ETAS INTECRIO V5.0

User Guide

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INTECRIO V5.0 I User Guide R05 EN – 06.2023

Contents

1 Safety and Privacy Information

In this chapter, you can find information about the intended use, the addressed target group, and information about safety and privacy related topics.

Please adhere to the ETAS Safety Advice (**Help > Safety Advice**) and to the safety information given in the user documentation.

ETAS GmbH cannot be made liable for damage which is caused by incorrect use and not adhering to the safety information.

1.1 Intended Use

INTECRIO is an integration platform for prototyping of automotive embedded control systems. It allows for the integration of application software from a wide variety of sources (e.g., ASCET, MATLAB® and Simulink®, C code) on embedded control units.

Virtual prototyping minimizes development times and is therefore becoming increasingly important. With the virtual prototyping capabilities of INTECRIO, system models can be analyzed without the need for complex prototyping hardware.

With the rapid prototyping capabilities of INTECRIO, control and diagnostic functions can be validated and verified under real conditions – also in the vehicle. Prototypes can be integrated into existing ECU vehicle networks via the ETAS rapid prototyping hardware. In a bypass application (via ETK, XETK, FETK, and XCP), INTECRIO enables the rapid prototyping hardware to be used as a simulation controller and calculates the parameters for new ECU functions.

1.2 Target Group

This manual is intended for trained personnel specializing in the area of function and software development for embedded electronic systems.

INTECRIO users should be familiar with the operating systems Microsoft Windows® 10 or Windows® 11.

Knowledge of a programming language, preferably ANSI-C, can be helpful to advanced users.

Knowledge of the behavioral modeling tools ASCET and MATLAB and Simulink supported by INTECRIO are assumed.

1.3 Classification of Safety Messages

Safety messages warn of dangers that can lead to personal injury or damage to property:

⚠ DANGER

DANGER indicates a hazardous situation with a high risk of death or serious injury if not avoided.

WARNING

WARNING indicates a hazardous situation of medium risk, which could result in death or serious injury if not avoided.

CAUTION

CAUTION indicates a hazardous situation of low risk, which may result in minor or moderate injury if not avoided.

NOTICE

NOTICE indicates a situation, which may result in damage to property if not avoided.

1.4 Safety Information

Please adhere to the ETAS Safety Advice and to the following safety information to avoid injury to yourself and others as well as damage to property.

WARNING

Harm or property damage due to unpredictable behavior of vehicle or test bench

Wrongly initialized NVRAM variables can lead to unpredictable behavior of a vehicle or a test bench. This behavior can cause harm or property damage.

INTECRIO systems that use the NVRAM possibilities of the experimental targets expect a *user-defined* initialization that checks whether all NV variables are valid for the current project, both individually and in combination with other NV variables. If this is not the case, all NV variables have to be initialized with their (reasonable) default values.

Due to the NVRAM saving concept, this is *absolutely necessary* when projects are used in environments where any harm to people and equipment can happen when unsuitable initialization values are used (e.g. in-vehicle-use or at test benches).

In addition, take all information on environmental conditions into consideration before setup and operation (see the documentation of your computer, hardware, etc.).

Further safety advice for this ETAS product is available in the following formats:

- In electronic form on the installation medium: `Documentation\General\ETAS Safety Advice.pdf`
- The "ETAS Safety Advice" window that opens when you start the program, or when you select **Help › Safety Advice**.

1.5 Privacy

Your privacy is important to ETAS so we have created the following Privacy Statement that informs you which data are processed in INTECRIO, which data categories INTECRIO uses, and which technical measure you have to take to ensure the users' privacy. Additionally, we provide further instructions where this product stores and where you can delete personal data.

1.5.1 Data Processing

Note that personal data respectively data categories are processed when using this product. The purchaser of this product is responsible for the legal conformity of processing the data in accordance with Article 4 No. 7 of the General Data Protection Regulation (GDPR). As the manufacturer, ETAS GmbH is not liable for any mishandling of this data.

1.5.2 Data and Data Categories

Please note that this product creates files containing file names and file paths, e.g. for purposes of error analysis, referencing source libraries, or for communicating with third-party programs.

The same file names and file paths may contain personal data, if they refer to the current user's personal directory or subdirectories (e.g., `C:\Users\`*`<UserId>`*`\Documents\...`).

Furthermore, using ETAS Rapid Prototyping solutions in test vehicles connected to real sensors, buses or ECUs, the ETAS tools may get access to personal data of the driver.

This data can also be stored using dataloggers as provided by INCA-EIP or the ETAS Experiment Environment.

When using the ETAS License Manager in combination with user-based licenses, particularly the following personal data respectively data categories can be recorded for the purposes of license management:

- Communication data: IP address
- User data: UserID, WindowsUserID

1.5.3 Technical and Organizational Measures

This product does not itself encrypt the personal data respectively data categories that it records. Ensure that the data recorded are secured by means of suitable technical or organizational measures in your IT system.

Personal data in log files can be deleted by tools in the operating system.

2 About INTECRIO

INTECRIO integrates code from various behavioral modeling tools, makes it possible to configure the prototype as well as a hardware system for Rapid Prototyping, and allows the generation of executable code.

This manual supports the user when getting to know INTECRIO to ensure fast results. It provides a step-by-step introduction to the system with all information easy to look up.

NOTE

See also chapter "About INTECRIO" in the Getting Started manual.

The INTECRIO user guide supports readers in becoming acquainted with INTECRIO.

Chapter 3 "Understanding INTECRIO" presents the concepts that are important for working with INTECRIO.

Chapter 4 "INTECRIO and AUTOSAR" describes how INTECRIO supports AUTOSAR.

Chapter 5 "INTECRIO Components" describes the different components of INTECRIO, their tasks and methods of operation. Operating the components is explained in the online help.

Chapter 6 "SCOOP and SCOOP-IX" describes the SCOOP concept for the description, management and exchange of C code interfaces and the interface describing language SCOOP-IX.

Chapter 7 "Modeling Hints" describes how the behavioral modeling tools are used in conjunction with INTECRIO and provides an overview of the modeling philosophy of INTECRIO.

Chapter 8 "Bypass Concept" contains information on service-based and hook-based bypass, and chapter 10 "Glossary" contains lists of the most important abbreviations and terms.

3 Understanding INTECRIO

Today, developers of electronic control units often face the problem that the control algorithms are developed for an embedded control software without the availability of any target hardware. The algorithms are created using behavioral modeling tools such as ASCET or MATLAB® and Simulink® – i.e. with tools that allow for generating code based on the models. To overcome the lack of target hardware, virtual prototyping or a rapid prototyping hardware system, such as the ES900 and ES800 systems of ETAS, is used.

INTECRIO is an ETAS product family that supports developers in their daily task of developing embedded control software by providing a uniform software platform for virtual prototyping and rapid prototyping applications.

INTECRIO integrates code from different behavioral modeling tools (BMTs) in a complete virtual prototyping or rapid prototyping system, enables configuring the prototype and a hardware system for rapid prototyping, and allows the creation of executable code. Finally, the ETAS Experiment Environment allows for performing the virtual prototyping or rapid prototyping experiment. (In this context, performance means the process of the experiment under real-time conditions and the possibility of measuring and calibrating values during the experiment.)

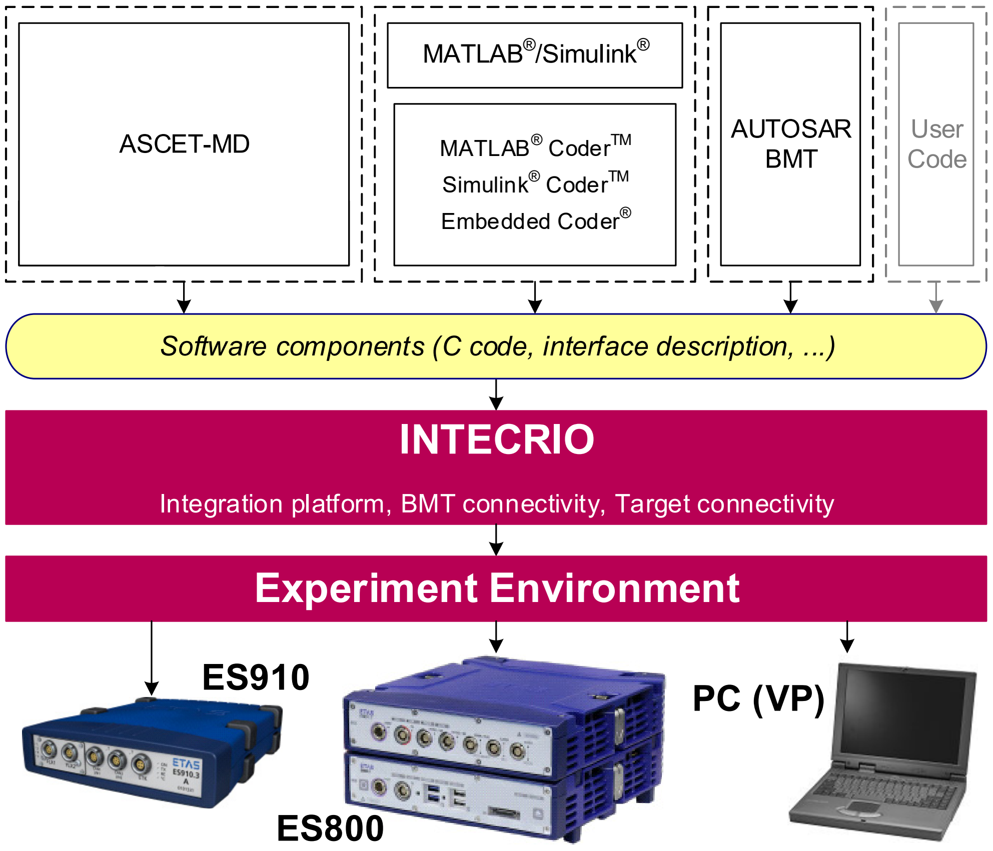


Fig. 3-1 INTECRIO – Overview

Before discussing the content details of INTECRIO in more detail, a few notes are necessary about electronic control unit development in general, about virtual prototyping and about the position of INTECRIO in the development cycle.

3.1 Challenges of the Electronic Control Unit Development

The electronic control unit development is a highly complex process: Partly because of the constantly increasing requirements of hardware and software, partly because of the development which is frequently spread across several manufacturers and suppliers.

3.1.1 Complexity Through System Requirements

Today, the complete description of an electronic control unit consists of the description of the software to be run on the electronic control unit and the description of the hardware. In most cases, control algorithms and electronic control unit software are closely linked with the target system on which they are executed.

ASCET introduced the first steps to dissolve this mutual dependency by describing the software (the control algorithm) independently of the hardware on which it is to run. ASCET accomplishes this by mapping the signals from the control algorithm onto the signals supplied by the hardware. If it is a rapid prototyping system, the hardware itself is described in a special editor. Different options exist for microcontroller targets.

In the future, this separation of the descriptions of the target hardware and the software will become increasingly more important for the successful implementation of a new electronic control unit.

On the one hand, it allows electronic control unit software and hardware to be developed in parallel (see Fig. 3-2; the figure is based on the V model). This shortens the total development time.

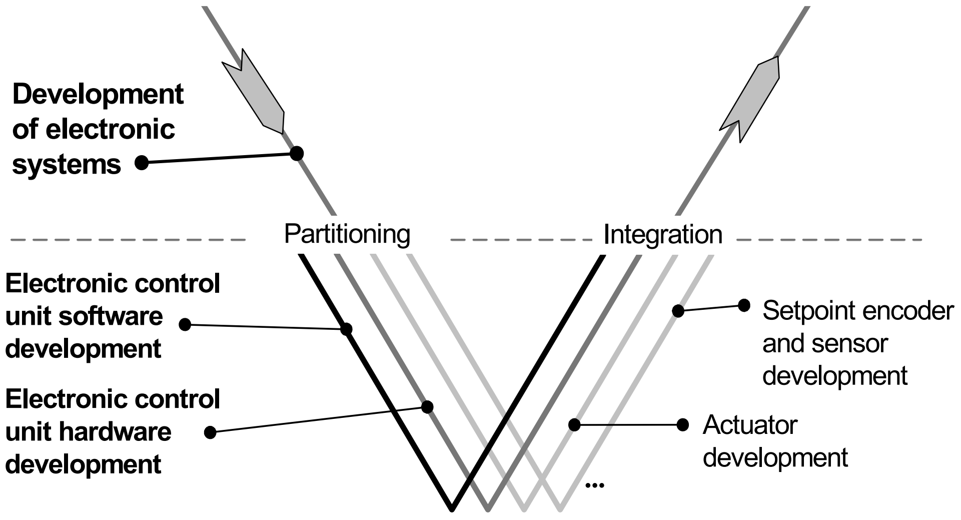

Development of electronic systems
Partitioning
Integration
Electronic control unit software development
Electronic control unit hardware development
Setpoint encoder and sensor development
Actuator development
...

Fig. 3-2 Overview of the development of electronic systems

On the other hand, the systems themselves become increasingly more complex, and correlations between the different electronic control units are increasing. The number of electronic control units per vehicle as well as the number of functions per electronic control unit constantly increased during recent decades (see Fig. 3-3).

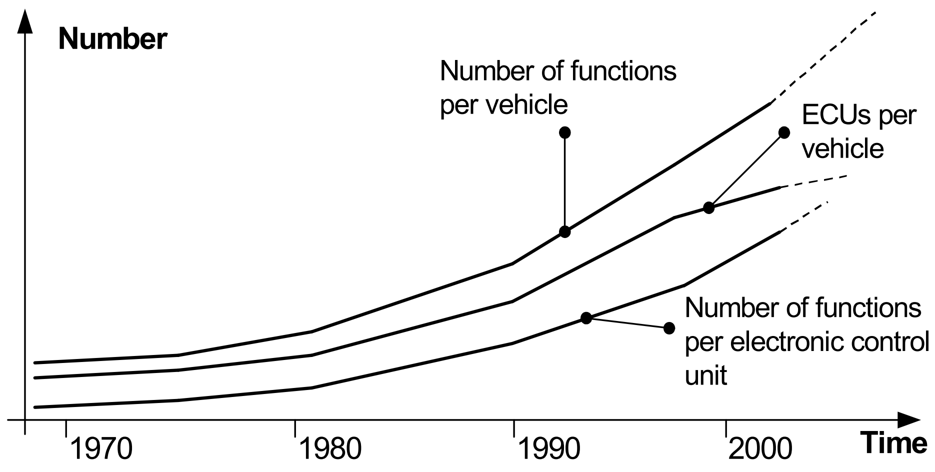


Fig. 3-3 Functions and electronic control units per vehicle (in *The Need for Systems Engineering. An Automotive Project Perspective*, Key Note at the 2nd European Systems Engineering Conference, Munich, H.-G. Frischkorn, H. Negele, J. Meisenzahl)

Car manufacturers and suppliers are faced with an enormous cost pressure; they are forced to reduce costs by means of reuse and variants. That is, a certain functionality is used for different vehicle types of a car manufacturer, and vehicle variants are created via software properties. The difference between two variants of a vehicle may consist only in the presence or absence of a certain software functionality and the corresponding sensors and actuators.

For this purpose, the hardware-independent development of the functionality is a great advantage since this allows the functionality to be used universally.

The costs can also be reduced by arranging the software components on the smallest possible hardware system. This limits the number of electronic control units in the vehicle, but it may require the distribution of the components of one functionality to several electronic control units.

In addition, new functionality can be added to a vehicle by means of so-called virtual sensors. These are sensors that do not measure their signals, but calculate them. This calculation can be performed by combining physical models with real sensor values. A good example is tire slip. Tire slip cannot be measured, but by combining the tire model with the current acceleration (measured by the electronic stability program ESP) and the current torque (from the engine control), it is possible to calculate the slip.

Today's vehicle can contain up to 120 microcontrollers that are mostly connected with each other via serial bus systems. The execution of a specific control algorithm depends not only on the electronic control unit on which it runs, but also on the inputs and outputs of other electronic control units.

An example of an already distributed control algorithm is the electronic stability program (ESP) and the engine control.

As soon as a critical driving situation is discovered, the ESP system requests a reduction in engine torque from the engine control. This request is generally transferred via the CAN bus. As soon as the engine torque is reduced, the car can stabilize itself and the torque can subsequently be increased again. If the vehicle does not stabilize itself, the engine torque must be further reduced.

The following components are involved in the control algorithm: The ESP must detect the necessity for reducing the engine torque. It must send the CAN message and wait for a free position on the CAN bus. Depending on the load on the CAN bus and the configuration of the communication, this may take some time. Next, the engine control unit must process the request for a torque reduction. The engine control unit also has other tasks (namely the engine control) that are very time-critical. As soon as it finds some time to reduce the torque, it will do so. The sum of all these waiting times provides an imperfect control behavior which the driver may even notice (which is extremely undesirable).

This example underscores the fact that the electronics in the vehicle is becoming more and more complex. On the other hand, the electronics plays an important role for the success of a vehicle since 90% of all innovations in today's vehicles are based on electronics. For this reason, car manufacturers and suppliers alike are very much interested in increasing the quality and functionality of their vehicles.

3.1.2 Complexity Through Distributed Development

An additional contribution to the complexity of the electronic control unit development consists of the fact that the development is often formed by a strong division of labor between car manufacturers and suppliers. While the user requirements to be considered on a function of the vehicle to be developed are generally defined by the car manufacturer, the implementation of the functions through electronic systems is often carried out by suppliers. However, the coordination and acceptance of the implemented functions in the vehicle is generally the responsibility of the car manufacturer.

An indispensable prerequisite for a successful development with such a division of labor is a precise definition of the interfaces between car manufacturer and supplier. They can be clearly represented in the V model (Fig. 3-4). While the car manufacturer carries the responsibility for the vehicle–on the left as well as the right branch of the V model–the suppliers are frequently in charge of the component level, at times even for the first integration steps.

These interfaces can be defined differently from case to case, but they must be defined exactly and completely in any case.

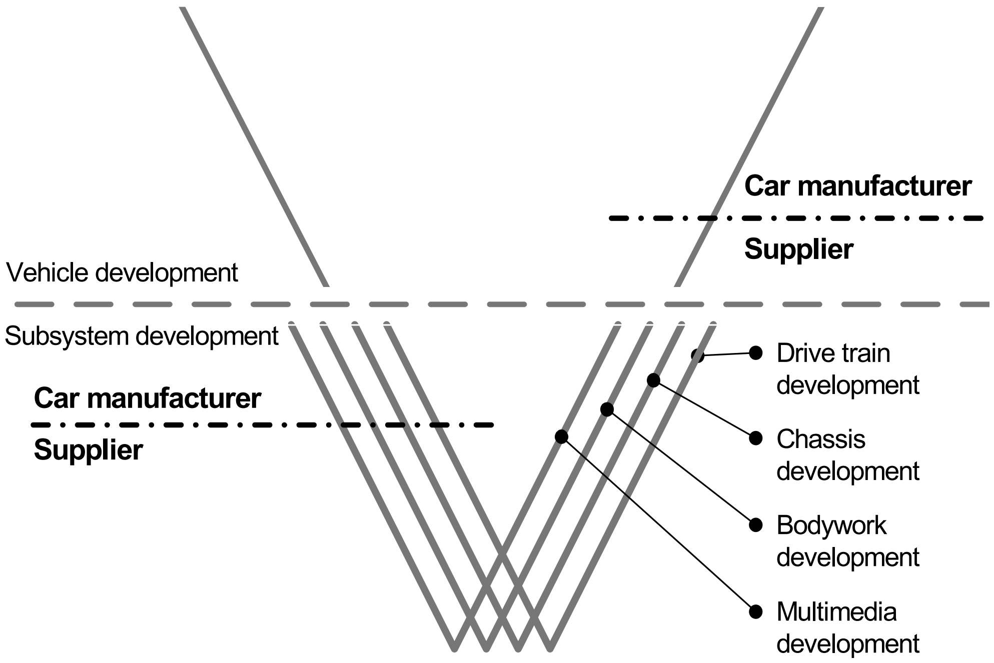


Fig. 3-4 Responsibilities of car manufacturers and suppliers. The interfaces entered (dot-dash-lines) are examples.

The AUTOSAR partnership develops a standardization of basic system and interface functions. INTECRIO V5.0 supports AUTOSAR; see chapter 4 for more information.

3.1.3 Possible Steps

One could say now that the best way for a cost reduction consists of first defining the functionality that a vehicle must have, and then to determine which hardware is required for the system to run.

However, this would mean to redevelop the complete vehicle functionality at once, which would involve significant effort and even risks. Therefore, it would be more obvious to first describe today's electronic system and to control the complexity it contains. INTECRIO was developed for this reason. As soon as it is under control, optimization is the next step.

Additional information can be found in

- J. Schäuffele, Dr. T. Zurawka: "Automotive Software Engineering – Principles, Processes, Methods, and Tools".

3.2 Description of Electronic Systems

A complete electronic control unit description requires a description of the hardware as well as the software. As mentioned above, today's software can no longer be viewed only as a collection of different software components that run on independent electronic control units. Frequently, a complete control algorithm is already distributed across several electronic control units and, therefore, must be viewed and described as a whole, without orientation to the special electronic control unit.

Since networks are not yet supported in INTECRIO V5.0, the focus of this section is on the description of an individual electronic control unit.

3.2.1 Design and Operating Method of Electronic Systems

Design and operating method of the electronic systems of the vehicle are explained in detail using the electrohydraulic braking system as an example.

