 248 days.[64] A similar problem was found in [redacted] which need to be powered down before reaching 149 hours of continuous power-on time, otherwise certain avionics systems or functions would partially or completely fail.[65]
- In early 2019, the transportation-rental firm [redacted] discovered a firmware bug with its electric scooters that can cause them to brake very hard unexpectedly, which may hurl and injure riders.[66]
- [redacted] had all cockpit displays go blank if a specific type of instrument approach to any one of seven specific airports was selected in the flight management computer.[67]
- [redacted] equipped with flight management systems by [redacted] would make wrong turns during missed approach procedures executed by the autopilot in some specific cases when temperature compensation was activated in cold weather.[68]
- In June 1996, [redacted] failed less than a minute after launch, because the horizontal bias value was too big for a 16 bit register.

- Modeling and Simulation-Based Systems Engineering

Motivation

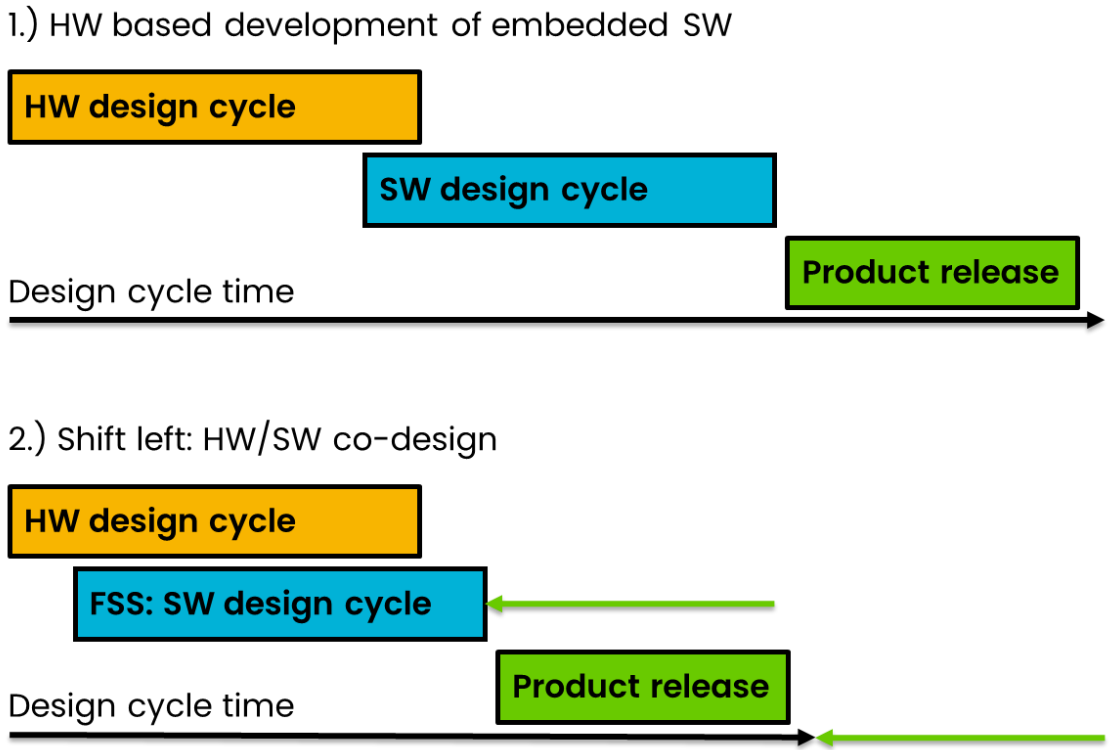
Models are the Basis for Engineering

- Contain more detail than text specifications
  - no need to reread (reinterpret) text specifications repeatedly
  - less ambiguous (execute and observe)
- Can be shared
  - virtual integration of component models build larger systems (reuse and integrate)
  - early customer involvement
- Evaluate safety functions
  - fault injection
- Enable hardware/software co-design
  - improve time-to-market (shift left)

Introduction

Shift Left with HW/SW Co-Design

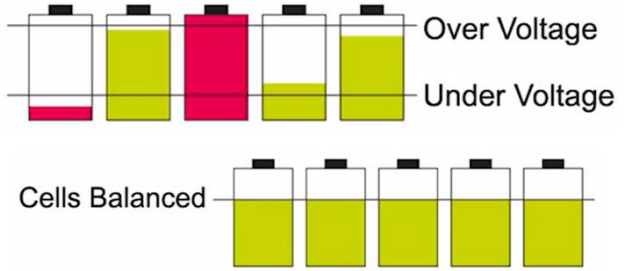
- Developing HW and SW in parallel
  - traditional: first develop ECU then SW
  - faster: start early SW development with virtual prototype
  - supports collaboration and quality of results reducing time to production
- Early SW testing
  - HW and lab space limit test cycles
  - fast and more test cycles enable increased coverage
  - fault injection to test safety features