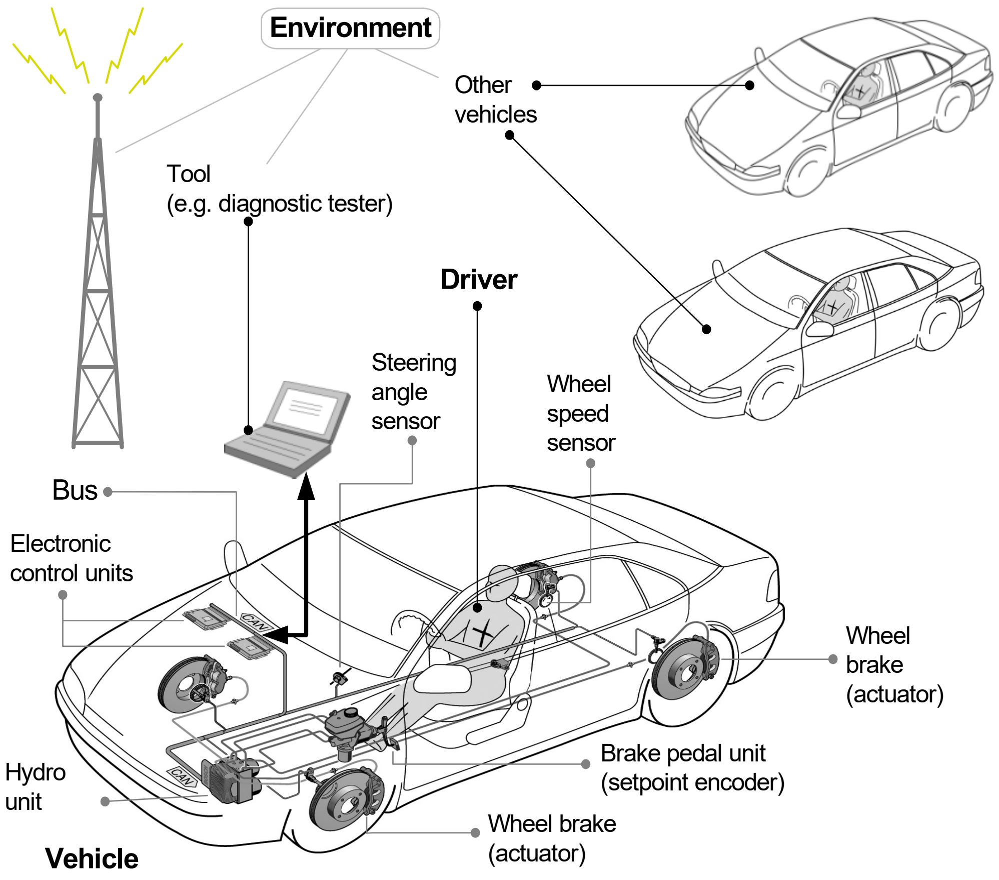


Fig. 3-5 Design of the electrohydraulic brake (in *Konventionelle und elektronische Bremssysteme*, Robert Bosch GmbH (ed.), Stuttgart, 2002)

Fig. 3-5 shows the design of the electrohydraulic braking system (Sensotronic Brake Control, SBC) from Bosch. The sensotronic brake control combines the functions of the power brake unit, anti-lock braking system (ABS) and ESP.

The mechanical activation of the brake pedal by the driver is sensed in the brake pedal unit and electrically transferred to the electronic control unit. This electronic control unit uses required values and different sensor signals, such as the steering angle signal or the wheel speed signals, to calculate output quantities which, in turn, are electrically transferred to the hydro unit where they are converted into controlled variables for the wheel brakes through pressure modulation. The handling of the vehicle, the so-called *route* (or controlled system) is influenced via the wheel brakes. For this reason, the wheel brakes are also referred to as *actuators*.

The electronic control unit can communicate with other electronic control units of the vehicle via a bus, such as CAN.

The system design illustrated by using the sensotronic brake control as an example (see Fig. 3-6) is typical for all electronic control/closed-loop control and tracing systems of the vehicle. In general, the following components of the vehicle can be distinguished: *setpoint encoder*, *sensors*, actuators, electronic control units for control/closed-loop control or tracing and route. The electronic control unit are linked by a network to allow for an exchange of data.

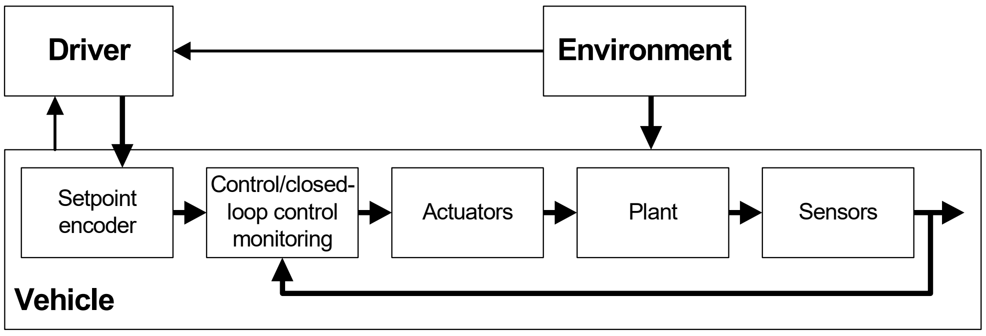


Fig. 3-6 Schematic representation of control/closed-loop control and tracing systems

The driver (possibly also other passengers) and the environment (including other vehicles or electronic systems such as diagnostic tools in the environment of the vehicle) can affect the behavior of the vehicle and are components of the higher-level system vehicle-driver-environment.

By itself, an electronic control unit is merely a means to an end. Only a complete electronic system consisting of electronic control units, setpoint encoders, sensors and actuators affects or monitors the route, thereby meeting the use expectations.

3.2.2 Architecture and Description of Electronic Systems

To describe an electronic system, a physical architecture that encompasses the electronic control units and networking of the vehicle as well as the distribution of the software to the existing hardware is required. Requirements such as the available space for the installation of electronic control units, required redundancies for safety-critical component, etc., enter into the physical architecture.

On the other hand, one needs a logical architecture that represents the functionality of the software, which ideally starts with a layout for the complete system that is subsequently broken down into functions, modules and individual classes.

In connection with AUTOSAR, AUTOSAR software components (SWC) take the place of modules and classes.

Naturally, the connection between both architectures, which distributes the functionality to the hardware, cannot be missing.

Fig. 3-7 shows the architectures; the areas where INTECRIO is used are circled.

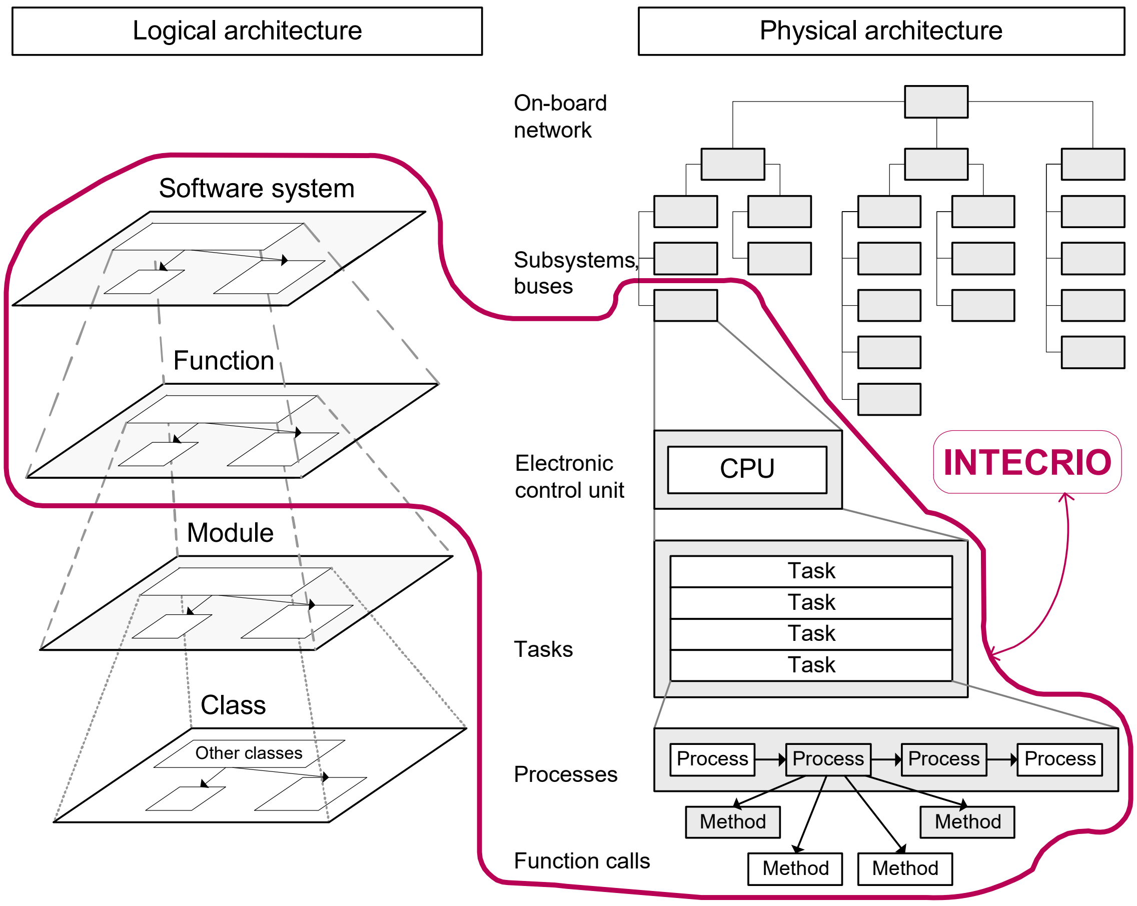


Fig. 3-7 Architecture of an electronic control unit description

A detailed description from the perspective of INTECRIO is presented below.

Fig. 3-8 shows an overview of the different components of an electronic control unit description.

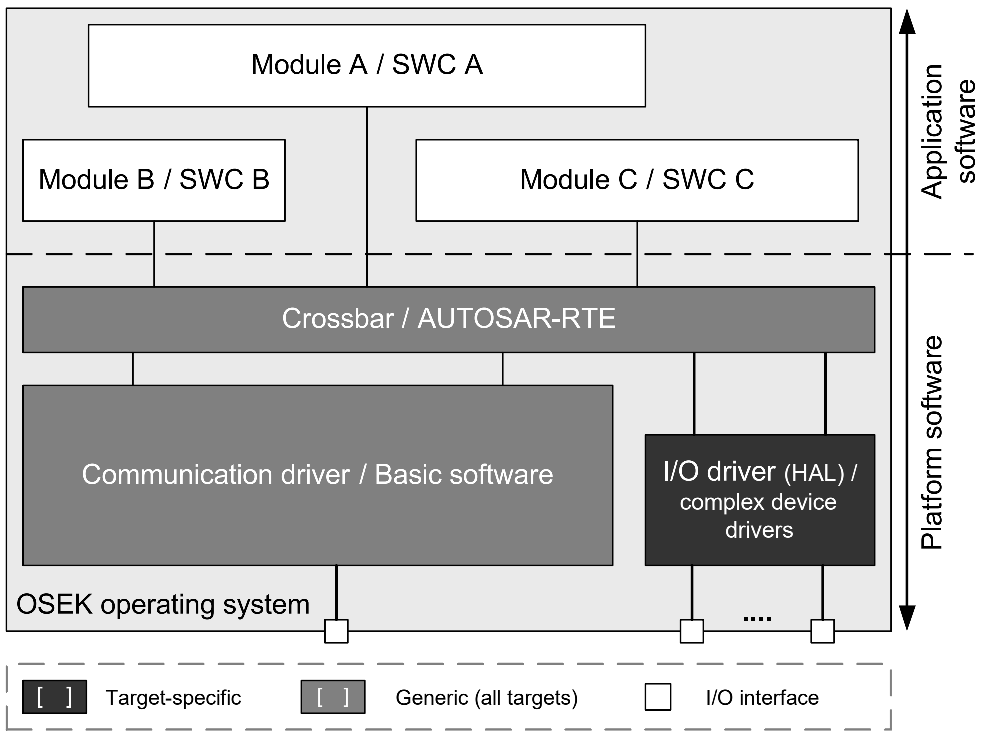


Fig. 3-8 Electronic control unit description: Overview (INTECRIO view)

3.2.2.1 Application Software

The *application software* (or functional software) contains the signal flow-driven control algorithm. This is a generic description that does not change its behavior (based on requirements and specifications). The software consists of individual modules or AUTOSAR software components and module/SWC groups or functions (see Fig. 3-9 and the left side of Fig. 3-7).

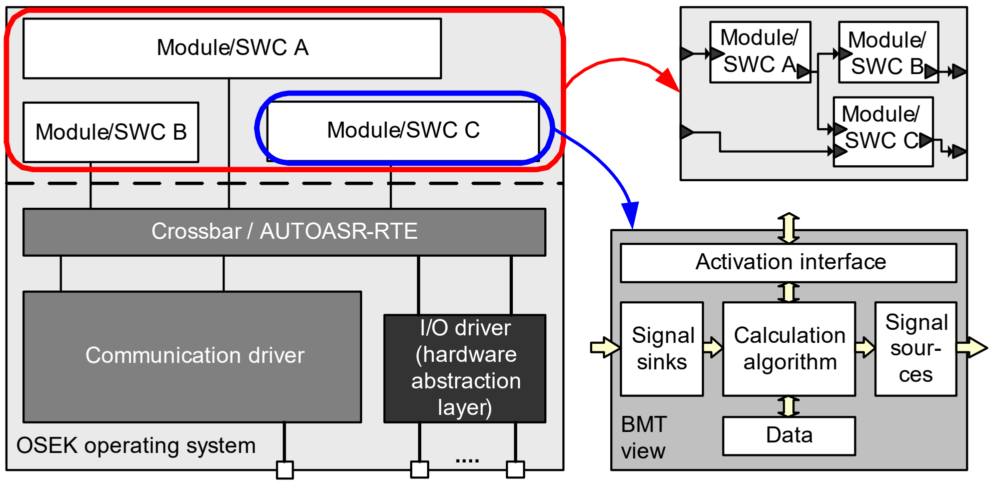


Fig. 3-9 Functional software: Details

The overview in Fig. 3-2 shows the development of the electronic control unit software as a single development phase; however, section 3.1.2, Fig. 3-4 already showed that this phase is divided again into other phases. This figure is still too rough, though; even in the development of a specific functionality, it is possible that the individual modules, SWC or functions are developed by different suppliers using different tools.

Modules and AUTOSAR software components are principally designed the same way from the INTECRIO perspective and feature the following interfaces:

- Signal sinks (inputs or clients and receivers),
- Signal sources (outputs or server and sender),
- Activation interfaces (processes or runnable entities (RE); graphically not shown).

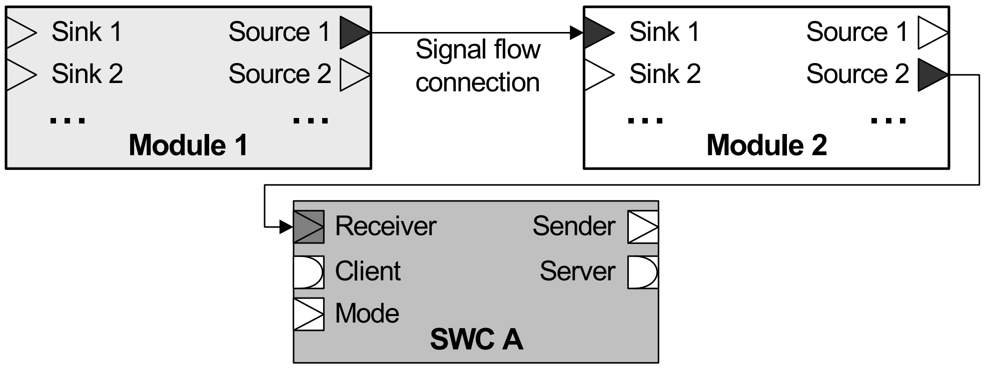


Fig. 3-10 Module/SWC: Schematic design (external view) and connection

Modules and AUTOSAR software components are also identical from an internal design. In addition to the interfaces listed, the internal view contains the following components:

- Calculation algorithm or functionality,
- Data of variables, constants and parameters.

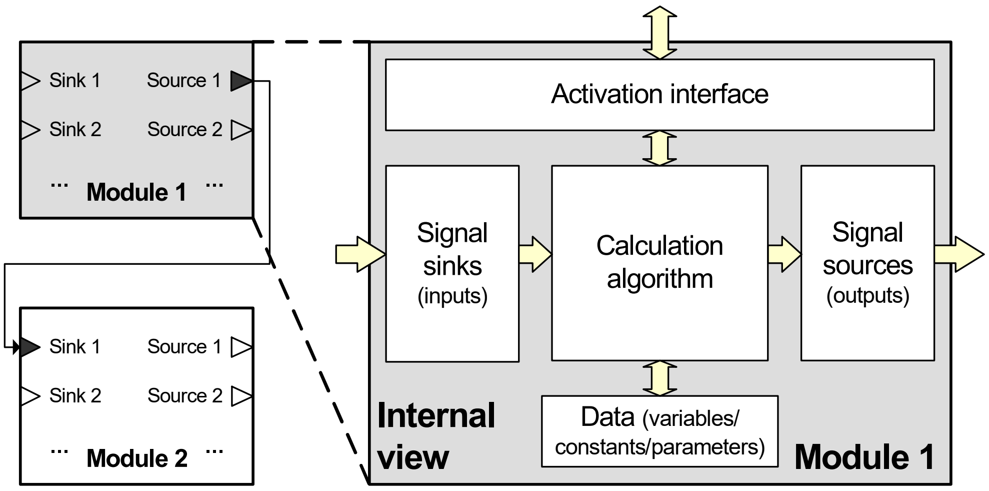


Fig. 3-11 Modules: schematic internal view

Fig. 3-12 shows a simple ASCET example for the internal view of a module.

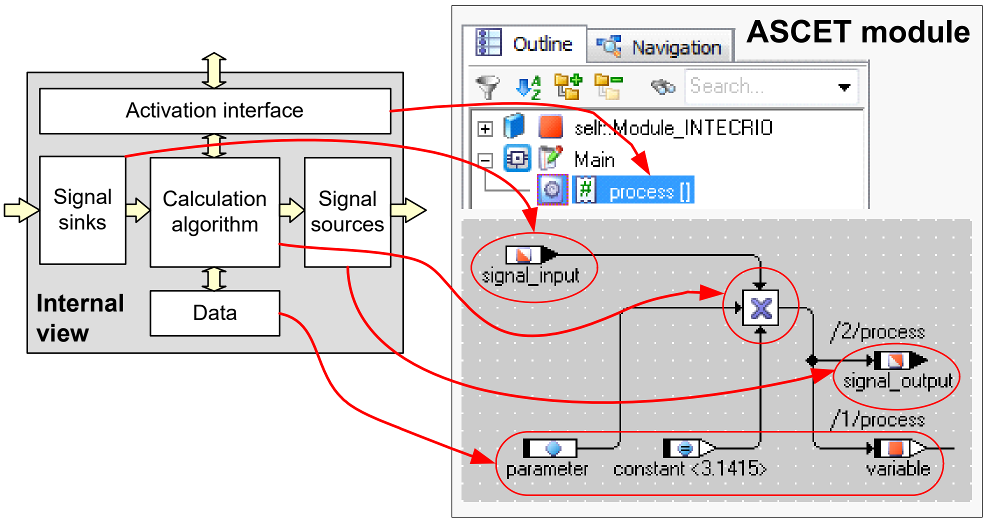


Fig. 3-12 Module: ASCET example

The activation interfaces correspond to the ASCET processes, signal sinks and sources correspond to the receive and send messages in ASCET. Variables, parameters and constants are represented by ASCET objects of the same name. Fig. 3-13 shows the same example for MATLAB and Simulink.

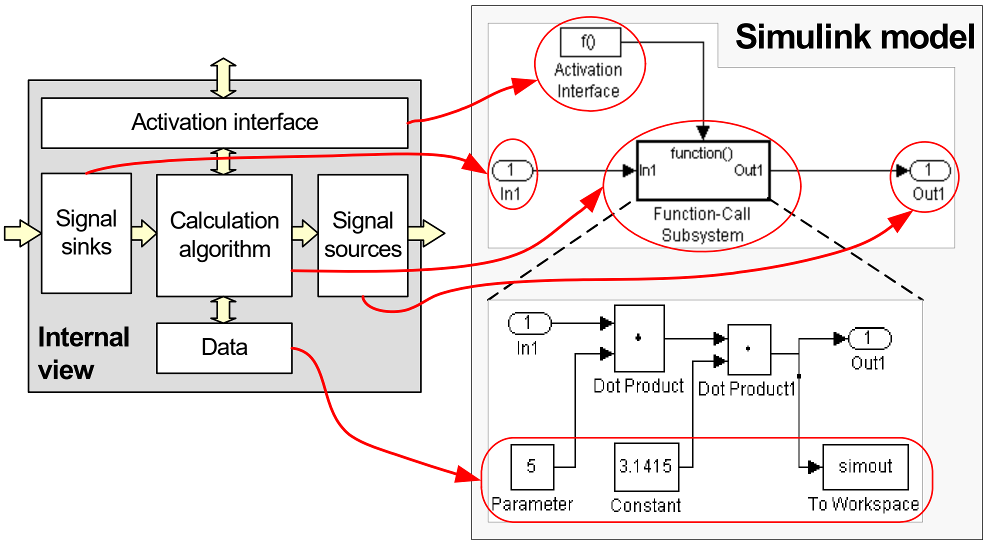


Fig. 3-13 Module: Simulink® example

For information to be exchanged between modules/SWC or functions and to create a functioning overall system, the objects must be interconnected, i.e. integrated. The calculation algorithms of the individual modules/SWC, i.e. their functionality, do not play a role for integration. The modules are handled as "black boxes" with

Source 1 = f_1(sink 1, sink 2, ...)

and

Source 2 = f_2(sink 1, sink 2, ...)

This integration is the responsibility of INTECRIO. To be able to fulfill this task, the model supplied by a BMT is dismantled for working with INTECRIO into description files for the interfaces and data as well as into C code (see Fig. 3-14). These files form a reusable software component; they can be processed by INTECRIO.

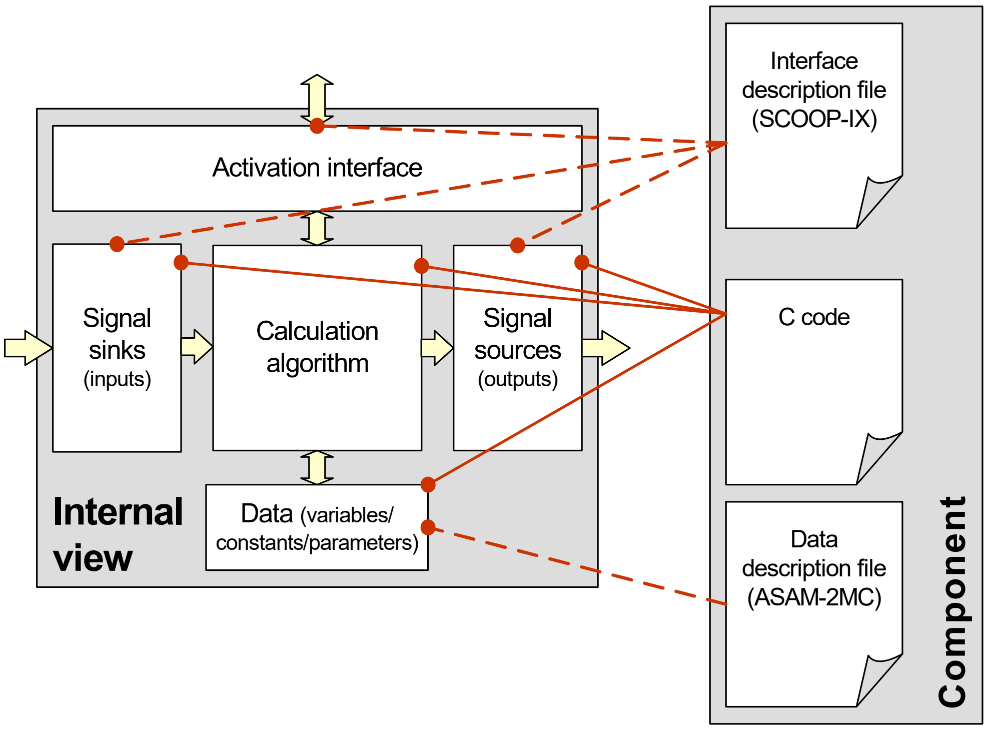


Fig. 3-14 Internal view and component view of a module (dashed: descriptions; solid: implementations)

3.2.2.2 Platform Software: Hardware Systems

On the other side are the hardware systems that are affected by cost factors and the different variants of a vehicle. The hardware is a network of electronic control units that form a complete hardware topology. The latter must describe all aspects of the hardware system that is available to the software. The hardware system is also a generic system whose behavior or properties do not change.

With virtual prototyping, a model of driver, vehicle and environment is used instead of real hardware and environment.

3.2.2.3 Connecting Hardware and Software

Finally, both systems must be connected with each other. To build a prototype (or an actual vehicle project), the description of the software system must be linked with the description of the hardware system. This linking forms a concrete application. Of course, this requires some "adhesive" to connect the generic software description and the generic hardware description.

INTECRIO is the tool that provides this "adhesive" in the form of a *project configurator* and connects the hardware description with the description of the application software. Here, the focus is on the hardware description – it is configured in INTECRIO while the components that form the application software are provided by special behavioral modeling tools.

Fig. 3-15 shows the representation of an electronic control unit description and the tasks taken on by the various INTECRIO components.

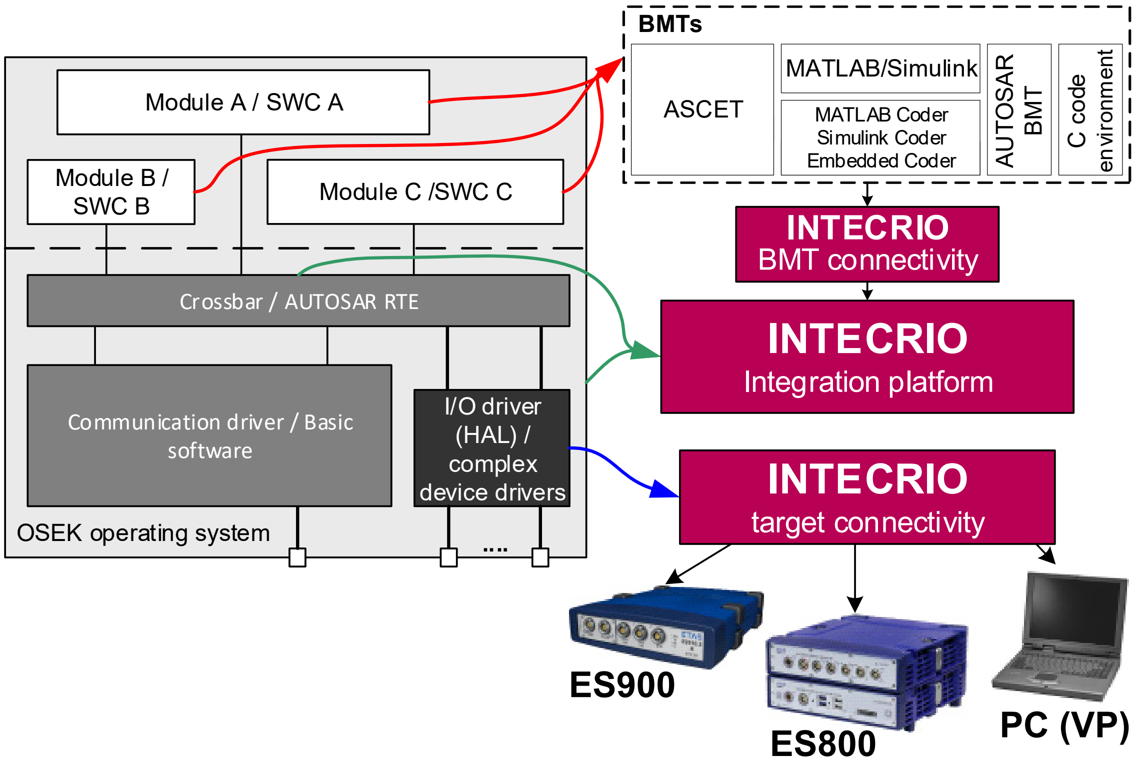


Fig. 3-15 System project (electronic control unit description) and INTECRIO components

3.3 Virtual Prototyping

Virtual prototyping means that function developers can create virtual prototypes of automotive electronic systems and test them on the PC. A virtual prototype of this kind comprises:

- Automotive embedded software
  - application software (functions for control and monitoring)
  - platform software (I/O drivers, operating system, etc.)
- Plant model
  - driver
  - vehicle
  - environment

Virtual prototyping enables collaboration in very early development phases between function developers on one hand and system developers and simulation experts on the other hand. Without virtual prototyping, these domains often do not come into contact until very late in the process, e.g., during HiL (Hardware-in-the-Loop) testing. With virtual prototyping, developers can use system models (such as chassis or engine models) in early stages of the process as well, and thus validate their functions through Model-in-the-Loop (MiL) technology. Access to system knowledge (and the corresponding models) early in the process creates synergies between function development and system development in an ideal way and fosters a more efficient development process.

3.3.1 Target-Close Prototyping

In INTECRIO, models can be created using a variety of different tools or a combination thereof (MATLAB and Simulink, ASCET, C code). With the PC connectivity provided by INTECRIO-VP, developers can now work within their familiar tool environment and execute their virtual prototype directly at their desks on a standard Windows PC. Already in the function design phase, developers can thus validate the functional architecture and verify the electronic architecture against the plant model. Moreover, they can do all of this under target-close conditions. To put it plainly:

```
  INTECRIO Integration Platform
+ Function Model
+ Plant Model
+ Standard PC
+ RTA Virtual OSEK
_____________________________________
=  Virtual Prototyping with INTECRIO
```

By supporting RTA-OSEK for PC, a complete OSEK operating system for the PC, INTECRIO-VP offers conditions that later exist on the vehicle ECU. These include task and process oriented scheduling and buffered message communication between individual OS processes. At the same time, INTECRIO-VP takes advantage of the flexibility and short turn-around times of testing on the PC, which offers ample room for experimentation due to fewer constraints in terms of timing, memory consumption, etc. than exist on the target ECU.

3.3.2 Advantages of Virtual Prototyping

Virtual prototyping offers new opportunities for early phases of vehicle development, such as pre-calibration in the office, detailed analysis of function behavior, and control over the execution speed of a prototype, as the following three examples illustrate.

A Saving time and money through pre-calibration

With virtual prototyping, developers can move some of the necessary development steps from the test bench to the lab or to their desks and validate, optimize, and pre-calibrate functions against a plant model right there. In addition, a virtual testing environment on the PC also offers developers the advantage of being able to minimize the execution time of experiments (given the computational power and the complexity of the model) and thus test a larger amount of functions or data variants in a shorter amount of time (Fig. 3-16 bottom).

B Detailed analysis using highly elaborate simulation models

The option of validating a new function based on elaborate plant simulations allows developers to conduct a detailed analysis of its behavior. This possibility is particularly valuable when an in-depth analysis is not possible in the real-world environment.

C Slow-motion and fast forward

With INTECRIO-VP, users can influence simulation time by defining a scaling factor and adjusting it while the simulation is running. Scaling factors < 1 allow users to accelerate the simulation, while scaling factors > 1 result in a "slow motion" effect (Fig. 3-16, top). With that, users can, e.g., run the relevant parts of a simulation in slow motion.

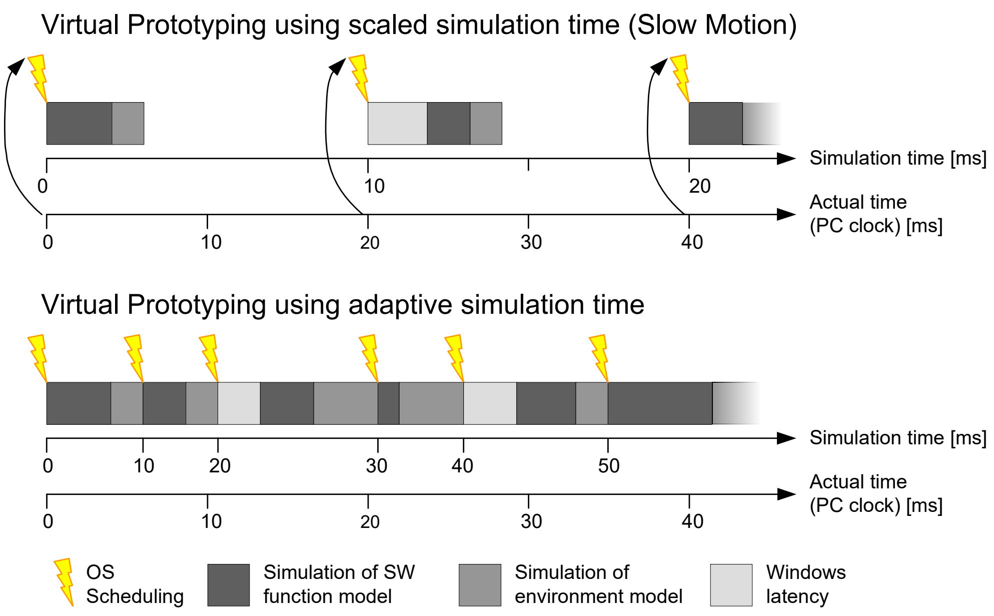

Virtual Prototyping using scaled simulation time (Slow Motion)
Simulation time [ms]
0
10
20
Actual time (PC clock) [ms]
0
10
20
30
40
Virtual Prototyping using adaptive simulation time
Simulation time [ms]
0
10
20
30
40
50
Actual time (PC clock) [ms]
0
10
20
30
40
OS Scheduling
Simulation of SW function model
Simulation of environment model
Windows latency

Fig. 3-16 *Top:* During simulation in scaled time, slow motion timing or fast forward timing can be achieved (within the limits of model complexity and computational power).
Bottom: In a simulation with adaptive time, complex models can be executed at the fastest possible speed (i.e., the least possible computation time).

3.3.3 Virtual Prototyping and Rapid Prototyping

In INTECRIO, the function model is strictly separated from OS configuration, hardware configuration, and instrumentation. Given this separation, fewer model variants have to be created, and the optimum re-use of software prototypes, experiments, and data sets can be ensured across teams, target platforms, and development phases. Being able to re-use virtual prototyping models in rapid prototyping will lead to considerable synergies.

To summarize the advantages of using both virtual and rapid prototyping:

Virtual Prototyping	Rapid Prototyping
enables developers to validate functions and software	enables developers to validate and verify functions and software
- in the context of a simulated world at their desks - with pre-calibration options - without any dedicated hardware - not restricted by real-time requirements	- in the context of the real world, i.e. using real world interfaces and signals - on particularly designed hardware systems - in real time (e.g., through a bypass experiment)

Virtual prototyping thus complements the prototyping options available in INTECRIO to date. With INTECRIO-VP, vehicle developers are able to test new functions against plant simulations in early phases of development, which will contribute to a more efficient development process.

3.4 INTECRIO in the Development Process

Electronic control unit software is generally developed according to the V model. In the process, smaller V cycles are typically passed through on every level. Fig. 3-17 shows the V model; the areas in which INTECRIO is used are marked.

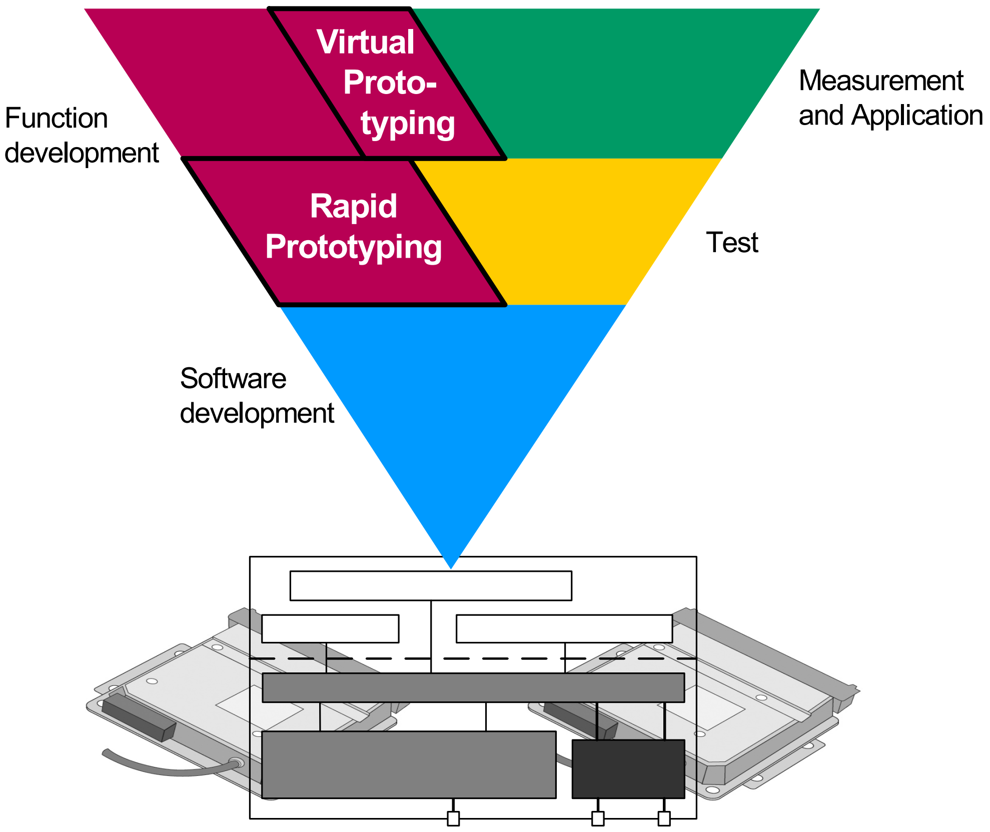


Fig. 3-17 V cycle and INTECRIO

In other words: INTECRIO allows the user a simple and quick integration of software components from different manufacturers and different BMTs as well as the verification and validation of the software (in whole or in part) in virtual or rapid prototyping. New experimenting options allow for quick and complete validation and verification of software modules.

Validation is the process for evaluating a system or a component with the purpose of determining whether the application purpose or the user expectations are met. Therefore, the validation is the check whether the specification meets the user requirements, whether the user acceptance is reached by a function after all.

Verification is the process for evaluating a system or a component with the purpose of determining whether the results of a given development phase correspond to the specifications for this phase. Therefore, software verification is the check whether an implementation of the specification specified for the respective development step is sufficient.

A clear separation of validation and verification is often not possible when classical development, integration and quality assurance methods for software are used. Therefore, a significant advantage of the use of INTECRIO as rapid prototyping tool consists of the fact that it allows for an early and electronic control unit-independent function validation with an experimental system in the vehicle.

3.5 INTECRIO Working Environment

The design of INTECRIO is modular. The graphical framework forms the working interface in which the various INTECRIO components are integrated.

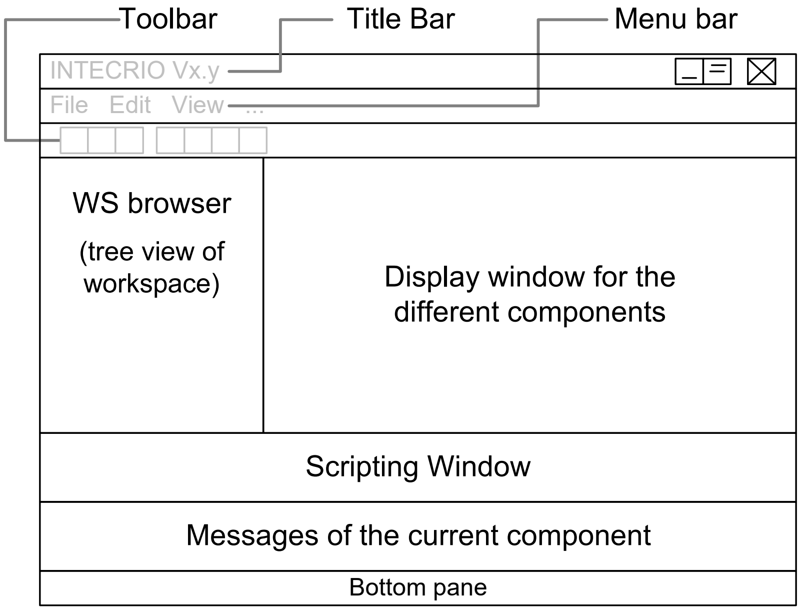


Fig. 3-18 INTECRIO – Scheme of the interface

The graphical interface of INTECRIO is always designed in the same way. Below a menu bar and a toolbar, the interface of the currently used configurator (OS, project or hardware configurator) with the respective processing options is displayed in the top right field. The two lower fields are used for scripting (see online help for details) and as display for messages of the currently used configurator. The bottom pane contains various status information.

The top left field, the WS browser, displays the current *workspace* in a tree structure. The workspace contains all the components of an electronic control unit description in four predetermined main folders for hardware systems, software systems, environment systems (virtual prototyping) and system projects.The entire electronic control unit description is processed from here.

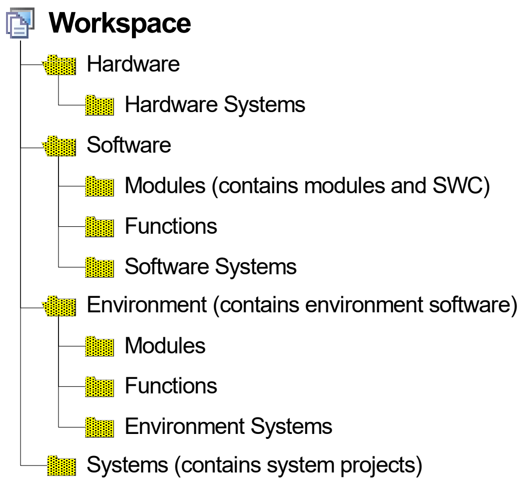

Workspace
Hardware
Hardware Systems
Software
Modules (contains modules and SWC)
Functions
Software Systems
Environment (contains environment software)
Modules
Functions
Environment Systems
Systems (contains system projects)

Fig. 3-19 Folder structure: workspace

Hardware systems: A *hardware system* is used for the configuration of the platform software. It contains the complete description of a hardware topology, consisting of the descriptions of the associated ECUs (rapid and virtual prototyping targets) as well as the descriptions of the interfaces (bus systems) between the devices.

The components of the hardware systems are stored in the `Hardware` folder.

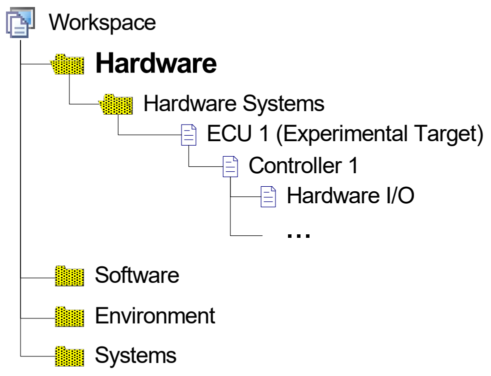


Fig. 3-20 Folder structure: hardware systems

Software systems and environment systems: A *software system* contains the application software, i.e. the generic parts of the control algorithm. For one thing, these are the modules and AUTOSAR software components[1)] (SWC) that contain the functionality. In addition, functions and connections between modules, SWC and functions are part of the software system. In INTECRIO V5.0, the execution sequence is automatically determined based on the overall configuration.

An *environment system* contains the plant model for virtual prototyping, i.e. the model of driver, vehicle, and environment. An environment system is built like a software system.

The components of the software systems are stored in the `Software` folder and the corresponding subfolders. The components of the environment systems are stored in the `Environment` folder and the corresponding subfolders.