High Voltage Battery Management System

High Voltage Battery Management System

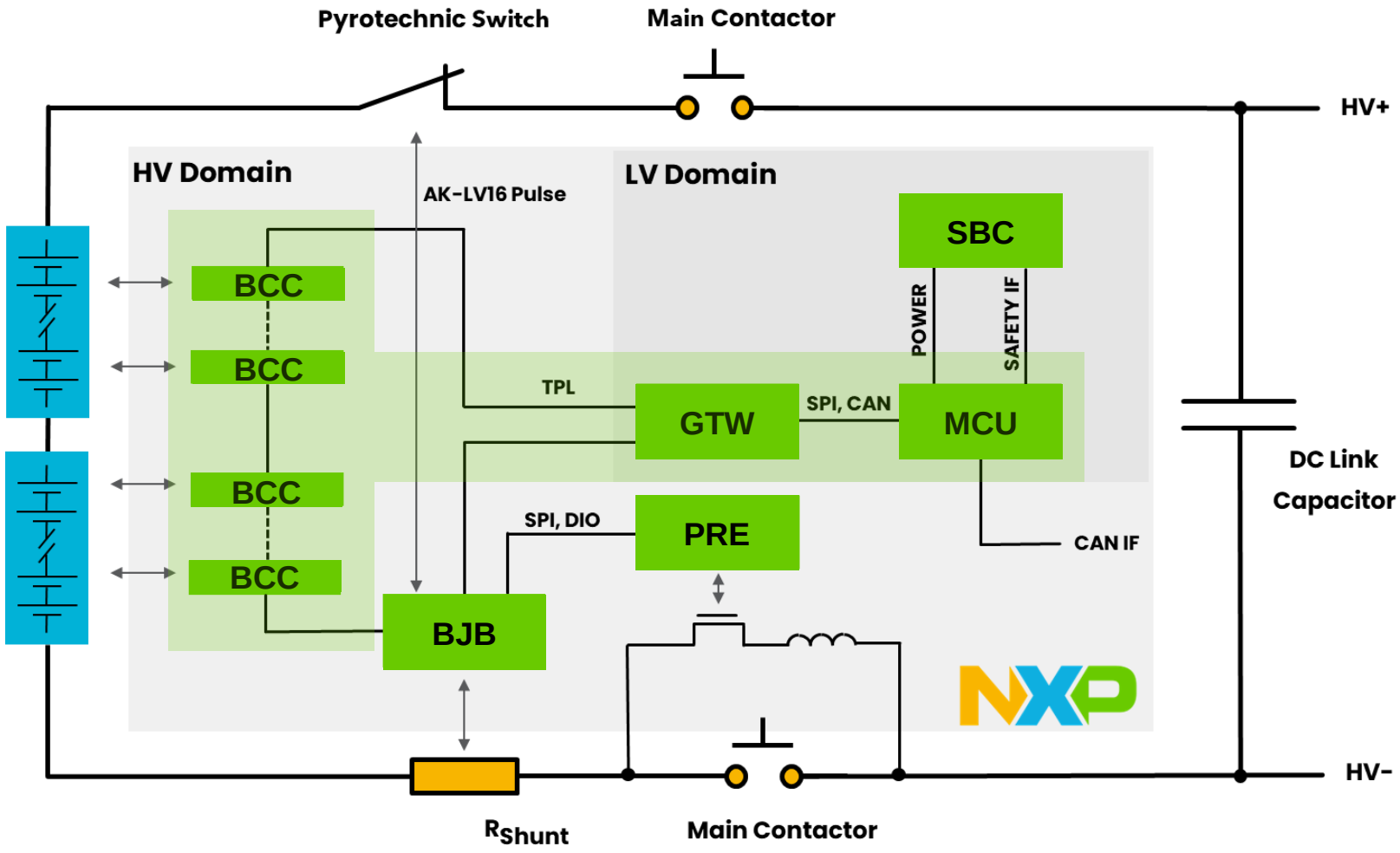
- No one size fits all BMS solution
  - scooters, motorcycles, buses, trucks, trains, boats or airplanes
  - battery packs as low as 14V or high voltages of 800V and more
- BCC directly connected to cells
  - no means of “turning off and on again”
  - low power consumption to avoid discharge of the cells
- Fire in an electric vehicle is an (ASIL) D hazard
- Supervises voltage and temperature of cells
- Cell balancing
  - lowest voltage cell limits discharge
  - highest voltage cell limits charging



High Voltage Battery Management System

System Solution of a HV BMS

- MCU
  Microcontroller Unit
- GTW
  Gateway
- BCC
  Battery Cell Controller
- TPL
  Transport Protocol Link
- BJB
  Battery Junction Box
- PRE
  Precharge
- SBC
  Safety System Basis Chip