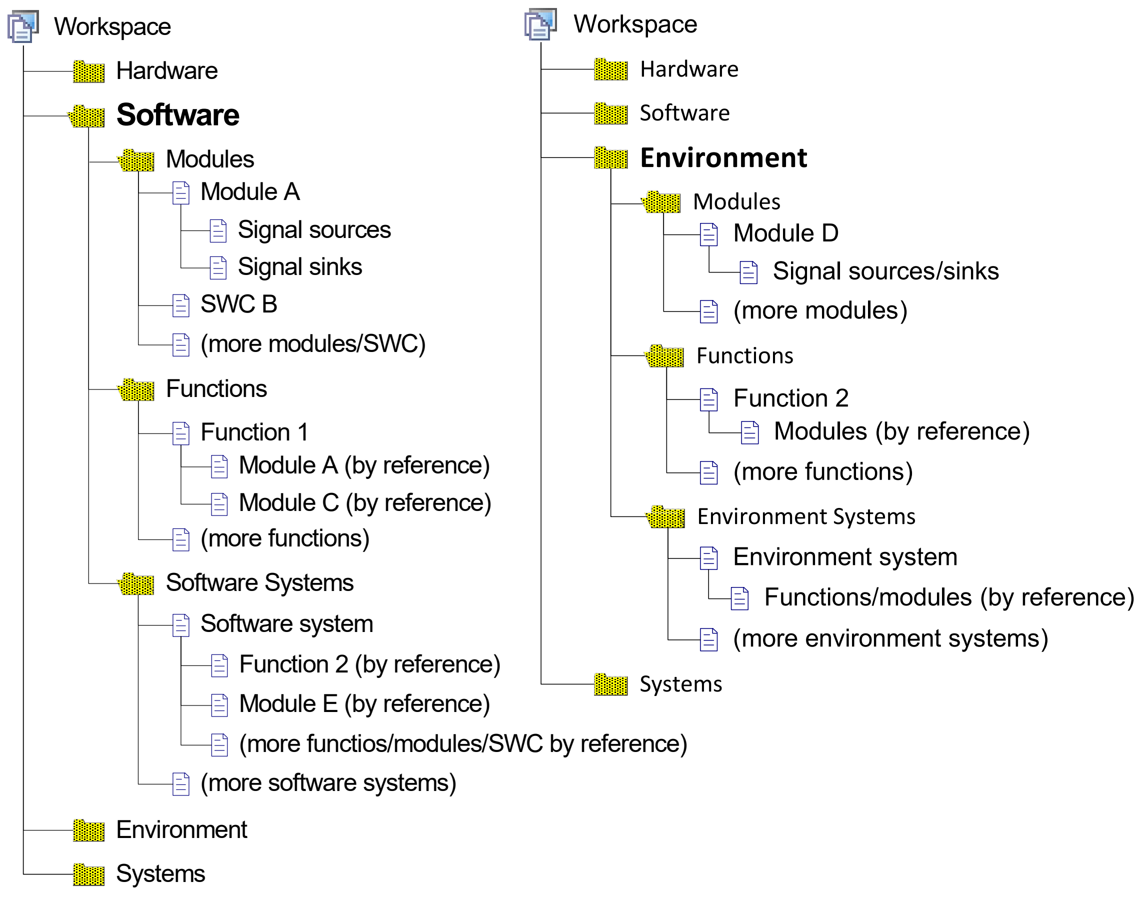


Fig. 3-21 Folder structure: software systems and environment systems

System projects: A *system project* is a complete electronic control unit description. It combines a hardware system, a software system and an environment system into an overall project. The mapping of the signals provided by the hardware onto the corresponding software signals and the configuration of the operating system (OS configuration) are also a part of the system project.

1) See section 3.5.1.1 "Modules and AUTOSAR Software Components" for more information.

The system project are stored in the `Systems` folder.

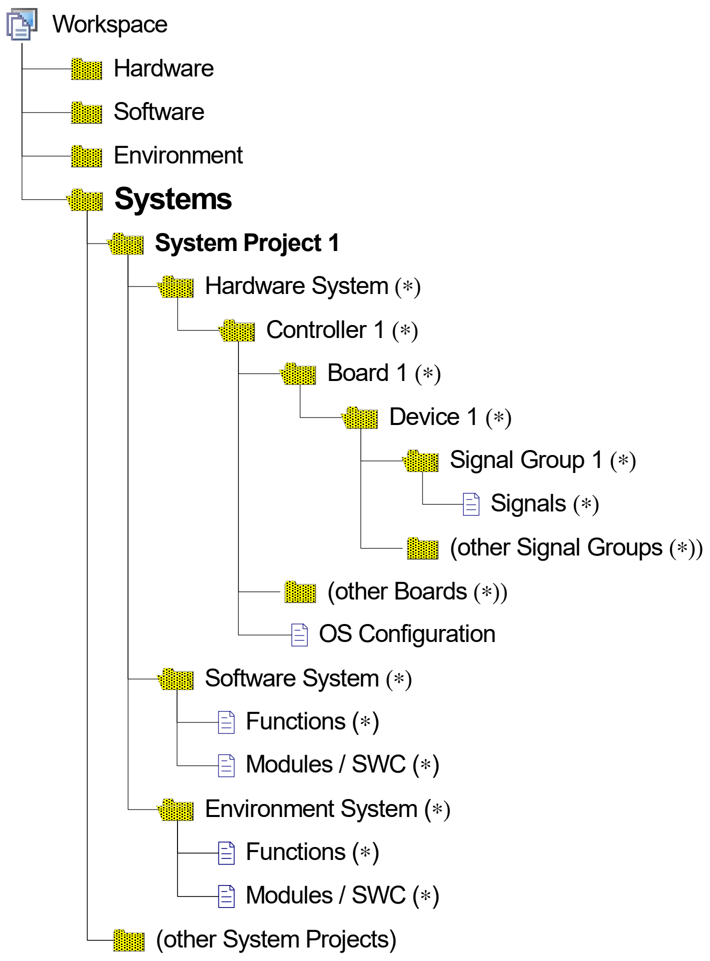


Fig. 3-22 Folder structure: system project (objects marked with * are referenced)

Software systems, hardware systems, environment systems (for virtual prototyping) and system projects are described in detail in the following sections.

3.5.1 Software Systems

This section provides a detailed description of software systems. Fig. 3-23 shows the content of a software system. The lines symbolize inclusion relationships; dashed objects in the background are optional (if available, they contain the same objects as the corresponding foreground object).

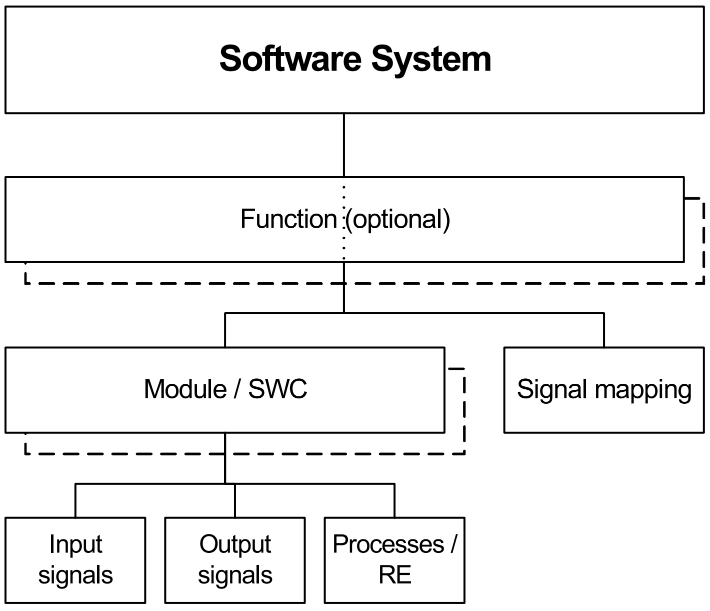


Fig. 3-23 Software system

3.5.1.1 Modules and AUTOSAR Software Components

NOTE

In INTECRIO V5.0.4, AUTOSAR support is limited to using existing work-spaces that contain legacy AUTOSAR modules. It is not possible to import new AUTOSAR software components.

The *modules* and *AUTOSAR software components (SWC)* in INTECRIO contain the descriptions of the software modules that were imported in the system.

These can be user-defined ASCET modules, Simulink models or AUTOSAR software components, but also test functions or complex stimulus generators in C code or plant models (for "software in the loop" applications). The descriptions are based on SCOOP-IX descriptions (see chapter 6 "SCOOP and SCOOP-IX") or XML for AUTOSAR software components.

The schematic design of a module and SWC is represented in Fig. 3-10 on page 20. INTECRIO only knows the signal sources and sinks (inputs and outputs) as well as the activation interfaces (processes, or runnable entities for SWC) of the user-defined modules and SWC (interface description file in Fig. 3-14). The functionality of the software modules and SWC that was created with different BMTs is not of importance here.

In INTECRIO, hardware I/O ports are also considered as modules with signal sources and sinks.

The*signal mapping*, i.e. the connections between the corresponding inputs and outputs that are required for information exchange, must be performed explicitly. There are no implicit connections, such as via same name.

Fig. 3-24 shows the simple connections: A source is connected with a sink (A) or with several sinks (B); source and sinks have the same timing.

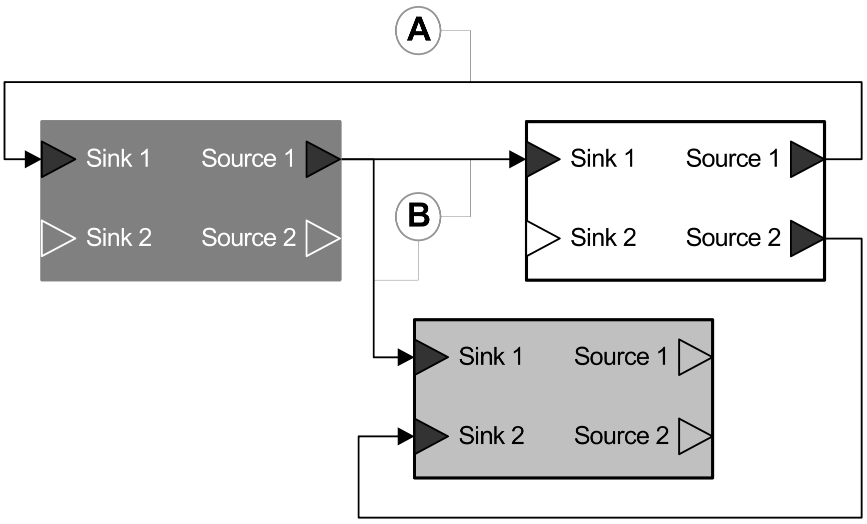


Fig. 3-24 Connections: A source, one or several sinks, same timing

In addition, other connections are possible:

- A source is connected with various sinks; source and sink(s) have a different timing.

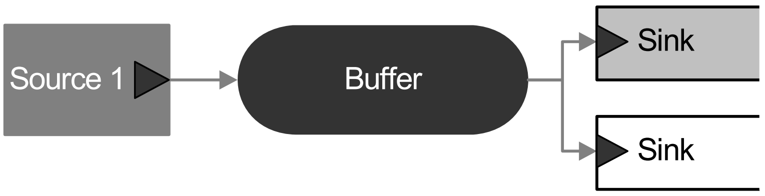


Fig. 3-25 Connection: One source, several sinks, different timing

The data of the source are buffered and then forwarded to the sink(s).

- Two sources are connected with a sink (*only* for rapid prototyping).

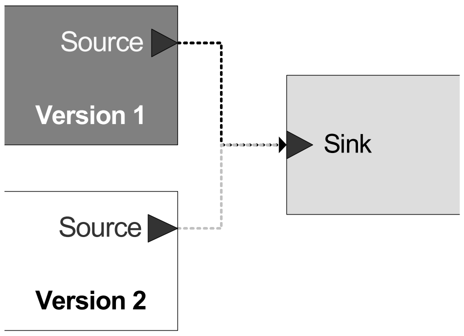


Fig. 3-26 Connection: several sources, one sink

There are two alternatives: On the one hand, switching between the two sources (see Fig. 3-26) during the prototyping phase is accomplished by using a crossbar manager (see section 3.5.5). On the other hand, the connection can be permanently coded during the software development phase.

3.5.1.2 Functions

Modules and SWC can be inserted in a software system either directly or – to provide a better overview or for a simple reuse – grouped in *functions*. These functions are classification objects without separate functionality (similar to the hierarchies in ASCET block diagrams).

A function consists of the following components:

- one or several modules or SWC
- connections between inputs and outputs of the contained modules or SWC
- the function interface (inputs, outputs and activation interfaces)

The inputs and outputs of a function cannot have their own data or implementations. Outputs can be connected with one or several sinks of the modules/functions contained in the function, inputs with exactly one source of a module/function. With SWC, the output type determines whether the output can be connected to one or more inputs (see “Ports and Interfaces” on page 47).

It is also possible to automatically create the inputs and outputs of the function. However, only the module/SWC inputs that are not yet connected can be taken into account. Outputs take into account either all sources of the modules/SWC contained in the function or only those that are not yet connected.

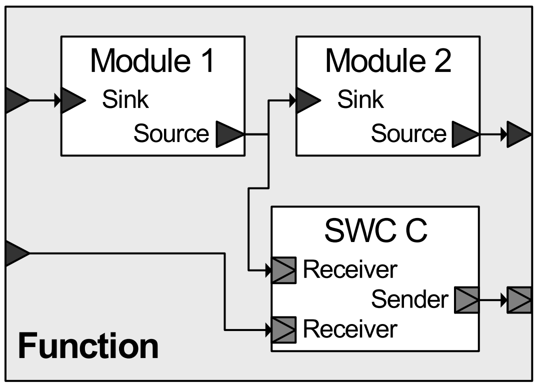


Fig. 3-27 Example for a function

Modules cannot be instantiated in INTECRIO. If a module is inserted into a function more than once (either directly or as part of an inserted function), an error message is issued during code generation.

3.5.1.3 Software Systems

A complete software system can be assembled from any number of functions and individual modules or SWC.

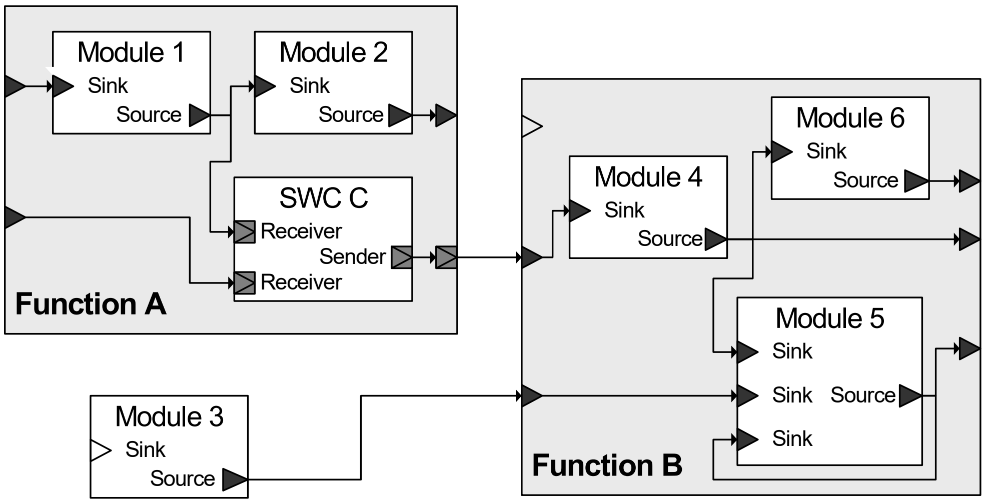


Fig. 3-28 Example for a software system

Since modules and SWC cannot be instantiated, each module/SWC may appear only once, regardless of whether it is a part of a function or not. Except for the creation of functions, an automatic check does not take place until the system project is created (see section 3.5.4).

NOTE

Make sure that no module/SWC already included in a function is individually inserted into the software system. Otherwise, the following error message is issued during code generation:

```
Build preparation error: Multiple instances of same module in
software system
```

3.5.2 Environment Systems

Environment systems are used to model the plant model for virtual prototyping (see section 3.3). They are built out of modules, SWC and functions, the same way as software systems.

A module, SWC or function can, within one workspace, be used *either* for a software system *or* an environment system. It is not possible to include modules, SWC or functions imported/created for a software system (`Software\Modules` and `Software\Functions` folders) in an environment system, and vice versa.

3.5.3 Hardware Systems

Fig. 3-29 shows the content of a hardware system (the lines symbolize inclusion relationships). In the framework of the hardware system, the existing hardware and the interfaces between the individual units (e.g. ETK, CAN) are described.

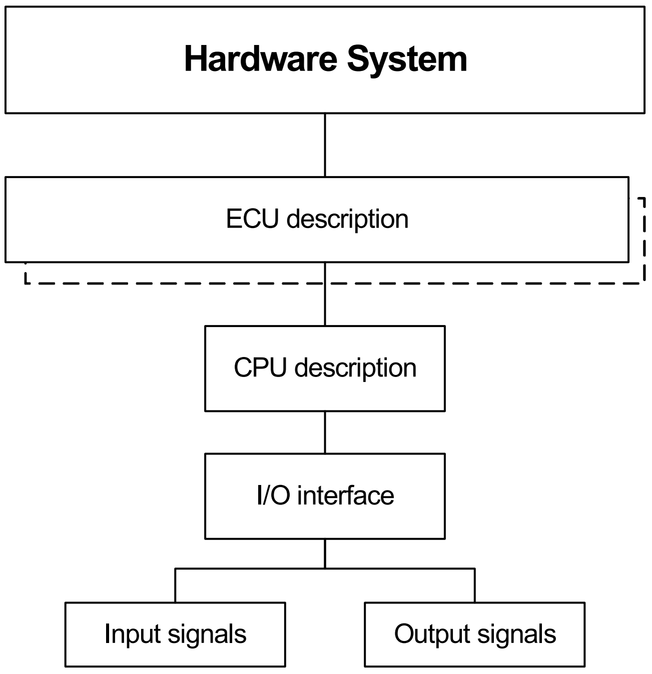


Fig. 3-29 Hardware system.

The *ECU description* is the description of an individual controller hardware that is usually installed inside a housing. (Despite different boards or interfaces, the experimental targets are considered electronic control units.)

This includes descriptions of all processors of the electronic control unit and the connections between the processors.

The *CPU description* is the description of an individual processor with all the relevant details. This includes

- Characteristics of the processor (type, brand, etc.),
- Processor speed,
- Memory layout,
- Additional processor-specific configurations.

The *I/O interface* describes the interface between the input/output signals and the processor.

The *input and output signals* are linked with a specific processor. They are used to configure the inputs and outputs of the hardware (sensors and actuators) and to establish the connection to the corresponding processor signals.

3.5.4 System Projects

The system project combines a hardware system, a software system and an environment system (optional; for virtual prototyping) into an overall project. A check is performed whether each module occurs only once in the overall project; if a module occurs multiple times, an error message is issued.

In the system project, the signals provided by the hardware are mapped onto the signals available in the software and the processing sequence of the processes is defined in the framework of the operating system configuration.

Fig. 3-30 shows a system project. Dashed objects in the background are optional; if available, they contain the same objects as the corresponding foreground object.

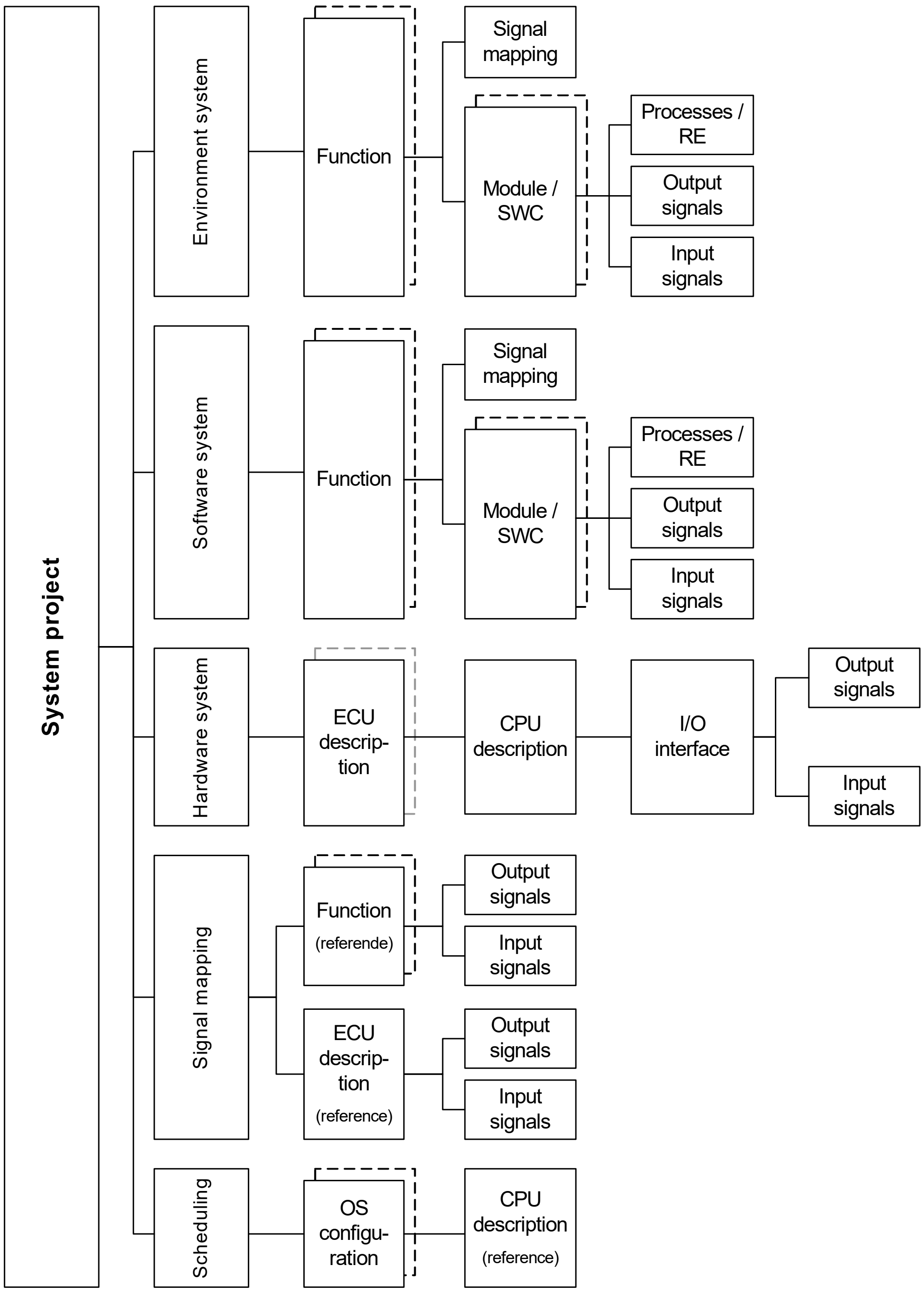


Fig. 3-30 System project

Software systems, environment systems, and hardware systems are described in sections 3.5.1, 3.5.2 and 3.5.3.

The signal mapping references the functions/modules/SWC of the software or environment and the ECU description with the respective inputs and outputs. The mapping is performed here. Since functions/modules/SWC and ECU description are referenced, changes to the software or hardware system immediately impact the signal mapping.

The *scheduling*, i.e. the processing sequence of the tasks and processes/runnable entities, is defined in the configuration of the operating system, i.e. the *OS configuration*. In the OS configuration, tasks are created and configured, to which the processes (activation interfaces) of the system are subsequently assigned.

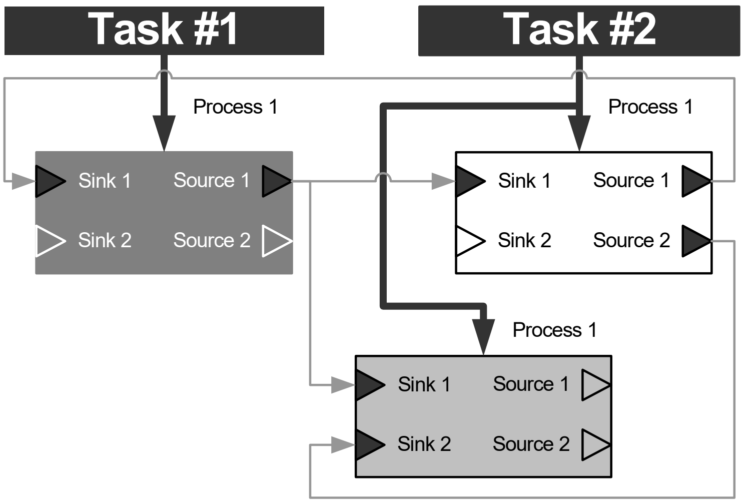


Fig. 3-31 Assigning processes to tasks

3.5.5 Crossbar

The connections between modules, functions and hardware are managed and controlled by the *Crossbar*. When a system project contains at least one SWC, an AUTOSAR runtime environment (see section 4.2 on page 46) is used instead of the Crossbar.

The Crossbar is a software component that is executed with the target (e.g., ES830). The task of the Crossbar consists of connecting any signal sources with any signal sinks. For this purpose, a signal source may be connected with several signal sinks, but a signal sink can be connected only with exactly one signal source.

The Crossbar can manage static and dynamic connections in interaction with the project configurator. Static connections cannot be changed during runtime; if you want a change, you must cancel the experiment, perform the change and recompile the project. Dynamic connections can be changed during runtime.

At runtime, the Crossbar receives the information about each connection (source, sink, involved processes, variable type, ...). Value assignments by the Crossbar are always performed before calling the "consuming" module. This allows the Crossbar to trigger the necessary actions at runtime. The result are connections between signal sources and sinks that are represented as gray circles in Fig. 3-32.

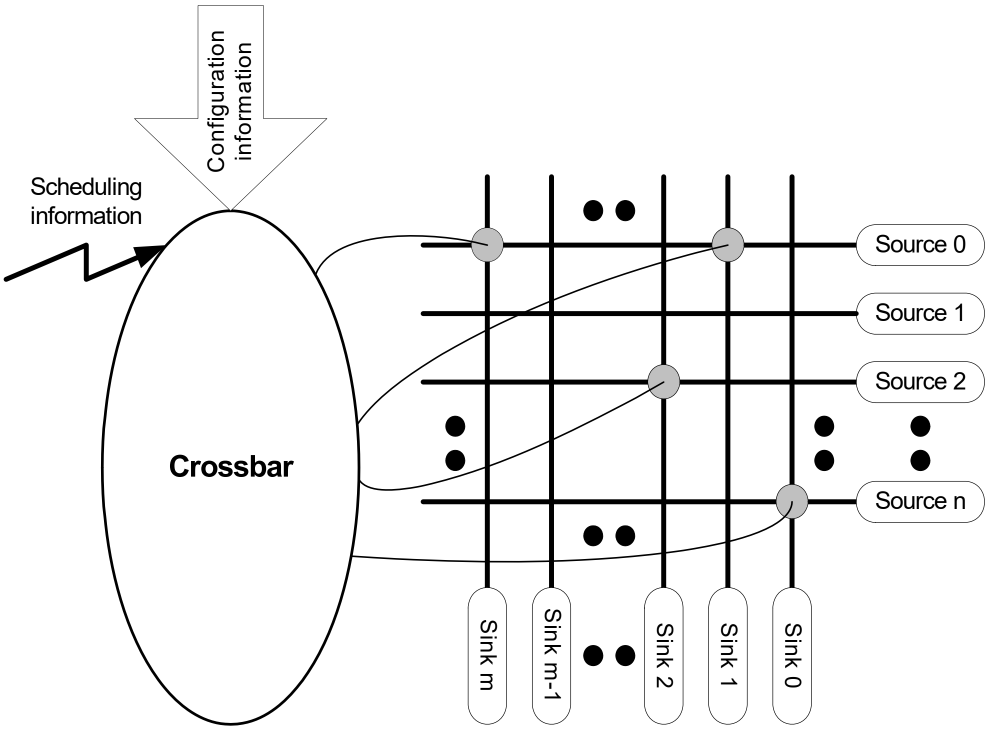


Fig. 3-32 Crossbar – Overview

The patented Crossbar guarantees real-time security for the modules through carefully arranged copy actions. Required requantizations and data type conversions are automatically performed.

A simple assignment serves as an example: `sink 1 = source 0`

If the two sides of the assignment are quantized differently, the value of `source 0` is requantized and then assigned to `sink 1`. If both sides feature different data types, `source 0` is converted to the data type of `sink 1`.

3.6 Experimenting with INTECRIO

The executable prototype is created from the system project by using the project integrator (see section 5.9 "Project Integrator"). Such a prototype shows the software functions in practical use – entirely with different goal directions and in a different appropriation.

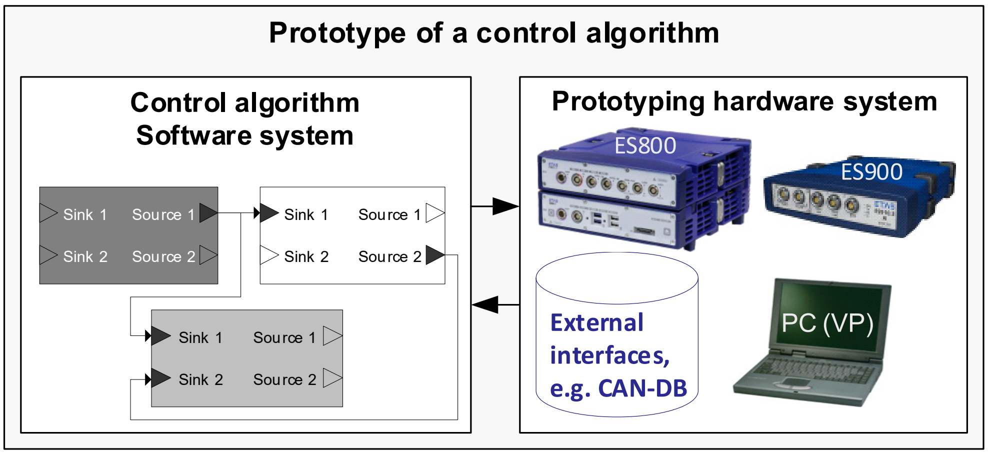

Prototype of a control algorithm
Control algorithm Software system
Sink 1
Source 1
Sink 2
Source 2
Prototyping hardware system
ES800
ES900
External interfaces, e.g. CAN-DB
PC (VP)

Fig. 3-33 Prototype for rapid or virtual prototyping experiment

By using the prototype, a rapid prototyping hardware and an experiment environment (e.g., the ETAS Experiment Environment), the experiment can be performed under real-time conditions (also automatically if needed). This experiment fulfills the following purposes:

- Validation of the control algorithm (in whole or in part)
- Verification of the software implementation
- Verification of the implementation information of the model magnitudes

In the experiment, values can be measured and calibrated in different measuring and calibration windows. The configuration of the measuring and calibration windows can be carried out either before or during the experiment. In a virtual prototyping experiment, also the simulation speed can be adjusted at runtime.

Connections that were created as dynamic connections during the creation can be changed during the running experiment. This can be useful, for example, if the fixed-point code implementation of a model is to be compared with the physical model or different versions of a model.

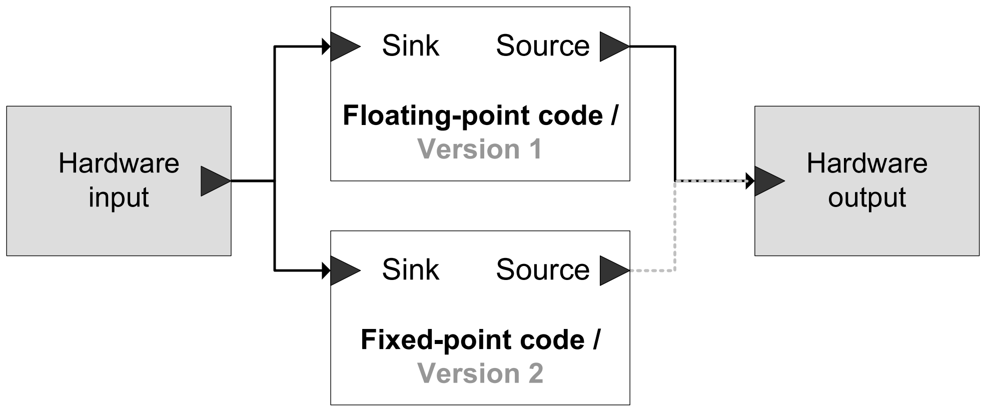


Fig. 3-34 Different models that can be connected with the hardware as an option

Additional modification options during the running experiment include the following:

- Change of conversion formulas of simple I/O signals
- Switching individual signal groups on/off
- Switching events on/off

The data gained during the experiment can be logged and analyzed under different points of view. The results can be documented automatically.

4 INTECRIO and AUTOSAR

This chapter describes how INTECRIO supports AUTOSAR. Section 4.1 overviews the purpose of AUTOSAR, section 4.2 describes the AUTOSAR runtime environment (RTE), section 4.3 lists the AUTOSAR elements supported by INTECRIO.

NOTE

In INTECRIO V5.0.4, AUTOSAR support is limited to using existing workspaces that contain legacy AUTOSAR modules. It is not possible to import new AUTOSAR software components.

This chapter contains no detailed introduction to AUTOSAR; corresponding documents can be found at the AUTOSAR website: https://www.autosar.org/

4.1 Overview

Today, special effort is needed when integrating software components from different suppliers in a vehicle project comprising networks, electronic control units (ECUs), and dissimilar software architectures. While clearly limiting the reusability of automotive embedded software in different projects, this effort also calls for extra work in order to provide the required fully functional, tested, and qualified software.

By standardizing, inter alia, basic system functions and functional interfaces, the AUTOSAR partnership aims to simplify the joint development of software for automotive electronics, reduce its costs and time-to-market, enhance its quality, and provide mechanisms required for the design of safety relevant systems.

To reach these goals, AUTOSAR defines an architecture for automotive embedded software. It provides for the easy reuse, exchange, scaling, and integration of those ECU-independent *software components* (SWCs) that implement the functions of the respective application.

The abstraction of the SWC environment is called the *virtual function bus* (VFB). In each real AUTOSAR ECU, the VFB is mapped by a specific, ECU-dependent implementation of the platform software. The AUTOSAR platform software is split into two major areas of functionality: the runtime environment (RTE) and the *basic software* (BSW). The BSW provides communications, I/O, and other functionality that all software components are likely to require, e.g., diagnostics and error reporting, or non-volatile memory management.

4.1.1 RTA-RTE and RTA-OS

The *runtime environment* provides the interface between software components, BSW modules, and operating systems (OS). Concerning the interconnection of SWCs, the RTE acts like a telephone switchboard. This is similarly true of components that reside either on single ECUs or networked ECUs interconnected by vehicle buses.

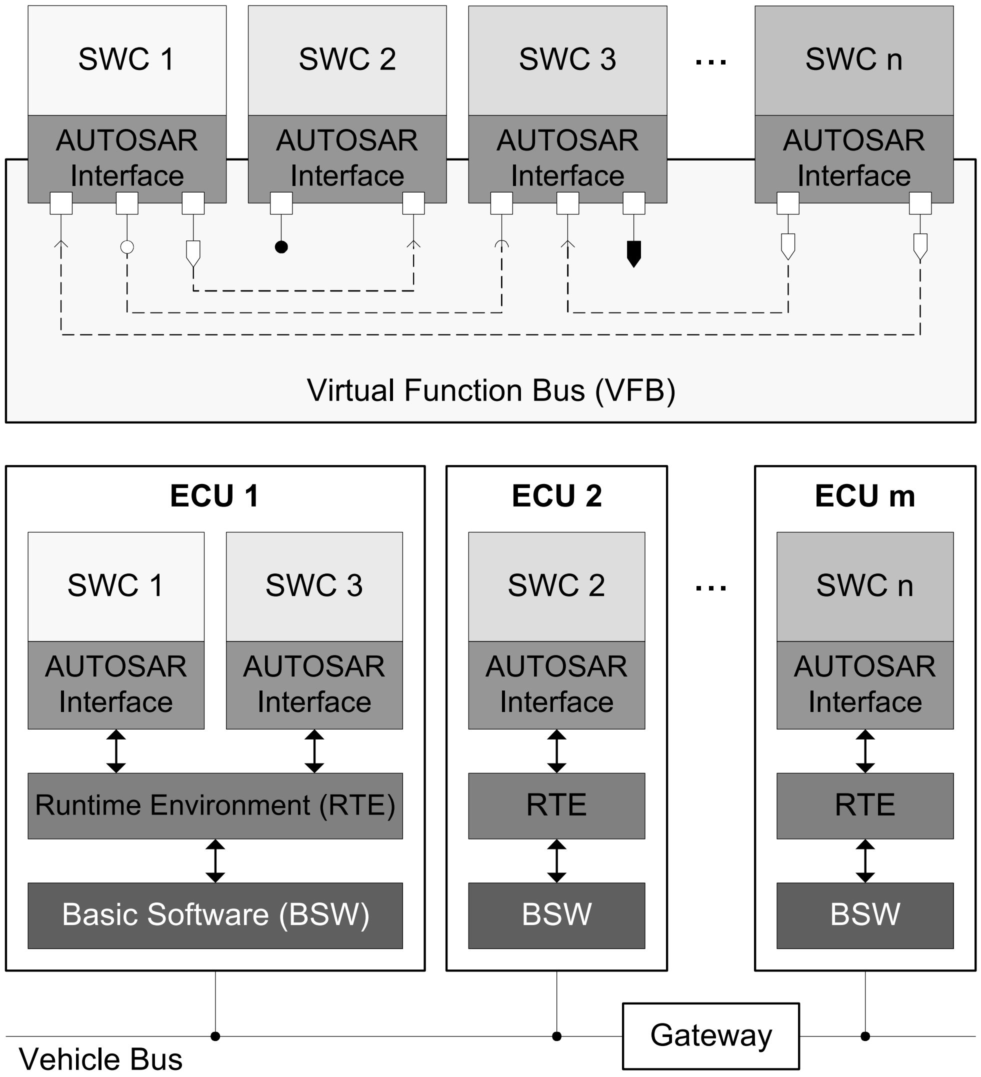


Fig. 4-1 AUTOSAR software component (SWC) communications are represented by a virtual function bus (VFB) implemented through the use of the runtime environment (RTE) and basic software (BSW).

In AUTOSAR, the OS calls the runnable entities of the SWCs through the RTE. RTE and OS are the key modules of the basic software with respect to controlling application software execution. ETAS offers the *RTA-RTE* AUTOSAR Runtime Environment and the *RTA-OS* AUTOSAR Operating System.

Based on their AUTOSAR interfaces, basic software modules from third-party suppliers can be seamlessly integrated with RTA-RTE and RTA-OS.

4.1.2 Creating AUTOSAR Software Components (outside INTECRIO)

INTECRIO is not intended for the creation of AUTOSAR software components. *ASCET*, however, can be used to define and implement the behavior of AUTOSAR-compliant vehicle functions. If necessary, an AUTOSAR authoring tool can provide initial descriptions of the system architecture and AUTOSAR interfaces,

Existing ASCET models can be easily adapted to AUTOSAR because many AUTOSAR concepts can be mapped to interface specifications in ASCET in a similar form. On the whole, it suffices to rework the interface of the respective application to make it AUTOSAR-compliant. As shown in practical demonstrations of adapting older models, the expenditure in terms of time is relatively minor, even with the ASCET version in current use.

Different ASCET versions support different AUTOSAR releases for the creation of AUTOSAR SWC descriptions and the generation of AUTOSAR-compliant SWC production code. See the ASCET documentation for details on the supported AUTOSAR versions.

4.1.3 Validating Software Components

The virtual function bus concept of AUTOSAR opens the road to virtual integration. Because the virtual function bus blurs the ECU borders, software components of different functions can be integrated in the design phase prior to having completed the final mapping to individual ECUs. This means that the interaction of software components integrated by an RTE can be easily tested on a PC running an AUTOSAR OS.

INTECRIO provides a powerful environment for prototyping and validating automotive electronic systems. Version V5.0 enables the integration of legacy AUTOSAR SWCs with function modules (Fig. 4-2). INTECRIO thus provides for the reuse of existing models and C code during the migration of ECU software to AUTOSAR architectures.

Legacy AUTOSAR SWC can be combined with functions (B in Fig. 4-2) or tested as a pure AUTOSAR system (C in Fig. 4-2).

By using plant models, Model-in-the-Loop experiments are realized on the PC.

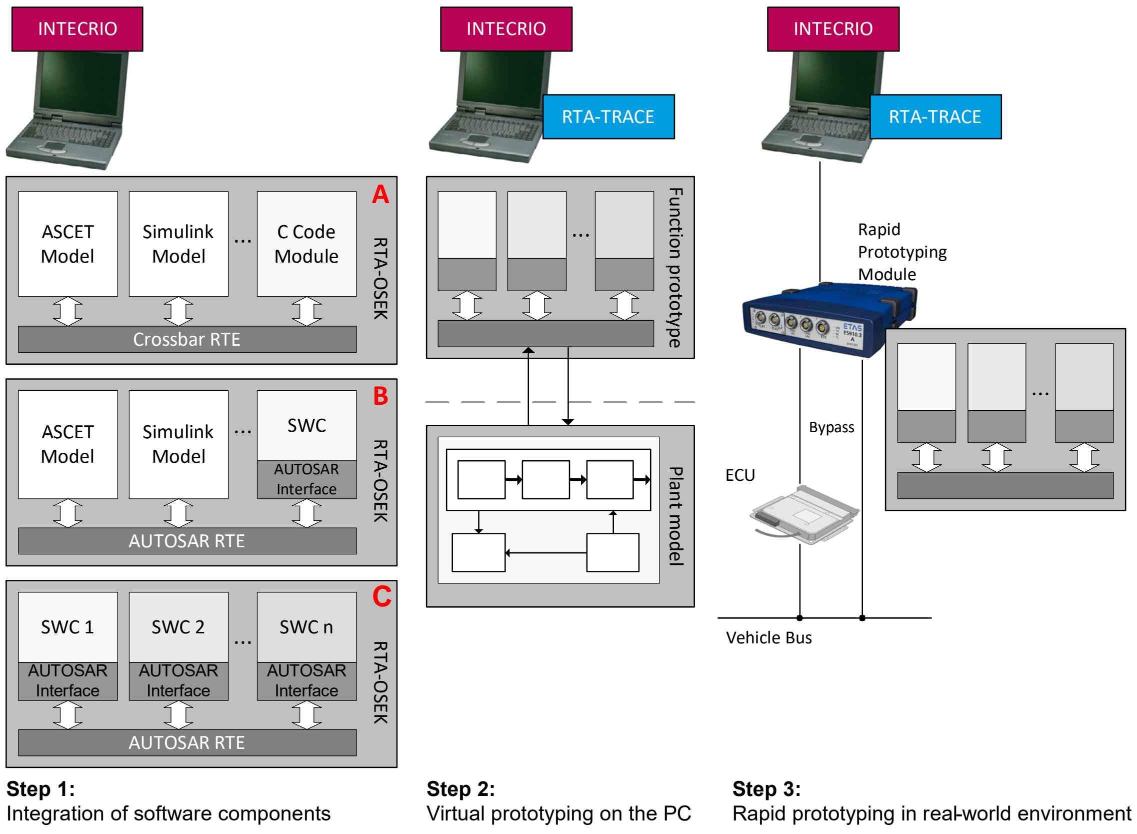


Fig. 4-2 Integration (left) of software modules for virtual prototyping (middle) or rapid prototyping (right) with the AUTOSAR RTE

INTECRIO V5.0 allows the use of legacy AUTOSAR SWC descriptions and the generation of the RTE configuration according to several AUTOSAR versions (see Tab. 4-1).

AUTOSAR version	Remarks
R3.0.0	not supported by ASCET
R3.0.1	
R3.0.2	
R3.1.0	
R3.1.2	
R3.1.4	
R4.0.2	NVData interfaces and ModeSwitch interfaces are not supported by INTECRIO V5.0
R4.0.3	

Tab. 4-1 Supported AUTOSAR versions

INTECRIO V5.0 also provides the interpolation routines required for AUTOSAR SWC descriptions generated by ASCET-SE.

With RTA-RTE[1)] for the AUTOSAR R4.0 releases mentioned in Tab. 4-1 and RTA-OSEK V5.0, INTECRIO V5.0 can create close-to-production AUTOSAR prototypes for PC and ETAS rapid prototyping systems.