Full System Simulation Setup

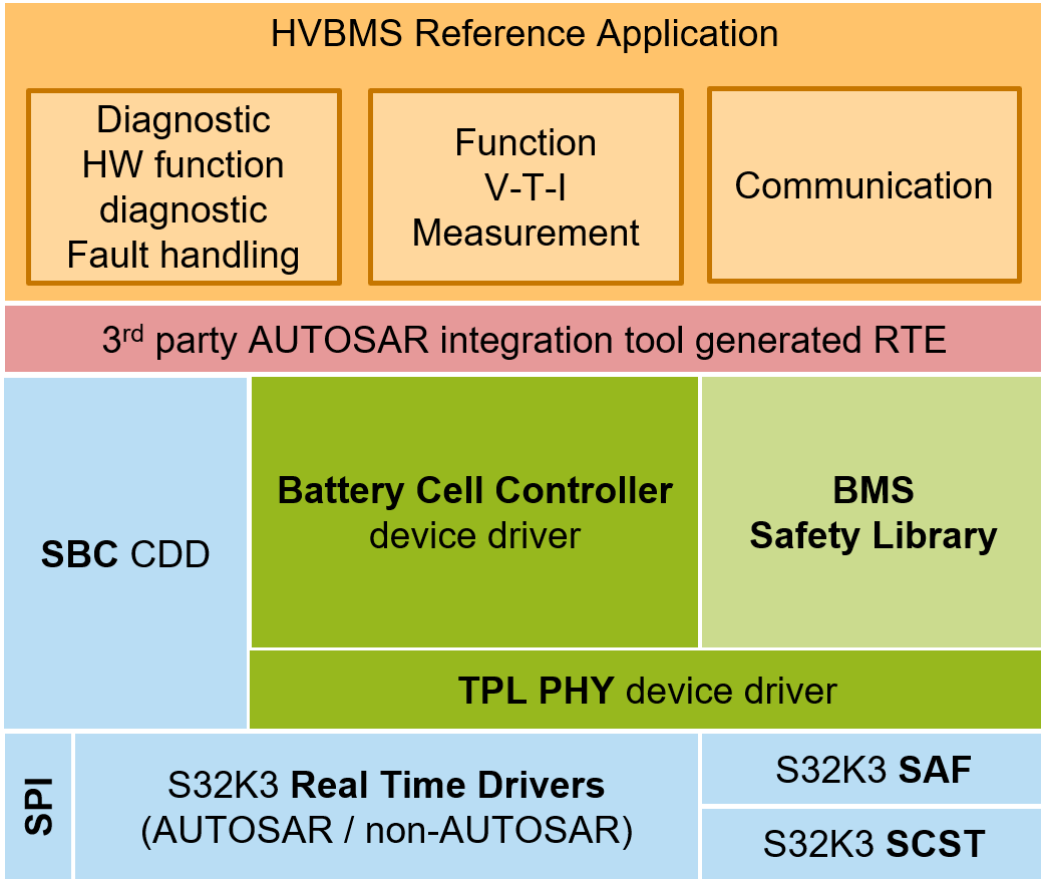
Full System Simulation Setup

Software Stack

- Real time drivers
  - real time communication
- Complex device drivers
  - system basis chips
  - battery cell controller
  - …
- Safety library