INTECRIO strictly separates the communications between software components from the prototyping hardware configuration. Thus, INTECRIO V5.0 is able to export the validated RTE configuration in the form of an XML file. An AUTOSAR RTE generator, e.g., RTA-RTE, can use this information to create the RTE of an AUTOSAR ECU.

4.2 What is a Runtime Environment?

The VFB provides the abstraction that allows components to be reusable. The *runtime environment* (RTE) provides the mechanisms required to make the VFB abstraction work at runtime. The RTE is, therefore, in the simplest case, an implementation of the VFB. However, the RTE must provide the necessary interfacing and infrastructure to allow software components to:

A be implemented without reference to an ECU (the VFB model); and

B be integrated with the ECU and the wider vehicle network once this is known (the Systems Integration model) without changing the application software itself.

More specifically, the RTE must do the following:

- Provide a communication infrastructure for software components.

  This includes both communication between software components on the same ECU (intra-ECU) and communication between software components on different ECUs (inter-ECU).
- Arrange for real-time scheduling of software components.

  This typically means that the runnable entities of the SWC are mapped, according to time constraints specified at design time, onto tasks provided by an operating system.

Application software components have no direct access to the basic software below the abstraction implemented by the RTE. This means that components cannot, for example, directly access operating system or communication services. So, the RTE must present an abstraction over such services. It is essential that this abstraction remains unchanged, irrespective of the software components location. All interaction between software components therefore happens through standardized RTE interface calls.

In addition, the RTE is used for the specific realization of a previously specified architecture consisting of SWC on one or more ECUs. To make the RTE implementation efficient, the RTE implementation required for the architecture is determined at build time for each ECU. The standardized RTE interfaces are automatically implemented by an RTE generation tool that makes sure that the interface behaves in the correct way for the specified component interaction and the specified component allocation.

1) RTA-RTE 5.4 can be used with AUTOSAR R4.0.*.

For example, if two software components reside on the same ECU they can use internal ECU communication, but if one is moved to a different ECU, communication now needs to occur across the vehicle network.

From the application software component perspective, the generated RTE therefore encapsulates the differences in the basic software of the various ECUs by:

- Presenting a consistent interface to the software components so they can be reused—they can be designed and written once but used multiple times.
- Binding that interface onto the underlying AUTOSAR basic software implemented in the VFB design abstraction.

4.3 AUTOSAR Elements in INTECRIO

The following AUTOSAR elements are supported in INTECRIO:

4.3.1 AUTOSAR Software Components

AUTOSAR software components are generic application-level components that are designed to be independent of both CPU and location in the vehicle network. An AUTOSAR software component (SWC) can be mapped to any available ECU during system configuration, subject to constraints imposed by the system designer.

An AUTOSAR software component is therefore the atomic unit of distribution in an AUTOSAR system; it must be mapped completely onto one ECU.

Before an SWC can be created, its component type (SWC type) must be defined. The SWC type identifies fixed characteristics of an SWC, i.e. port names, how ports are typed by interfaces, etc. The SWC type is named, and the name must be unique within the system. Thus, an SWC consists of

- a complete formal SWC description that indicates how the infrastructure of the component must be configured,
- an SWC implementation that contains the functionality (in the form of C code).

To allow an SWC to be used, it needs to be instantiated as configuration time. The distinction between type and instance is analogous to types and variables in conventional programming languages. You define an application-wide unique type name (SWC type), and declare one uniquely named variableof that type (one SWC instance).

4.3.2 Ports and Interfaces

In the VFB model, software components interact trough ports which are typed by interfaces. The *interface* controls what can be communicated, as well as the semantics of communication. The port provides the SWC access to the interface. The combination of port and port interface is named *AUTOSAR interface*.

There are two classes of ports:

- *Provided ports (Pports)* are used by an SWC to provide data or services to other SWC. Pports are implemented either as sender ports or as server ports.

- *Required ports (Rports)* are used by an SWC to require data or services from other SWC. Rports are implemented either as receiver ports or as client ports.

> **NOTE**
>
> In the following, AUTOSAR ports are referred to as Rports or Pports, to avoid confusion with non-AUTOSAR ports.

INTECRIO V5.0 supports the following interface types in existing legacy AUTOSAR modules[1]:

- sender-receiver (signal passing)
- client-server (function invocation)
- calibration parameter interfaces

If an SWC contains other interfaces (i.e. an NVData interface or a ModeSwitch interface), these interfaces are skipped during import, and a warning is issued for each skipped interface.

Each Pport and Rport of an SWC must define the interface type it provides or requires.

If a system project is built from SWC instances, the Rports and Pports of the instances are connected. Senders must be connected with receivers, clients with servers.

4.3.2.1 Sender-Receiver Communication

Sender-receiver communication involves the transmission and reception of signals consisting of atomic data elements sent by one SWC and received by one or more SWC.

An SWC type can have multiple sender-receiver ports.

Each sender-receiver port can contain multiple data elements each of which can be sent and received independently. Data elements within the interface can be simple (integer, float, ...) or complex (array, matrix, ...) types.

Sender-receiver communication is one-way; each reply by a receiver must be modeled as separate sender-receiver communication.

An Rport of an SWC that requires a sender-receiver interface can read the data elements of the interface. A Pport that provides the interface can write the data elements.

In INTECRIO V5.0, sender-receiver communication can be only "`1:n`" (one sender, several receivers). "`n:1`" (several senders, one receiver) is not supported in this version.

1) A *legacy AUTOSAR module* is an AUTOSAR module that was imported with INTECRIO V5.0.0 or earlier.

4.3.2.2 Client-Server Communication

Client-server communication involves an SWC invoking a defined server function in another SWC; the latter may or may not return a reply.

An SWC type can have multiple client-server ports.

Each client-server port can contain multiple operations that can be invoked separately. An Rport of an SWC that requires an AUTOSAR server interface to the SWC can independently invoke any of the operations defined in the interface by making a client-server call to a Pport providing the service. A Pport that provides the client-server interface provides implementations of the operations.

Supported are several clients invoking the same server, i.e. "`n:1`" with `n ≥ 0`. It is not possible for a client to invoke multiple servers with a single request; several requests are necessary for that purpose.

4.3.2.3 Calibration Parameter Interfaces

Calibration parameter interfaces are used for communication with Calibration components.

Each calibration parameter interface can contain multiple calibration parameters. A port of a software component that requires an AUTOSAR calibration interface to the component can independently access any of the parameters defined in the interface by making an RTE API to the required port. Calibration components provide the calibration interface and thus provide implementations of the calibration parameters.

4.3.3 Runnable Entities and Tasks

A *runnable entity* is a piece of code in an SWC that is triggered by the RTE (cf. section 4.2) at runtime. It corresponds largely to the processes known in INTECRIO.

A software component comprises one or more runnable entities the RTE can access at runtime. Runnable entities are triggered, among others, by the following events:

- *Timing events* represent some periodic scheduling event, e.g. a periodic timer tick. The runnable entity provides the entry point for regular execution.
- Events triggered by the reception of data at an Rport (DataReceive events).

AUTOSAR runnable entities can be sorted in several categories. INTECRIO supports runnable entities of category 1.

In order to be executed, runnable entities must be assigned to the tasks of an AUTOSAR operating system.

Inter-Runnable Variables

The RTE allows the configuration of inter-runnable variables that provide a way for the runnable entities of a software component to communicate with each other. In INTECRIO, these inter-runnable variables can be measured during an experiment.

4.3.4 Runtime Environment

The runtime environment is described in section 4.2.

An RTE is – like the crossbar (section 3.5.5) – delivered with the INTECRIO installation. It is configured in INTECRIO via assignment of SWC to software systems, graphical connections and the OS configuration.

5 INTECRIO Components

INTECRIO consists of a series of base components and connectivity packages.

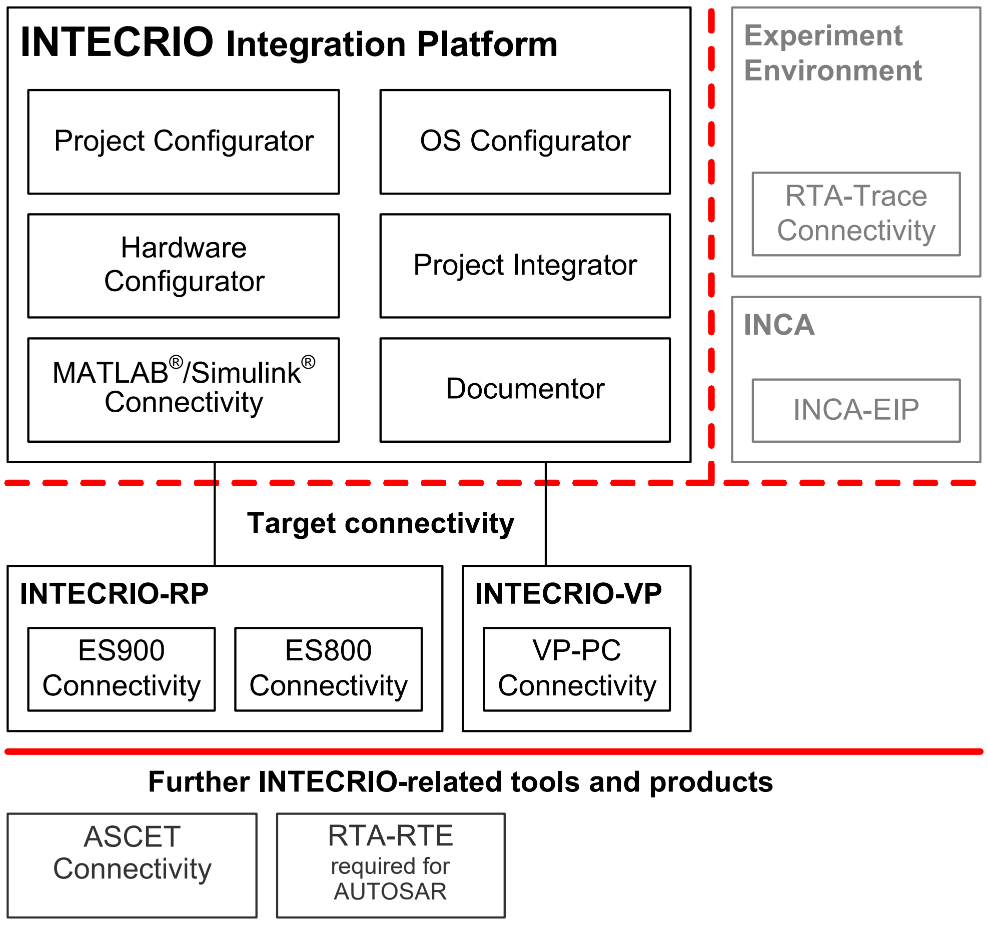


Fig. 5-1 INTECRIO – components
(black: INTECRIO, dark gray: INTECRIO-related ETAS tools,
light gray: ETAS tools that can be used to experiment with INTECRIO)

The project configurator (section 5.7), OS configurator (section 5.8), hardware configurator (section 5.3) and project integrator (section 5.9) are indispensable for working with INTECRIO; they are part of the INTECRIO integration platform. The documentor (section 5.11) is also part of the INTECRIO integration platform.

The ETAS Experiment Environment (section 5.10), which includes RTA-TRACE connectivity (section 5.12), INCA and INCA-EIP are separate products. The ETAS experiment is shipped with INTECRIO; INCA and INCA-EIP have to be purchased individually.

Target Connectivity: The INTECRIO-RP package provides connectivity to the rapid prototyping hardware, i.e. ES900 (section 5.4) and ES800 (section 5.5), and the INTECRIO-VP package provides connectivity to the PC (section 5.6) and all prerequisites for virtual prototyping.

BMT Connectivity: Different behavioral modeling tools (BMTs) allow users to model the functionality of the application software. The models are integrated in the system project. Checking or editing the models is not part of INTECRIO; INTECRIO only serves as integration tool in this context.

- MATLAB® and Simulink® connectivity (cf. section 5.1) is provided by the INTECRIO integration platform directly.
- ASCET connectivity (cf. section 5.2)

  In ASCET V6.3 and higher, ASCET connectivity is integrated in ASCET-MD.

  In ASCET V6.2 and lower, ASCET connectivity is available as a separate ASCET add-on named INTECRIO-ASC, or as a part of ASCET-RP. You can install it directly from the ASCET installation medium, according to your needs. The license is included with the license for the INTECRIO integration platform.

Other Tools and Products: The *RTA-RTE* tool provides the runtime environment (see section 4.2 on page 46) required for AUTOSAR.

5.1 MATLAB® and Simulink® Connectivity

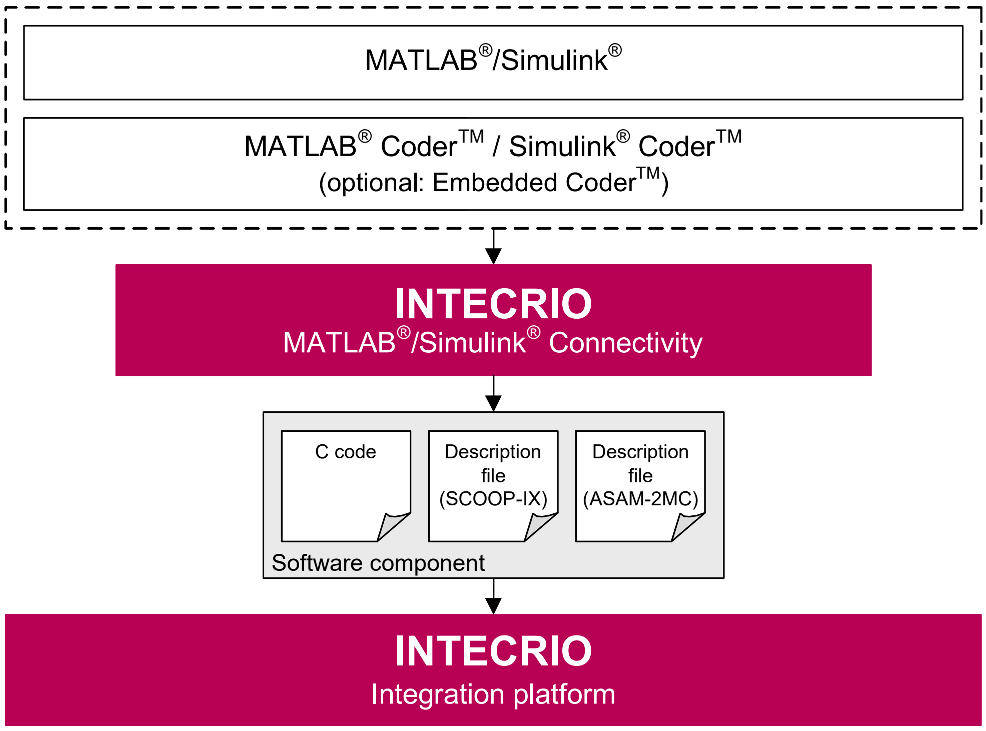

MATLAB®/Simulink®
MATLAB® Coder™ / Simulink® Coder™
(optional: Embedded Coder™)
INTECRIO
MATLAB®/Simulink® Connectivity
C code
Description file (SCOOP-IX)
Description file (ASAM-2MC)
Software component
INTECRIO
Integration platform

Fig. 5-2 INTECRIO-IP: MATLAB® and Simulink® connectivity

MATLAB and Simulink connectivity is provided by the INTECRIO integration platform without the need of further add-on installations. The integration platform contains everything required for a successful linking of Simulink models in INTECRIO for integration and rapid prototyping.

It allows the integration of code generated by MATLAB® Coder™ + Simulink® Coder™ + (optional) Embedded Coder®.

MATLAB and Simulink versions R2016a – R2022a and their related service packs known at the time of the INTECRIO V5.0 release are supported. If several supported MATLAB and Simulink versions are installed, all of them are supported at the same time.

Unsupported MATLAB and Simulink versions cannot be used to create code for use with INTECRIO.

Model code created with MATLAB and Simulink R2006b – R2015b can still be imported and integrated in INTECRIO V5.0.

During the installation of MATLAB and Simulink connectivity, the MATLAB and Simulink installation is adjusted so that MATLAB and Simulink can interact with INTECRIO.

MATLAB and Simulink connectivity has the following tasks:

- Providing the INTECRIO target `irt.tlc` that must be selected if the Simulink model must be further processed with INTECRIO.
- Providing the INTECRIO target `ier.tlc` that must be selected if the Simulink model to be used in INTECRIO was created with the MATLAB Coder + Simulink Coder + Embedded Coder software.
- Providing the automatic creation of the SCOOP-IX description file (see chapter 6) during code generation with one of the following setups:
  - MATLAB Coder + Simulink Coder
  - MATLAB Coder + Simulink Coder + Embedded Coder

  The contents of this description file is explained in section 5.1.2.
- Providing the option to start the integration in a newly created INTECRIO system and the INTECRIO build process directly from Simulink (one-click prototyping).
- Automatic re-import of the model in INTECRIO after changes and new code generation in Simulink.

If no MATLAB and Simulink installation was available during INTECRIO installation, or if you want to change the MATLAB and Simulink version associated with INTECRIO, proceed as follows.

To connect INTECRIO and MATLAB and Simulink subsequently:

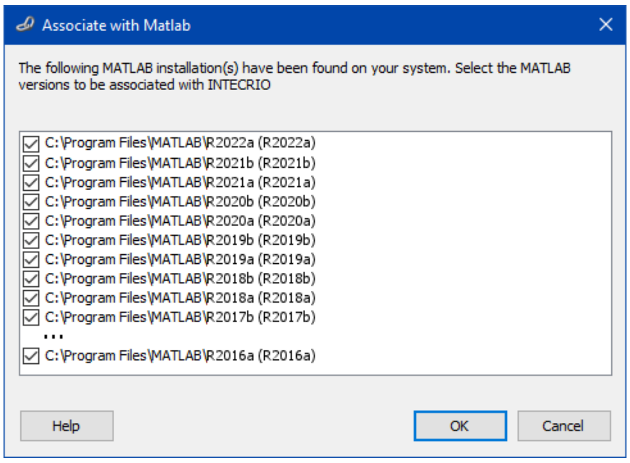
NOTE

If you want to use a network installation of MATLAB and Simulink, click on the **Help** button and follow the instructions given in the message window.

1. Install MATLAB and Simulink as described in the relevant installation instructions.

2. In the Windows Start menu, INTECRIO folder, select **Connectivity > Associate with Matlab**.

   The "Associate with Matlab" window opens. It offers all supported MATLAB and Simulink installations available on your computer for selection.



Associate with Matlab

The following MATLAB installation(s) have been found on your system. Select the MATLAB versions to be associated with INTECRIO

- ☑ C:\Program Files\MATLAB\R2022a (R2022a)
- ☑ C:\Program Files\MATLAB\R2021b (R2021b)
- ☑ C:\Program Files\MATLAB\R2021a (R2021a)
- ☑ C:\Program Files\MATLAB\R2020b (R2020b)
- ☑ C:\Program Files\MATLAB\R2020a (R2020a)
- ☑ C:\Program Files\MATLAB\R2019b (R2019b)
- ☑ C:\Program Files\MATLAB\R2019a (R2019a)
- ☑ C:\Program Files\MATLAB\R2018b (R2018b)
- ☑ C:\Program Files\MATLAB\R2018a (R2018a)
- ☑ C:\Program Files\MATLAB\R2017b (R2017b)

...

- ☑ C:\Program Files\MATLAB\R2016a (R2016a)

Fig. 5-3 "Associate with Matlab" window

3. In the "Associate with Matlab" window, select one or more MATLAB and Simulink installations.
4. Click **OK** to continue.

   INTECRIO and the selected MATLAB and Simulink installation(s) are connected.

5.1.1 Characteristics in the Creation of the Simulink Model

Several points must be observed when creating the Simulink model for later use with INTECRIO. Only the most important points are listed here; additional information about modeling in Simulink can be found in section 7.2 "Modeling with Simulink®".

- Only the signal ports of the top-level hierarchy of the model are recognized as signal sources or sinks in INTECRIO.

  NOTE

  Signal ports from lower levels of the hierarchy are not recognized as signal sources or sinks. (Exceptions are listed in the INTECRIO section in the MATLAB AND SIMULINK online help viewer.)

- INTECRIO supports floating-point code that was generated with MATLAB Coder + Simulink Coder (+ Embedded Coder).

  This entails that all Simulink blocks for which code can be generated with MATLAB Coder + Simulink Coder are supported.
- INTECRIO target `irt.tlc` or `ier.tlc` must be selected for the code generation to create the SCOOP-IX file.

- INTECRIO allows for the integration of several Simulink models. Each model can be assigned a different integration algorithm (solver for continuous states) with fixed step width.
- Since V4.7.2, INTECRIO supports the Model Referencing feature of Simulink.