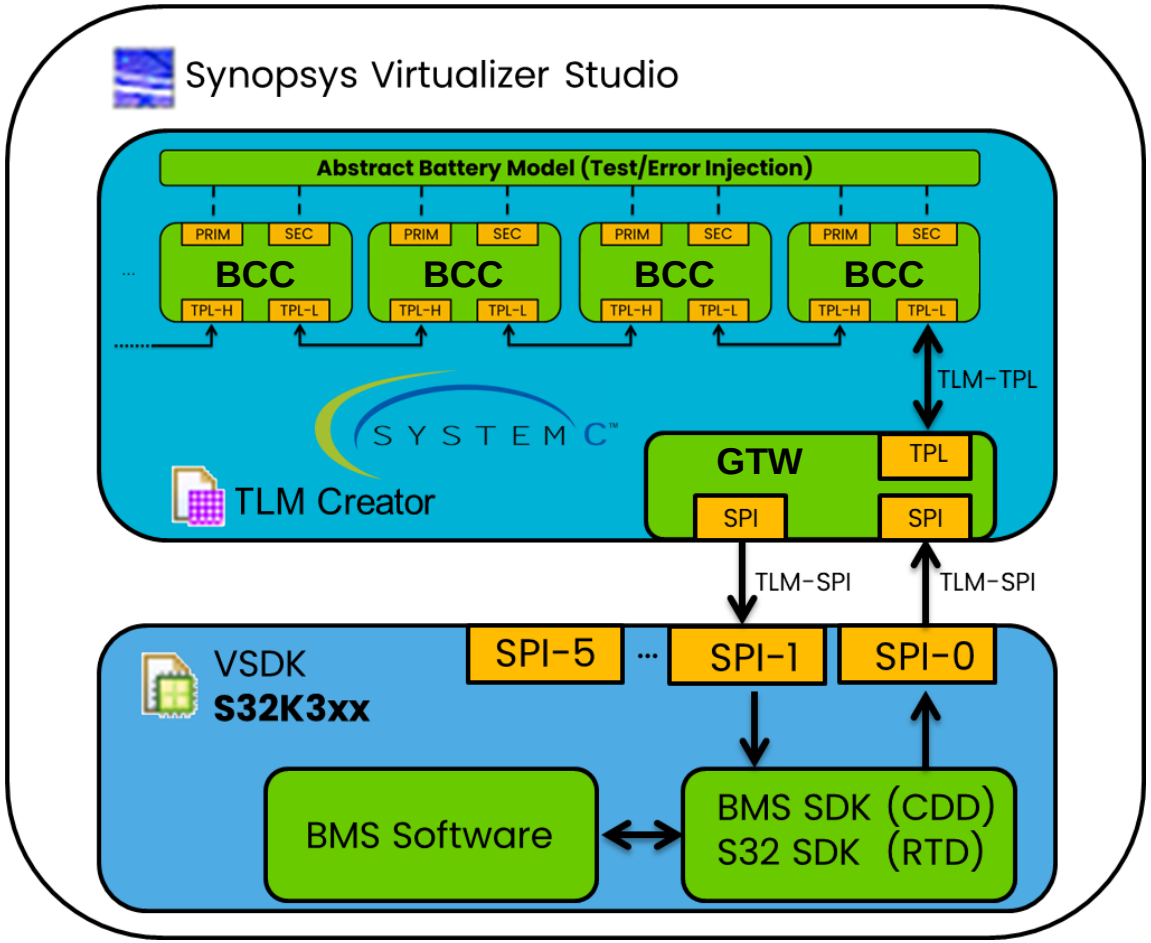
- Application

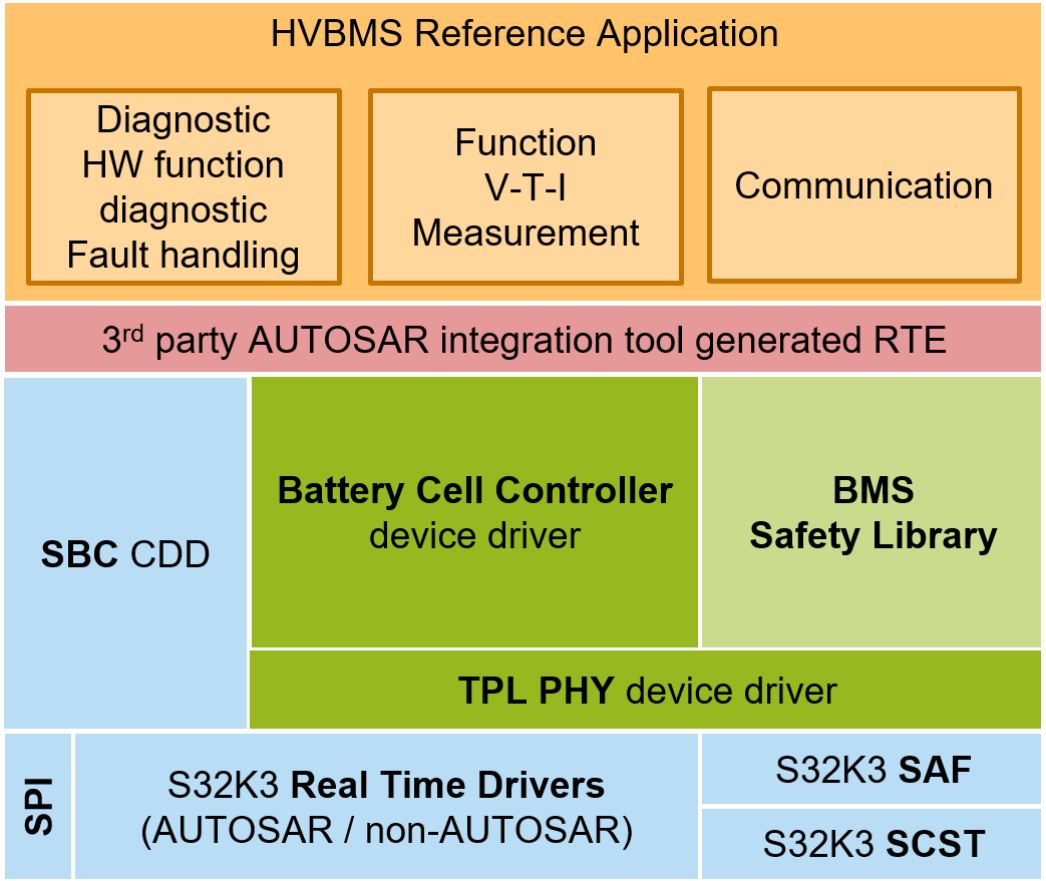
Software Stack Based on AUTOSAR Standard



Full System Simulation Setup

Hardware





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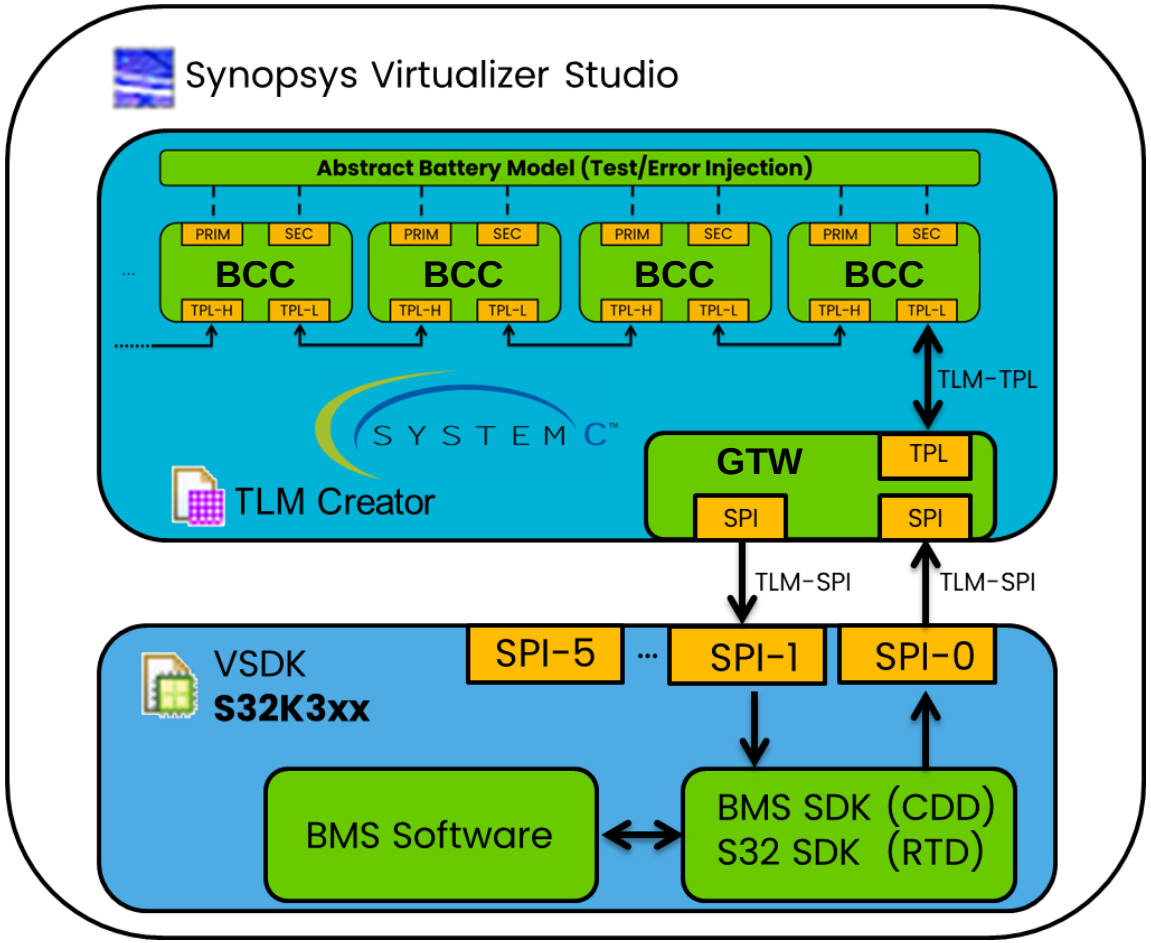
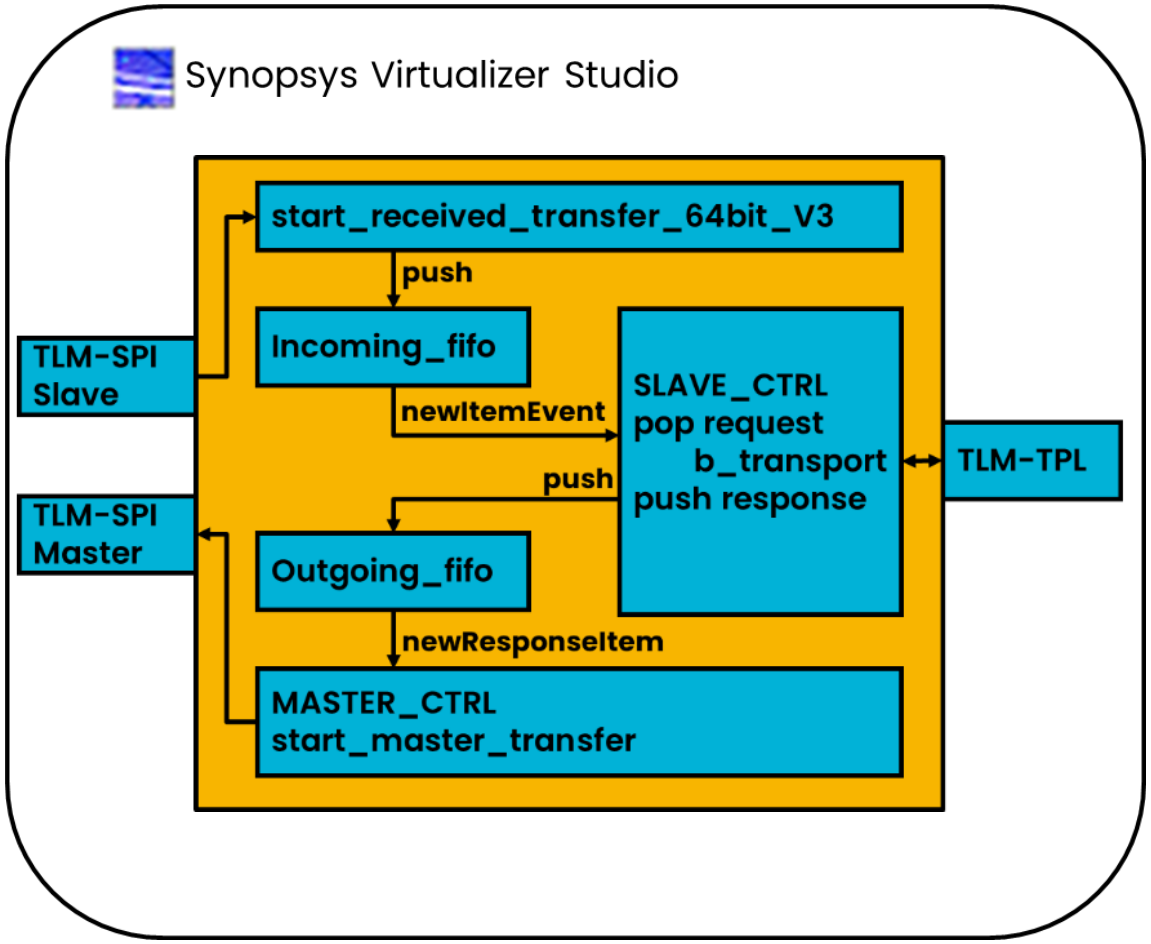


- Synopsys VSDK of NXP's MCU
  - complete hardware perspective with registers and peripherals (GPT, UART, CAN, SPI)
- BCC functional SystemC model
  - SystemC architecture generated from SysML
  - functional behavior added manually
  - importing SystemC into TLM creator using python script (300 path- and filenames)
- Gateway
  - helpful Synopsys tutorial on SPI controller
  - translates TLM-SPI to TLM-TPL
- Drag and drop into VSDK
  - components in Virtualizer Studio Library

Full System Simulation Setup

Hardware



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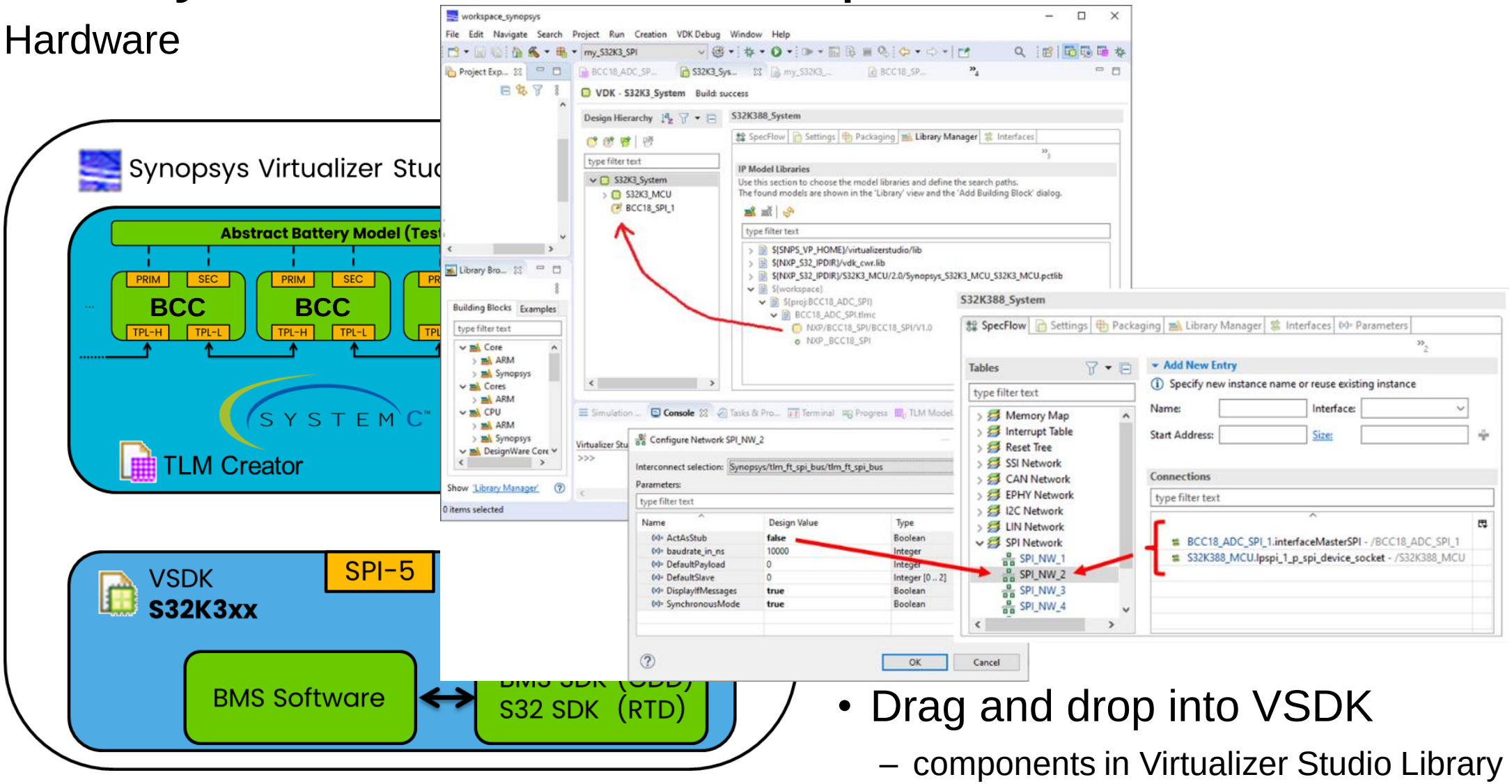