5.1.2 Contents of the Description File

The interface description file that is automatically created during the code generation, the SCOOP-IX file, contains the following information if they were specified in Simulink:

- Signal sources and sinks (inports and outports of the highest modeling level)
    - Name
    - Physical value range
    - Implementation data type and value range (can also be calculated using the physical value range and the quantization formula)
    - Quantization formula
- A signal for each one-dimensional Simulink signal
- One signal for the real part and one signal for the imaginary part of a complex Simulink signal
- Parameters and variables (no distinction is made between one, two and three-dimensional quantities)
    - Name
    - Physical value range
    - implementation data type and quantization
    - Hierarchical information, i.e. the exact location of the quantity in the model
- Activation interfaces (processes)
    - Timing information for cyclical processes

5.2 ASCET Connectivity

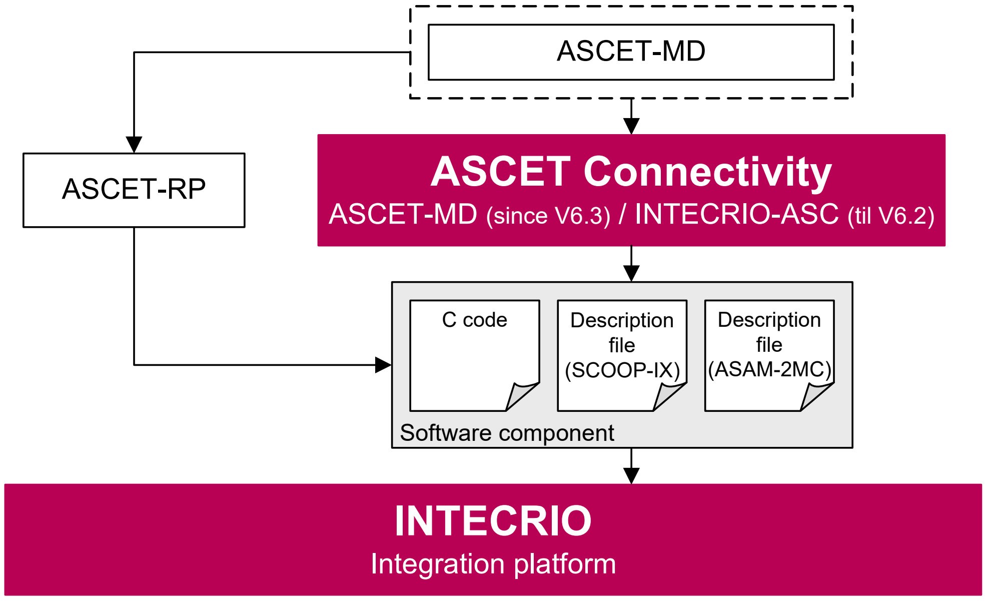

ASCET-MD
ASCET-RP
ASCET Connectivity
ASCET-MD (since V6.3) / INTECRIO-ASC (til V6.2)
C code
Description file (SCOOP-IX)
Description file (ASAM-2MC)
Software component
INTECRIO
Integration platform

Fig. 5-4 ASCET connectivity

ASCET Connectivity contains everything required for a successful linking of ASCET models in INTECRIO for integration and rapid prototyping.

NOTE

Since V5.0.1, INTECRIO no longer supports ES1000 and RTPRO-PC hardware systems. ASCET models that include either of these hardware systems cannot be transferred to INTECRIO.

In ASCET V6.2 and earlier, ASCET connectivity is available as an add-on named INTECRIO-ASC. During the installation of INTECRIO-ASC, the required files and settings are automatically inserted in the existing ASCET installation. INTECRIO-ASC supports ASCET V5.1 – V6.2; if several ASCET versions are installed, all of them are supported at the same time.

In ASCET V6.3 and higher, ASCET connectivity is included in ASCET-MD. Nothing else has to be installed.

ASCET connectivity has the following tasks:

- Providing the targets `Prototyping` and `ES900`, one of which must be selected if the ASCET model is to be further processed with INTECRIO.

  NOTE

  ASCET connectivity does not support ES8xx hardware.

- Selection of INTECRIO as rapid prototyping environment in the project editor of ASCET.

- In the context of an ASCET project, provision of a special code generation for INTECRIO in which all required files (C code, ASAM-MCD-2MC file, SCOOP-IX description file) are created.

  The contents of the SCOOP-IX description file is explained in section 5.2.2.

  In addition, an `*.oil` file is generated that contains the OS configuration. This file can be manually imported into INTECRIO.
- If the ASCET code generation for INTECRIO is used, automatic import of the project in INTECRIO.
- Adjusting the handling of non-resolved global variables and messages to the needs of INTECRIO.
- Providing options for the migration of existing projects.
- Providing the option to start the integration in an INTECRIO system and the INTECRIO build process directly from ASCET (one-click prototyping).
- Automatic re-import of the model in INTECRIO after changes and new code generation in ASCET.

5.2.1 Characteristics in the Creation of the ASCET Model

When you create an ASCET model for later use with INTECRIO, you can make use of all ASCET facilities. Keep in mind the following points:

- Receive messages without corresponding send messages form the signal sinks in INTECRIO, send messages without corresponding receive messages form the signal sources in INTECRIO.

  If desired, you can make connected messages appear as signal sinks and sources, too.
- When your project contains unresolved messages (imported messages without corresponding export), code generation for INTECRIO produces an error message.

  You can resolve the messages automatically, or cancel code generation and resolve the messages manually.
- Using global variables and parameters is possible, but *strongly* discouraged.
- In the project options, you must select an appropriate target so that code generation for INTECRIO is available.

5.2.2 Contents of the Description File

The interface description file that is automatically created during the code generation, the SCOOP-IX file, contains the following information if they were specified in ASCET:

- Signal sources (send messages) and signal sinks (receive messages)
  - Name
  - Physical value range
  - Implementation data type and value range (can also be calculated using the physical value range and the quantization formula)
  - Quantization formula

- Parameters and variables (no distinction is made between one, two and three-dimensional quantities)
  - Name
  - Physical value range
  - implementation data type and quantization
  - Hierarchical information, i.e. the exact location of the quantity in the model
- Activation interfaces (processes)
  - Timing information for cyclical processes

5.3 Hardware Configurator

During the development of a control algorithm, the actual controlled system must be addressed at some time so that realistic results can be achieved. The controlled system (or the technical process) appears to the rapid prototyping system as a set of sensors and actuators with which the system can be connected using a series of appropriate peripheral devices.

These peripheral devices must be configured so that they fit the actual technical process that must be modeled. For example, for A/D converters it is possible to configure the input range, scanning/keeping, etc. In addition, the signal must be conditioned to adjust it to the control algorithm. The conditioning essentially consists of converting measured electrical signals to physical signal values.

These tasks are handled by the Hardware Configurator and the target connectivity packages (section 5.4 and section 5.5) in INTECRIO.

If an algorithm passed the first general validation check in the virtual model, it can be examined for errors, refined and optimized until it meets the specified requirements of functionality, quality and code size. As a direct troubleshooting option, the Hardware Configurator offers, for example, to measure the signal values of the hardware directly in the ETAS Experiment Environment.

5.3.1 Discontinued Hardware

Since V4.7.3, INTECRIO no longer supports ES1000 and RTPRO-PC hardware systems.

Until INTECRIO V5.0.0, these hardware systems were still visible when you opened an existing workspace. The hardware systems and targets were marked as unusable with a red X in the Workspace Browser, but you could view the hardware systems.

Since INTECRIO V5.0.1, ES1000 or RTPRO-PC hardware systems are deleted when you open an existing workspace. Only ES800 and ES900 and VP-PC hardware systems are shown.

> NOTE
>
> Once an ES1000 or RTPRO-PC hardware system has been deleted, the system project that used it is no longer usable.
>
> You have to add a new hardware system, add devices, connect hardware and software, and set up the OS, before you can again build the system project. See the online help for details.

5.3.2 HWX Import/Export

As an alternative to manual configuration (see section 5.4.1 or section 5.5.1), it is possible to export and import hardware descriptions (`*.hwx` files). For that purpose, INTECRIO provides the necessary context menu options and dialog windows.

You can import `*.hwx` files created with several tools[1], and you can import `*.hwx` files exported with INTECRIO into these other tools.

> NOTE
>
> If your hardware configuration contains a bypass[2] configuration that requires an ASAM-MCD-2MC file, or a daisychain configuration that requires an `*.xml` file, keep in mind the following:
>
> - If you *export* the hardware configuration, make sure that the `*.a2l`/`*.xml` files are exported, too. See the online help for details.
> - For a successful *import* of such a hardware configuration, the `*.a2l`/`*.xml` files have to be provided at the same location as the `*.hwx` file. so that the HXW importer finds them automatically.
>
> An ASAM-MCD-2MC file that was exported by ASCET may cause errors when imported in INTECRIO. It is thus strongly recommended to use *only original* ASAM-MCD-2MC files.

The file extension `*.hwx` is used for two description formats, the outdated HWX1 format and the HWX2 format.[3] INTECRIO V5.0 uses only HWX2; if you try to import an HWX1 file, an error is issued.

The hardware description is mapped onto an existing or new ES900, ES800, or VP-PC hardware system during import.

The log window displays a list with information about the import procedure.

If the `*.hwx` file contains elements not supported by INTECRIO and the selected target, these elements are skipped, and warnings are issued.

1) INTECRIO, ASCET V6.3 or higher, ASCET V5.1 – V6.2 and INTECRIO-ASC or ASCET-RP V5.3 (or higher), INTECRIO-RLINK, or customer-specific ASCET extensions
2) ETK/XETK/FETK/XCP bypass
3) The *HWX2* format is used by INTECRIO V3.2 and higher and by the Hardware Configurator in ASCET-RP V6.1 and higher.

5.3.3 Ethernet Controller and XCP on UDP

The Rapid Prototyping targets ES910 and ES830 support one Ethernet controller that can be used for XCP bypass on UDP and X/FETK bypass.

The Ethernet controller supports up to four XCP on UDP interfaces and one (ES910) or three (ES830) X/FETK bypass devices.

NOTE

In a hardware system, 4 is the maximum number of *all* XCP interfaces, i.e. XCP on UDP and XCP on CAN.

Fig. 5-5 shows the schematic structure of the Ethernet controller and XCP on UDP in the WS browser.

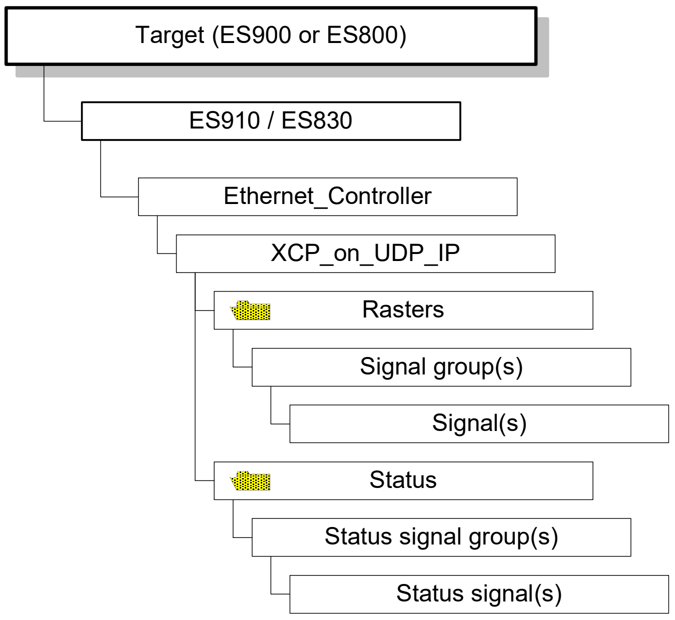


Fig. 5-5 Ethernet and XCP on UDP structure in the WS browser

5.3.4 XXX to CAN Gateway

The *XXX to CAN Gateway* functionality serves to generate a gateway from an ETK, X/FETK, XCP on CAN or XCP on UDP device to a CAN device. The signal interfaces between the devices are generated in a semi-automated way; the behavior is controlled by an `*.xml` settings file. For details, see the online help.

5.4 ES900 Connectivity and Hardware Configurator

INTECRIO V5.0 supports the ES900 hardware, i.e. the ES910.2 and ES910.3 rapid prototyping modules and the ES920 (FlexRay), ES921 (additional CAN) and ES922 (additional CAN or CAN FD) modules. The ES4xx, ES63x and ES930 modules are supported, too. In combination with ES900 connectivity, the Hardware Configurator (HC) is provided for the integration and configuration of this hardware.

NOTE

The ES900 configuration capabilities of the Hardware Configurator are only available if you installed the INTECRIO-RP package and have an appropriate license key.

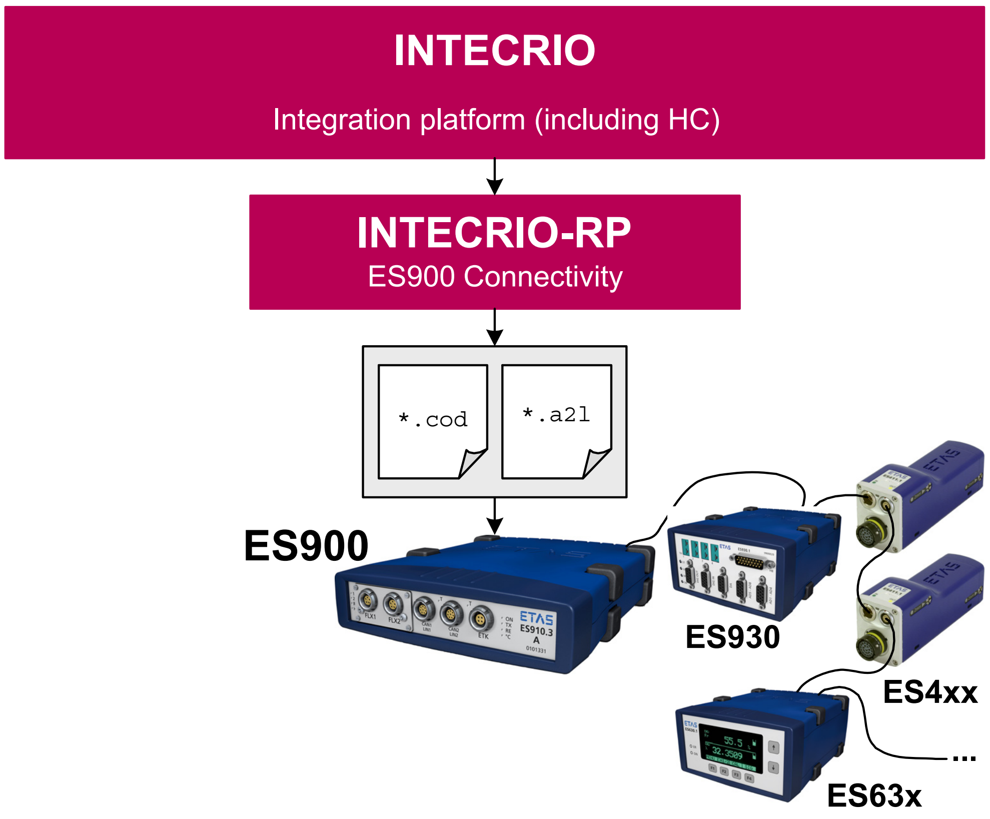


Fig. 5-6 INTECRIO-RP: ES900 connectivity

The Hardware Configurator allows the configuration of ES900 hardware systems to provide real physical signals for inputs and outputs of the model, which can be linked with the software function model in the project configurator (see section 5.7). It is used to configure interfaces available in the ES900 for the experiment. They do not have to be installed at the time of configuration.

Information about the individual interfaces can be found in section 5.4.2 and in the manuals of the hardware products.

5.4.1 ES900 Configuration in the Hardware Configurator

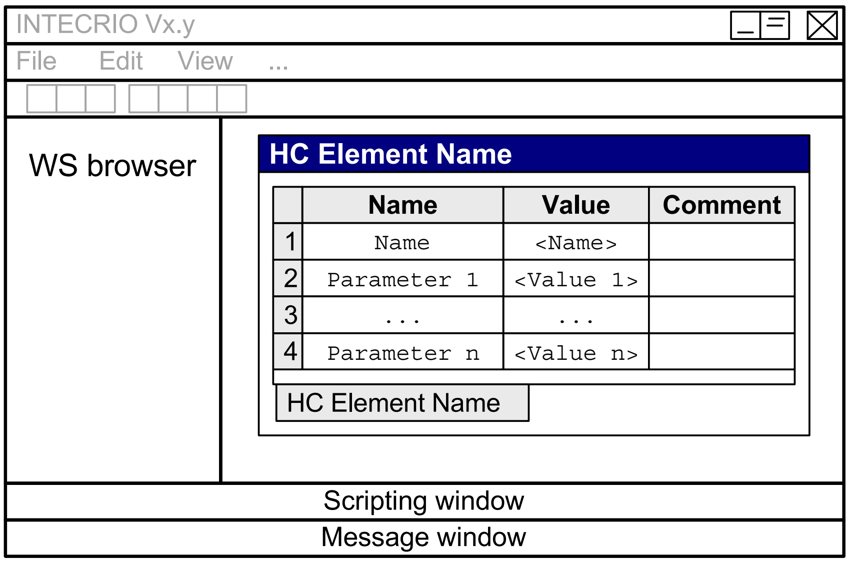
The Hardware Configurator contains the following components required for ES900 configuration:

- A framework that provides the basic editor and connections to other INTECRIO components (e.g. OS configurator, project integrator, ETAS Experiment Environment), among others.
- A specific expansion of the basic editor for each interface supported by INTECRIO. Each of these expansions allows for the configuration of the respective interface based on parameters that are displayed in various tabs.
- A generator for the configuration of the device drivers.

These components can be used for the following tasks:

- Configuring interfaces (or loading a daisy chain, CAN, FlexRay or LIN configuration)
- Assigning input or output actions for operating system tasks (defined in the OS configurator)
- Providing conversion formulas for describing the mapping of physical signals (model view) to raw values (driver view)

The current hardware system is displayed in the WS browser as a tree structure. The ES900 itself is located in the `Hardware/Hardware Systems` folder on the top level, the current simulation controller (ES910) is shown on the level directly underneath it. This is the master with which all other interfaces are linked as slaves. The available hardware signals are placed in a lower hierarchy level. Each level has parameters that can be adjusted in appropriate editors.



	Name	Value	Comment
1	Name	<Name>	
2	Parameter 1	<Value 1>	
3	...	...	
4	Parameter n	<Value n>	

Fig. 5-7 Hardware Configurator – diagram

The entry (controller, device, signal group, signal) to be edited is selected in the WS browser, while the corresponding editor is opened in the display window. It is possible to edit several objects at the same time.

The editor lists all parameters of the respective object in tables. Number and names of the parameters and registers depend upon the object.

Manual Configuration: In offline mode, the Hardware Configurator allows for the configuration of the interfaces supported by INTECRIO to build a hardware system. The following points must be observed when the board hierarchy is created:

- You can create an arbitrary number of ES900 hardware systems. Each hardware system can contain only one ES910 target.
- The ES910 target is mandatory.
- A hierarchy consists of the target as master and one or several slave interfaces controlled by the master.
- All slave interfaces are located on the same hierarchy level; a slave interface cannot have its own slave interfaces.
- Each slave interface is assigned to its master.
- Some interfaces are present several times in an ES900 system. Tab. 5-1 lists the available numbers of interfaces.

	ES910	**Remarks**
CAN Controller	0 – 2 (4)	two additional classic CAN interfaces with ES921 two additional classic CAN/CAN FD interfaces with ES922
XCP on CAN (via CAN controller)	0 – 4	4 is the maximum number of *all* XCP interfaces, i.e. XCP on CAN *and* XCP on UDP.
LIN	0 – 2	The LIN interfaces use the same ES910 hardware connectors as the main two CAN interfaces. With a suitable cable, you can use CAN and LIN simultaneously.
ETK Bypass	0 – 1	Can be used as hook-based bypass or service-based bypass.
SystemDevice	0 – 1	
ES920 (FlexRay)	0 – 1	
Daisychain (IO interface)	0 – 1	A chain of ES4xx and/or ES63x and/or ES930 modules.
Ethernet and XCP on UDP	0 – 4	See section 5.3.3 on page 60 for details. 4 is the maximum number of *all* XCP interfaces, i.e. XCP on CAN *and* XCP on UDP.
Ethernet and X/FETK_Bypass	0 – 1	Can be used as hook-based bypass or service-based bypass. The **X/FETK bypass device is used** for XETK.

NOTE

INTECRIO supports ETK and XETK on ES900 systems. XETK bypass is supported via the Ethernet controller with an XETK bypass device in the INTECRIO hardware configuration. In addition, XETK can be accessed via XCP bypass.

To connect the **XETK** hardware, the ECU port on the ES910 is used.

Starting with INTECRIO V5.0.1, support of FETK bypass with ES910 is deprecated. Please use a combination of ES830 and ES89x for FETK bypass.

See the INTECRIO online help for details on XETK configuration.

Tab. 5-1 Number of interfaces/elements per system controller

- For the CAN/CAN FD interfaces, you must make sure that each interface features a unique ID.

  For the remaining interfaces, the ID is automatically assigned.

  In each case, it must be ensured that the ID of the interface to be used is correctly set in the Hardware Configurator.
- To use CAN FD, the ES922 must be mounted in the ES910. A suitable port (`CAN* (ES922 FD)`) must be assigned to the CAN controller.
- Interfaces of different types can be used with a master.

> **NOTE**
>
> During insertion, the Hardware Configurator offers a list with objects that may be inserted at the current location of the tree view.

Interfaces, devices and other sublevels can be inserted in the hierarchy, and deleted when these points are taken into account.

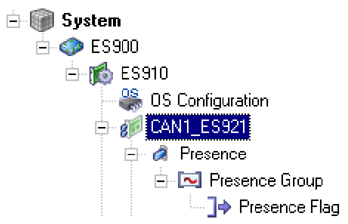
The interfaces, devices, signal groups and signals of the hardware system – except the daisy chain which is configured in a separate configuration tool – can be configured in the Hardware Configurator. The following points must be observed during the configuration:

- While a series of interface parameters are preset, the tasks and processes associated with the signals/signal groups are defined in the OS configurator. All signals of a signal group are processed at the same time.
- During the configuration of individual signals, conversion formulas for sensors and actuators can be specified. The following formulas are available:
  - Identity: `f(phys) = phys`
  - linear: `f(phys) = a*phys + b`
- An implementation (i.e. a conversion formula and a valid value range) can be specified for CAN signals.
- ES920 (FlexRay) and ES921/ES922 (additional CAN/CAN FD controllers) can be configured in the same hardware system, even though only one plugin module can be connected to the ES910.

  At runtime, only that plugin module actually present in the hardware is activated. The other plugin modules produce an error message.

  It is thus recommended to set the ES910 parameter "I/O Failure Behavior" to `continue` so that the experiment continues despite the error. (Otherwise, the experiment is stopped immediately due to the error.)

  The RP model can use the Presence flag to check whether a configured plugin module is actually available and ready for use, and act accordingly.



- Up to four CAN controllers and two LIN controllers can be configured in the same hardware system. To access all of them at runtime, you need a suitable cable.

Parts of the hardware system can be copiedvia **Copy** and **Paste**. The settings of the target parts are overwritten; if no target part is selected, a new one is created.

Import: As an alternative to manual configuration, it is possible to import a hardware description (`*.hwx` file); see “HWX Import/Export” on page 59.

5.4.2 Interface Types and Supported Interfaces

Tab. 5-2 contains the interface classes for the ES900 and the names of the interface supported by INTECRIO. The listed interfaces of the ES900 can be configured using the Hardware Configurator.