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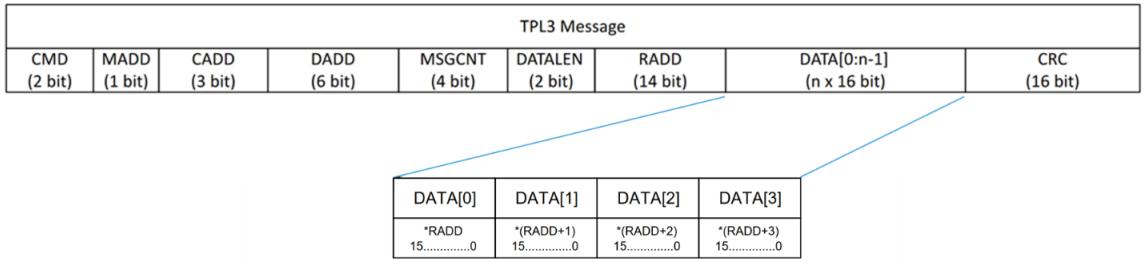
Issue with TLM-SPI

Issue with TLM-SPI

Transport Protocol Link



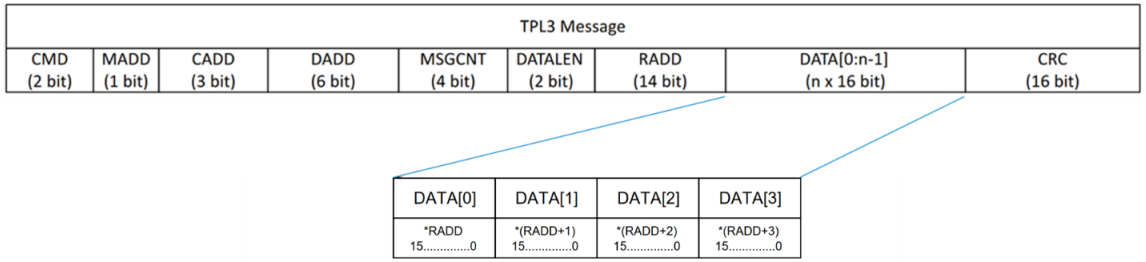
- Copy frame bits from SPI to TPL
- TPL can have 64, 80, 96 or 112 bits
  - Length encoded inside the frame itself
- TLM-SPI can carry max of 64 bit
  - decided to send 16 bit TLM-SPI messages
  - Four to Seven TLM-SPI for one TLM-TPL
- How to know start of new TPL-frame?

```
received_transfer_64bit_V3(
    unsigned long long data,
    unsigned bit_length,
    bool continuous_select
)
```

Issue with TLM-SPI

How to know start of new TPL-frame?

- Decode the frame and look for DATALEN
  - bitwise interpretation breaks level of abstraction
  - adds function to GTW that is not there
- Collect until continuous select flag becomes ‘0’
- We would see cases with faulty flag
  - SW RTD? HW GTW? TLM-SPI?
  - Fix for VSDK by Synopsys within three days




```
received_transfer_64bit_V3(
    unsigned long long data,
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    bool continuous_select
)
```
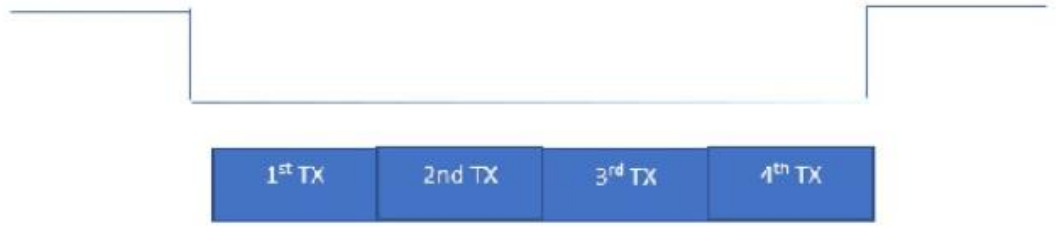

Figure 2-3 Continuous Select Flag Sending 64 Bits of Data



To send 64 bits of data in a single `job` of SPI, when only 16 bits of data can be sent by the SPI device at a time (that is, in a single payload), the continuous select flag is set as follows:

`1st Tx payload`: Continuous Select = `1` (start of `Tx`)

`2nd Tx payload`: Continuous Select = `1`

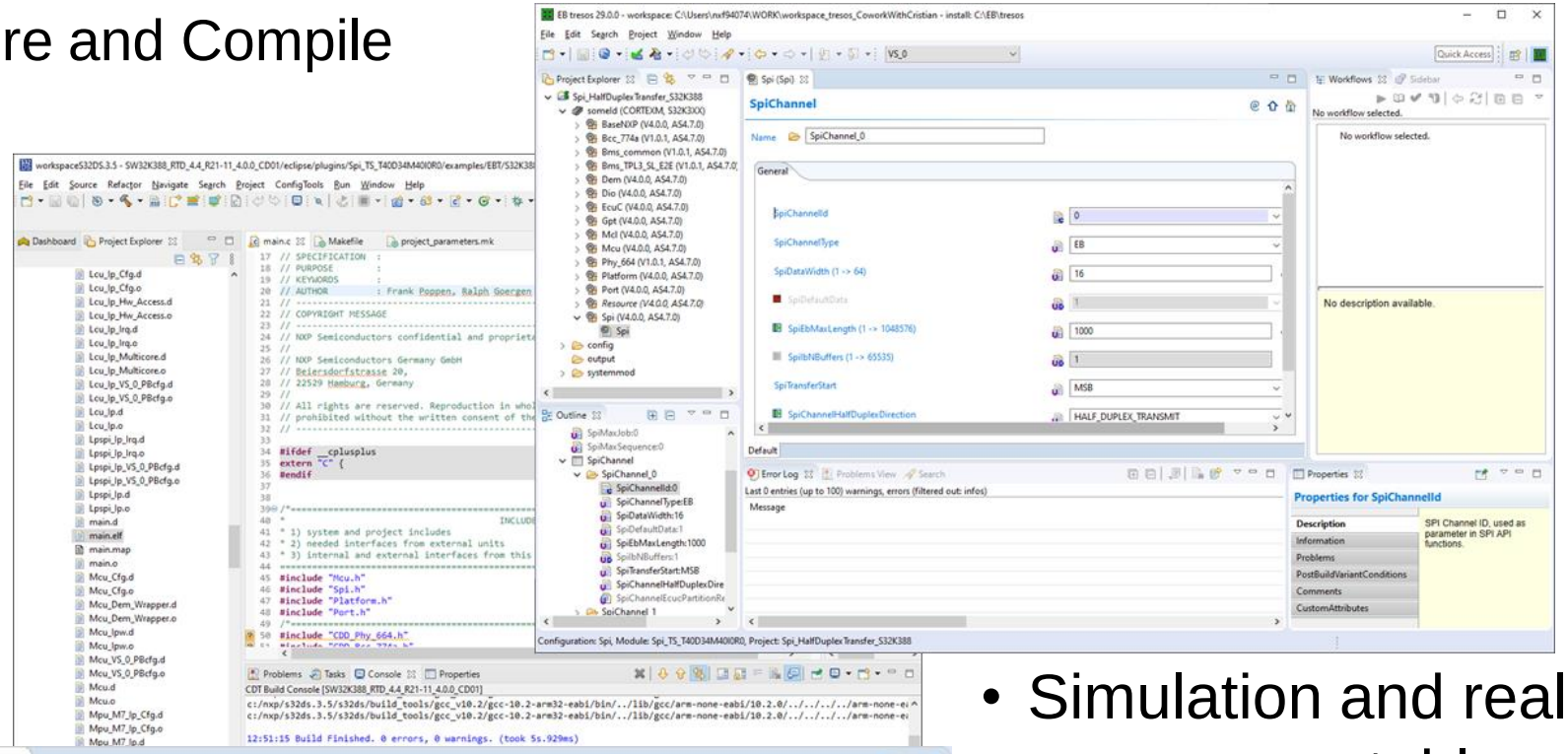
`3rd Tx payload`: Continuous Select = `1`

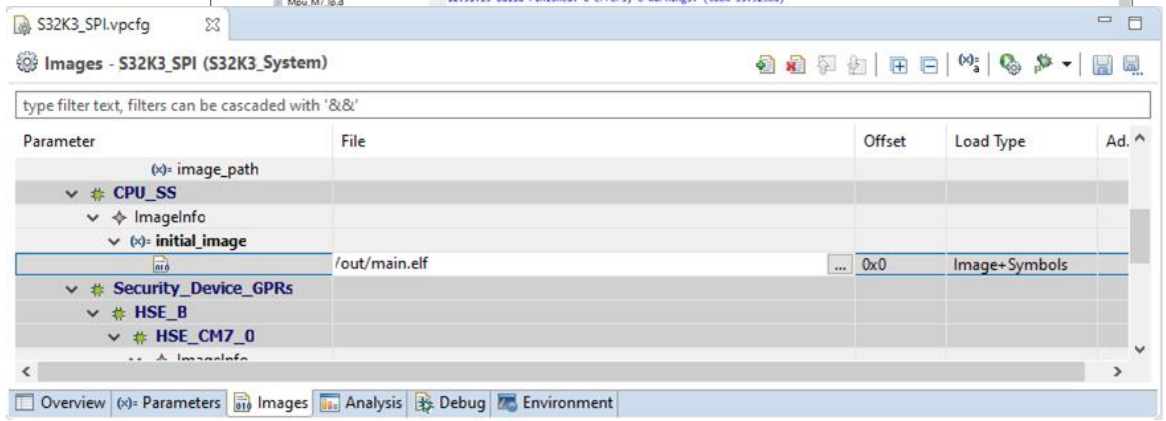
`4th Tx payload`: Continuous Select = `0` (end of `Tx`)

Complete SW Stack Execution

Complete SW Stack Execution

Configure and Compile



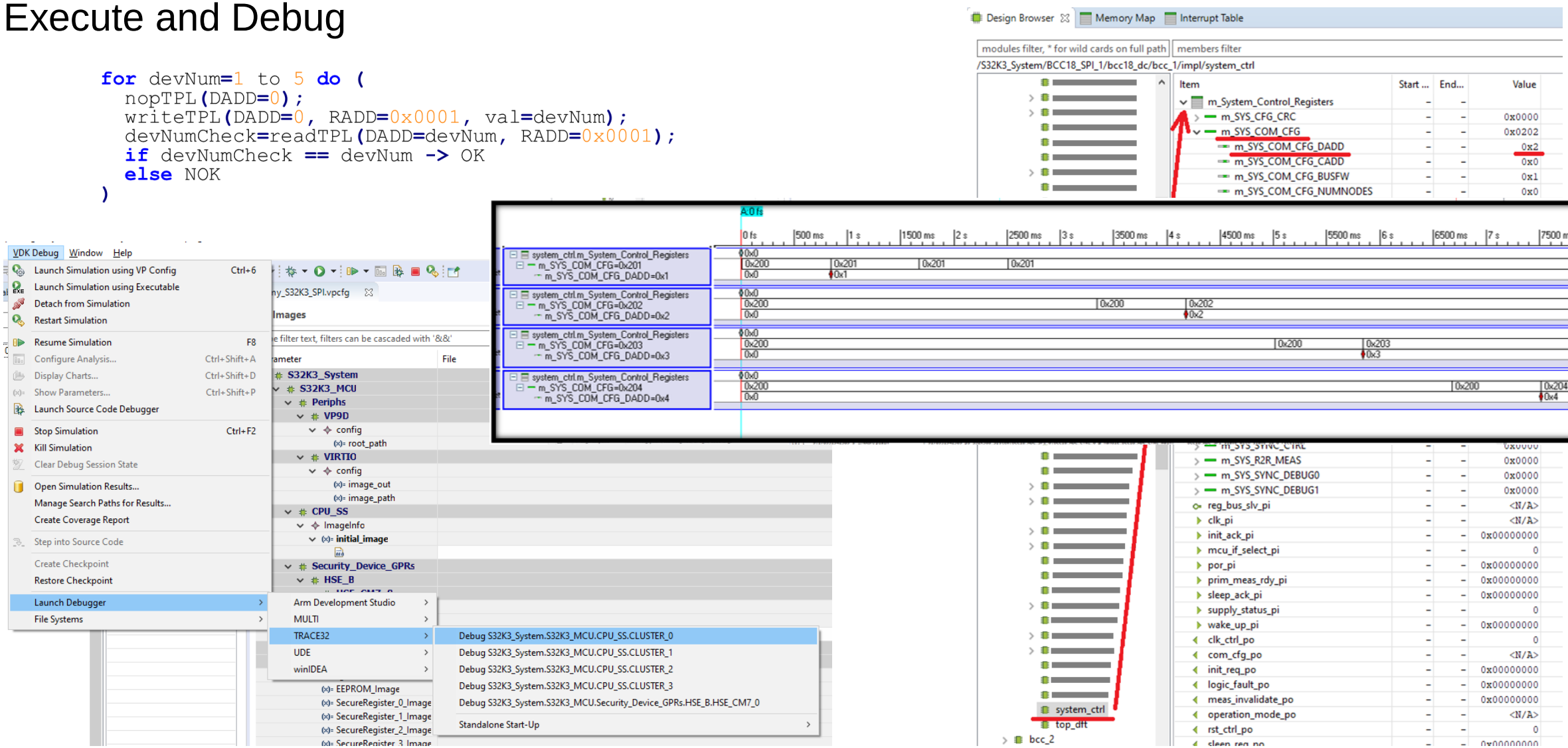


- Simulation and real device operate on same executable
- Compiler setup is used for both cases
  - Elektrobit (EB) Tresos as microcontroller abstraction layer (MCAL) AUTOSAR workflow
  - design and compilation environment S32 Design Studio (S32DS)

Complete SW Stack Execution

Execute and Debug

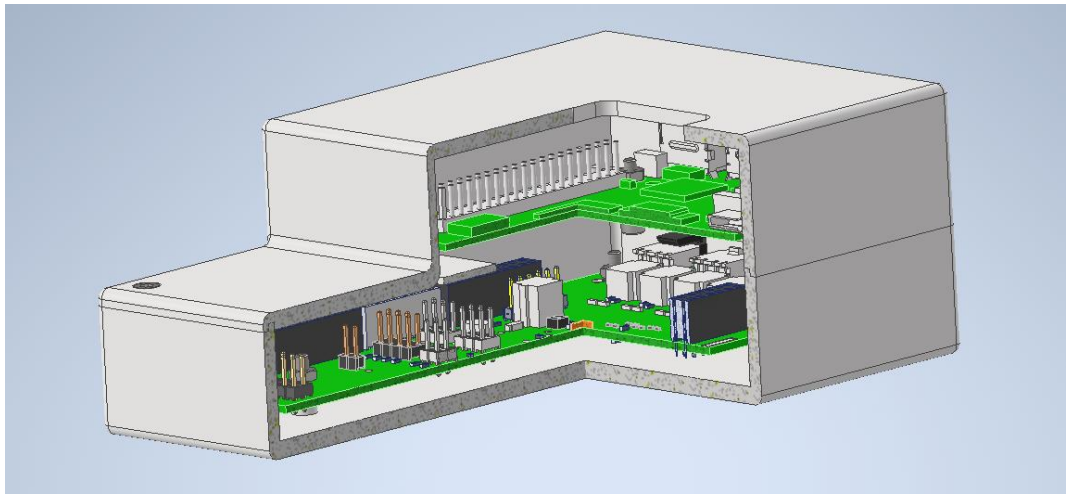
```
for devNum=1 to 5 do (
  nopTPL(DADD=0);
  writeTPL(DADD=0, RADD=0x0001, val=devNum);
  devNumCheck=readTPL(DADD=devNum, RADD=0x0001);
  if devNumCheck == devNum -> OK
  else NOK
)
```



Conclusions and Future Work

Conclusion and Future Work

- Experience and results are very convincing
- Investment of resources is justified
- Involved RTD/CDD developers:
  - “when to make use of this in our projects?”
  - “would help to clean out laboratory space!”



- Functionality behind registers must be coded manually and is not complete
- Product variants to be modelled
  - reuse potential expected between models
- Accurate battery cell models
  - simple model does not respond to load
  - possibly connect to Matlab/Simulink or similar
- Ideally, Synopsys would open up SCML as open-source standard
- Emulation with MIL (Model In the Loop)
  - first experiments with Raspberry Pis 4 and 5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