Interface class	Name	Description
Simulation controller	ES910	system controller
Communication interface	CAN_Controller + CAN_IO	CAN IO interface
	CAN_Controller + XCP_on_CAN	XCP bypass on CAN
	ETK_Bypass	ETK interface
	LIN_Controller	LIN interface
	ES920	FlexRay interface
	Ethernet_Controller	Interface for XCP bypass on UDP and XETK bypass
IO interface	Daisychain	A chain of ES4xx and/or ES63x and/or ES930 modules; connected to the IO interface
System interface	SystemDevice	controls display and monitoring modes

Tab. 5-2 Interface classes of the ES900 and names of supported interfaces/ elements

Tab. 5-1 on page 63 indicates how many interfaces of a type can be used with which system controller.

Fig. 5-8 shows the schematic structure of the interfaces in the WS browser.

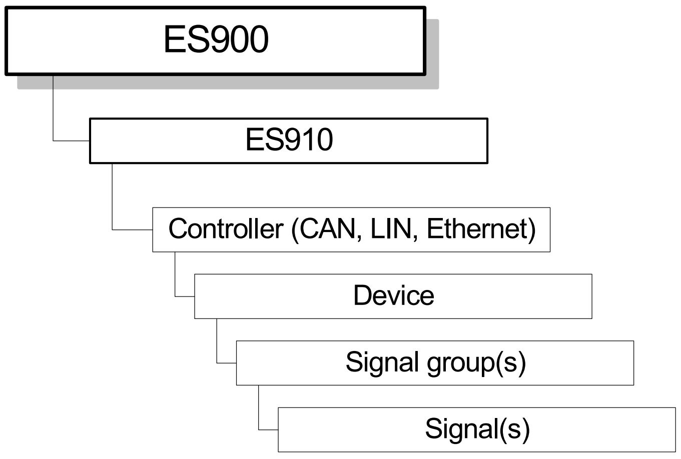


Fig. 5-8 Display of the interfaces in the WS browser

Simulation controller: The simulation controller (ES910 in Fig. 5-8) is equipped with an Ethernet interface (named *ECU* on the ES910) for XCP on UDP and XETK, interfaces to the CAN/CAN FD, LIN and FlexRay bus of the vehicle, and an ETK interface.

Communication interfaces: Communication interfaces are used for distributing messages on the network (such as the CAN bus). The display of supported communication interfaces in the Hardware Configurator varies so much that all are described below.

CAN Controller + CAN IO

- In the tree view, the first hierarchy level (i.e. the one underneath the ES910) is occupied by the CAN controller.
- The second hierarchy level is occupied by the CAN node (device, CAN IO).
- The third hierarchy level is occupied by folders for CAN frames (signal groups) and CAN signals.

  Underneath the folder for *CAN frames*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by CAN frames (signal groups).
  - The fifth hierarchy level is occupied by simple CAN signals and/or CAN signals of type *multiplexor*.
  - Underneath a CAN signal of type *multiplexor,* the sixth hierarchy level is occupied by CAN multiplex groups.
  - The seventh hierarchy level under the CAN multiplex group is occupied by CAN signals of type *multiplexed*.

  Underneath the folder for *CAN signals*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by CAN signals of type *standard*.

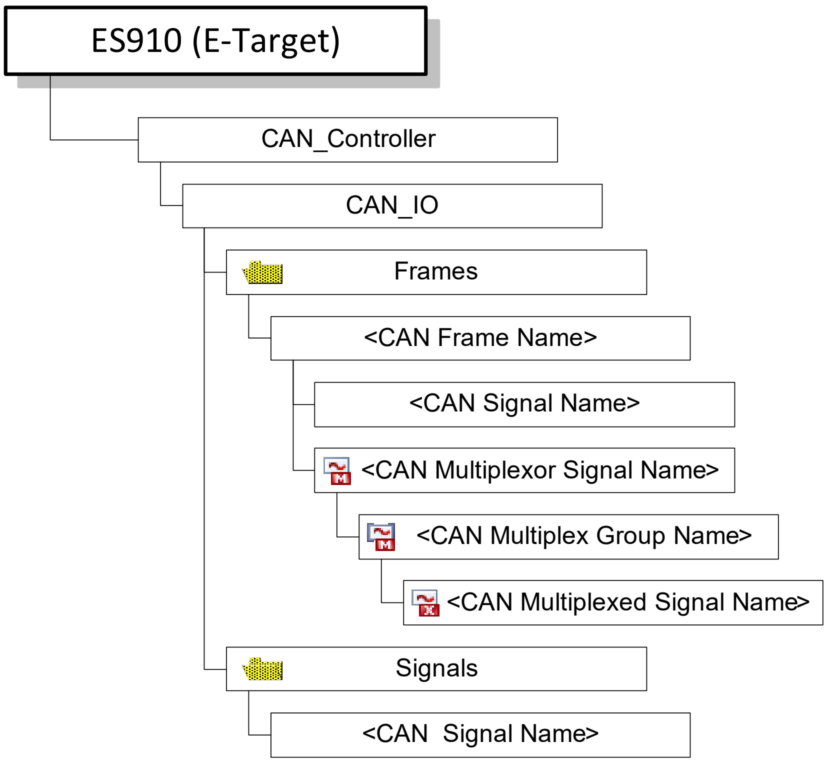


Fig. 5-9 Display of the CAN IO interface in the WS browser

CAN Controller + XCP bypass

- In the tree view, the first hierarchy level (i.e. the one underneath the ES910) is occupied by the CAN controller.
- The second hierarchy level is occupied by the XCP on CAN node (device).
- The third hierarchy level is occupied by folders for rasters and status.

  Underneath the folder for *rasters*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by XCP rasters (signal groups).
  - The fifth hierarchy level is occupied by XCP signals.

  Underneath the *Status* folder, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by status signal groups.
  - The fifth hierarchy level is occupied by status signals.

ETK interface

- The first hierarchy level is occupied by the ETK bypass device.

> i NOTE
>
> The ETK interface supports hook-based and service-based bypass (V2 and V3). Both types can be used separately or in parallel.
>
> INTECRIO does not support service-based bypass on an ETK with 8 Mbit/s.

For a hook-based bypass, the levels underneath the bypass device are occupied as follows:

- The second hierarchy level is occupied by the signal groups for sending and receiving.
- The third hierarchy level is occupied by individual signals.

For a service-based bypass, the levels underneath the bypass device are occupied as follows:

- The second hierarchy level is occupied by the signal groups for sending and receiving and by the service points and hooked service points.

  The ASAM-MCD-2MC file contains service point descriptions. Number and configurations of the service points actually used in the bypass are determined in the service point selection editor.
- *Below the signal groups*, the third hierarchy level is occupied by individual signals.
- *Below the service points*, the third hierarchy level is occupied by the signal groups for sending and receiving.

  The available signal groups depend on the settings made in the service point and hooked service point selection editors.
- The fourth hierarchy level is occupied by individual signals.

LIN interface

NOTE

Instead of configuring the LIN interface manually, you can import a cluster configuration from a LIN description file.

- In the tree view, the first hierarchy level (i.e. the one underneath the ES910) is occupied by the LIN controller.
- The second hierarchy level is occupied by the LIN node (device, LIN I/O).

  A LIN node can be used either as *master* or as *slave*. The selected node type determines availability and direction of several items below the node level.
- The third hierarchy level is occupied by folders for schedule tables (only available for *Master* nodes), status display, frames, diagnostic frames, and signals.

  Underneath the folder for *schedule tables*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by schedule tables.
  - The fifth level is occupied by frames of the various types.
  - For *unconditional frames*, the sixth level is occupied by signals.
  - For *event-triggered* and *sporadic frames*, the sixth level is occupied by references to unconditional frames.
  - For *event-triggered* and *sporadic frames*, the seventh level is occupied by references to signals of unconditional frames.

  Underneath the folder for *status display*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by status signal groups.
  - The fifth hierarchy level is occupied by status signals.

  Underneath the folder for *frames*, the hierarchy levels are occupied as follows:

- The fourth hierarchy level is occupied by folders for event-triggered frames, sporadic frames (only available for *Master* nodes), and unconditional frames.
- The fifth level is occupied by frames of the various types.
- For *unconditional frames*, the sixth level is occupied by signals.
- For *event-triggered* and *sporadic frames*, the sixth level is occupied by references to unconditional frames.
- For *event-triggered* and *sporadic frames*, the seventh level is occupied by references to signals of unconditional frames.

Underneath the folder for *diagnostic frames*, the hierarchy levels are occupied as follows:

- The fourth hierarchy level is occupied by diagnostic frames (signal groups).
- The fifth hierarchy level is occupied by diagnostic signals.

Underneath the folder for *signals*, the hierarchy levels are occupied as follows:

- The fourth hierarchy level is occupied by LIN signals of type *standard*.

FlexRay interface

- The first hierarchy level is occupied by the FlexRay IO device (i.e. the ES920).
- The second hierarchy level is occupied by folders for channels, status display, FlexRay frames, FlexRay PDUs, and FlexRay signals.

  Underneath the folder for *channels*, the hierarchy levels are occupied as follows:

  - The third hierarchy level is occupied by two channels.
  - The fourth hierarchy level is occupied by slots. Up to 2047 slots can belong to one channel.
  - The fifth hierarchy level is occupied by frames. Up to 64 frames can belong to one slot.
  - The sixth hierarchy level underneath a frame is occupied by the frame's PDUs.

    The levels below a PDU are described on Page 69.

  Underneath the folder for *status display*, the hierarchy levels are occupied as follows:

  - The third hierarchy level is occupied by status signal groups.
  - The fourth hierarchy level is occupied by status signals.

  Underneath the folder for *frames*, the hierarchy levels are occupied as follows:

  - The third hierarchy level is occupied by FlexRay frames.
  - The fourth hierarchy level is occupied by FlexRay PDUs (signal groups).
  - The fifth hierarchy level is occupied by simple FlexRay signals and/or FlexRay signals of type *multiplexor*.
  - Underneath a FlexRay signal of type *multiplexor*, the sixth hierarchy level is occupied by FlexRay multiplex groups.
  - The seventh hierarchy level under the FlexRay multiplex group is occupied by FlexRay signals of type *multiplexed*.

  Underneath the folder for *PDUs*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by FlexRay PDUs (signal groups).
- The fourth hierarchy level is occupied by simple FlexRay signals and/or FlexRay signals of type *multiplexor*.
- Underneath a FlexRay signal of type *multiplexor*, the fifth hierarchy level is occupied by FlexRay multiplex groups.
- The sixth hierarchy level under the FlexRay multiplex group is occupied by FlexRay signals of type *multiplexed*.

Underneath the folder for *FlexRay signals*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by FlexRay signals of type *standard*.

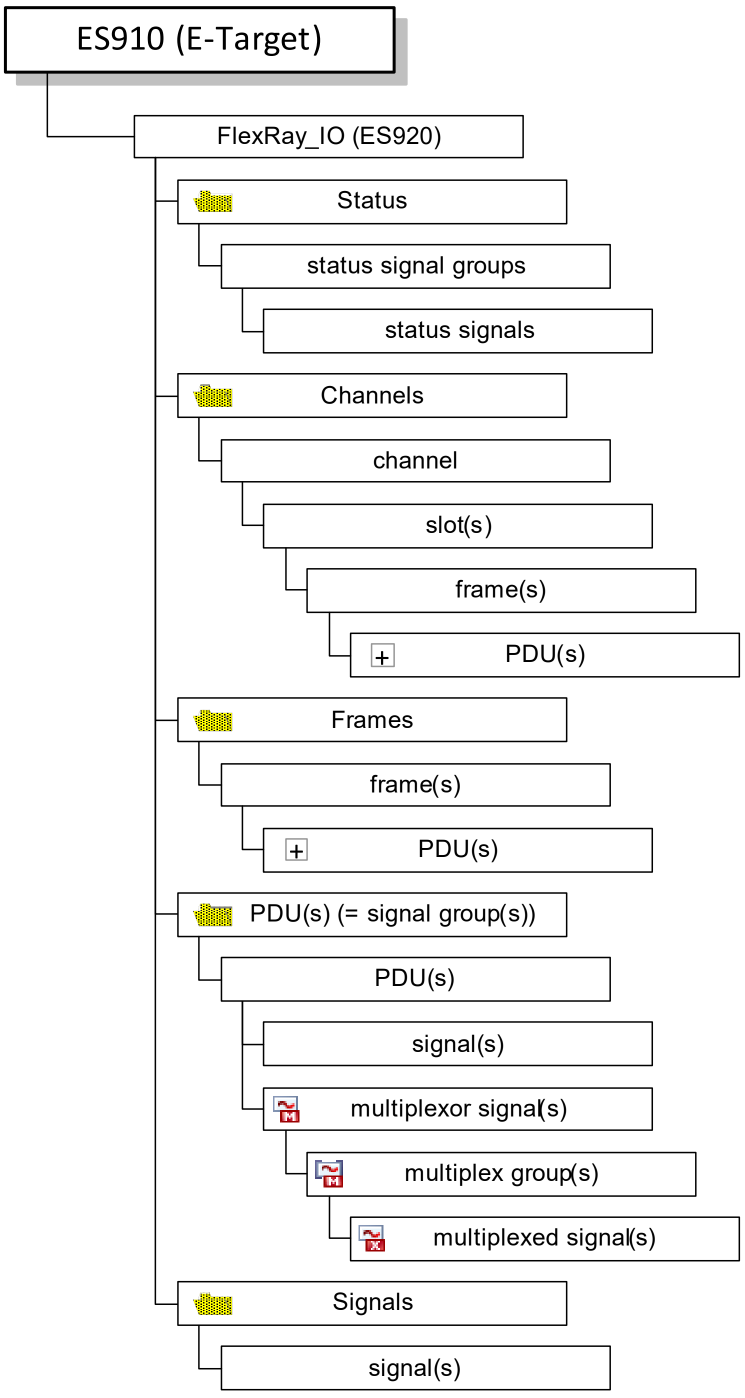


Fig. 5-10 Display of the FlexRay interface in the WS browser

Ethernet interface: The Ethernet interface is used to configure an XCP bypass (XCP on UDP and XETK) or an XETK bypass.

For a description of the XCP bypass (XCP on UDP and XETK), see section 5.3.3 on page 60.

XETK Bypass

- In the tree view, the first level (i.e. the one underneath the ES910) is occupied by the Ethernet Controller.
- The second hierarchy level is occupied by the X/FETK bypass device.
- The third hierarchy level is occupied by the service points and hooked service points.

  The ASAM-MCD-2MC file contains service point descriptions. Number and configurations of the service points actually used in the bypass are determined in the service point selection and hooked service point selection editors.
- The fourth hierarchy level is occupied by the signal groups for sending and receiving.

  The available signal groups depend on the settings made in the service point selection and hooked service point selection editors.
- The fifth hierarchy level is occupied by individual signals.

System interface: The system interface is used to configure the monitoring and display modes of the ES910. Signal groups for the different modes can be activated independently.

- The first hierarchy level is occupied by the system interface device.
- The second hierarchy level is occupied by the signal groups for the different modes.
- The third level is occupied by the individual signals of the different modes. The signals of a mode are predetermined.

IO interface / Daisychain: An ES4xx/ES63x/ES930 daisy chain can be connected to the IO interface at the back of the ES910. The WS browser in INTECRIO does not display the individual elements of the chain, it displays only the chain as a whole, with one signal group for each chain element and sample period.

NOTE

Different from the other interfaces, the daisy chain cannot be configured in INTECRIO. Instead, an externally created configuration file is imported.

If the configuration file is edited, the changes must be imported, via the **Update** context menu, into INTECRIO.

- The first hierarchy level combines the daisy chain and the device.
- The second hierarchy level is occupied by the signal groups for the different sample periods and chain elements.

- The third hierarchy level is occupied by the individual signals assigned to the sample periods and chain elements. The actual signals depend on the daisy chain.

5.5 ES800 Connectivity and Hardware Configurator

INTECRIO V5.0 supports the ES800 hardware, i.e. the combination of one ES830 rapid prototyping module and up to four ES891 or ES892 or ES882 or ES886 ECU and bus interface modules.

In combination with ES800 connectivity, the Hardware Configurator (HC) is provided for the integration and configuration of this hardware.

NOTE

The ES800 configuration capabilities of the Hardware Configurator are only available if you installed the INTECRIO-RP package and have an appropriate license key.

Experimenting with an ES800 hardware system requires INCA V7.4 or higher with INCA-EIP or the ETAS Experiment Environment V3.8.4 or higher.

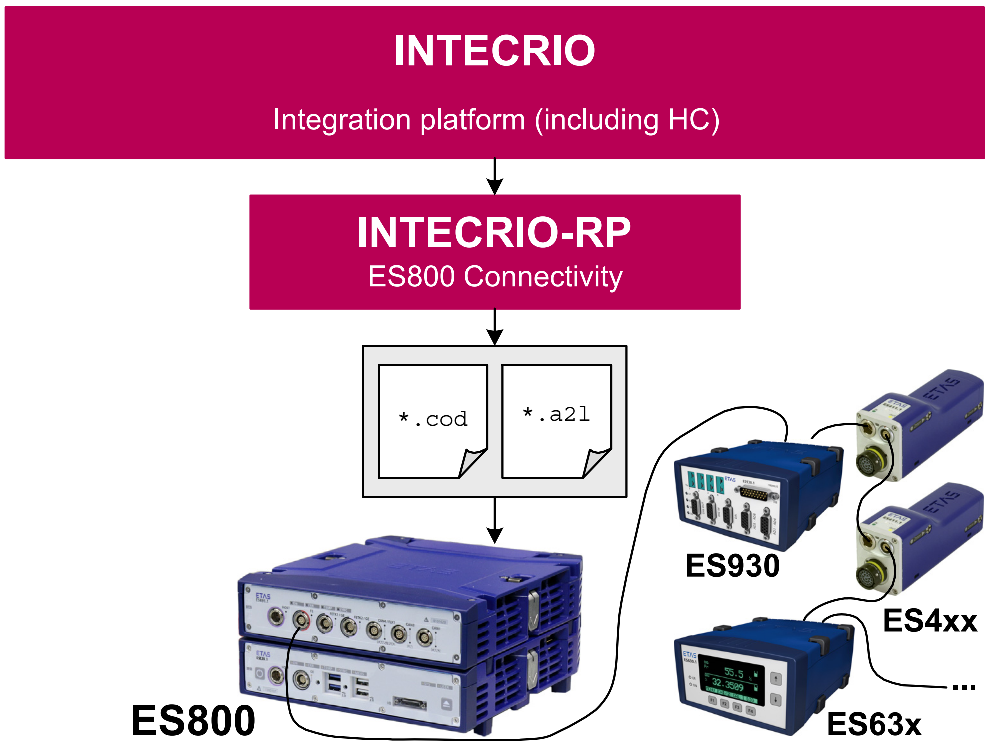


Fig. 5-11 INTECRIO-RP: ES800 connectivity

The Hardware Configurator allows the configuration of ES800 hardware systems to provide real physical signals for inputs and outputs of the model, which can be linked with the software function model in the project configurator (see section 5.7). It is used to configure interfaces available in the ES800 for the experiment. They do not have to be installed at the time of configuration.

Information about the individual interfaces can be found in section 5.5.2 and in the manuals of the hardware products.

5.5.1 ES800 Configuration in the Hardware Configurator

The Hardware Configurator contains the following components required for ES800 configuration:

- A framework that provides the basic editor and connections to other INTECRIO components (e.g. OS configurator, project integrator, ETAS Experiment Environment), among others.
- A specific expansion of the basic editor for each interface supported by INTECRIO. Each of these expansions allows for the configuration of the respective interface based on parameters that are displayed in various tabs.
- A generator for the configuration of the device drivers.

These components can be used for the following tasks:

- Configuring interfaces (or loading a daisy chain, CAN, or FlexRay configuration)
- Assigning input or output actions for operating system tasks (defined in the OS configurator)
- Providing conversion formulas for describing the mapping of physical signals (model view) to raw values (driver view)

The current hardware system is displayed in the WS browser as a tree structure. The ES800 itself is located in the `Hardware/Hardware Systems` folder on the top level, the combination of simulation controller (ES830) and interface modules (ES891, ES892, ES882, or ES886) is shown on the level directly below. This is the master with which all other interfaces are linked as slaves. The available hardware signals are placed in a lower hierarchy level. Each level has parameters that can be adjusted in appropriate editors. Their appearance is the same as for the ES900 interface editors (cf. Fig. 5-7 on page 62).

The entry (controller, device, signal group, signal) to be edited is selected in the WS browser, while the corresponding editor is opened in the display window. It is possible to edit several objects at the same time.

The editor lists all parameters of the respective object in tables. Number and names of the parameters and registers depend upon the object.

Manual Configuration: In offline mode, the Hardware Configurator allows for the configuration of the interfaces supported by INTECRIO to build a hardware system. The following points must be observed when the hierarchy is created:

- You can create an arbitrary number of ES800 hardware systems. Each hardware system can contain only one ES830 target.
- The ES830 target is mandatory.
- A hierarchy consists of the ES830 as master and one or several interfaces on the ES891/ES892/ES882/ES886 controlled by the master.
- All slave interfaces are located on the same hierarchy level; a slave interface cannot have its own slave interfaces.

- Each slave interface is assigned to its master.
- Some interfaces are present several times in an ES800 system. Tab. 5-1 lists the available numbers of interfaces.

	ES830	**Remarks**
CAN Controller	0 – 5 per module	classic CAN / CAN FD To actually use four or five CAN ports of an ES891/ES892, you have to set the **CAN4/FLX1** and/or **CAN5/FLEX2** ports to CAN in the ES800 web interface. *In that case, you cannot use FlexRay.* In addition, you need suitable cables, e.g., CBCFI100, to use both ports that share a socket: - CAN1 and CAN2 - ES89x: • CAN3 and LIN • CAN4 and CAN5 - ES88x: • CAN3 and CAN4 • CAN5 and LIN
XCP_on_CAN (via CAN controller)	0 – 4	4 is the maximum number of *all* XCP interfaces, i.e. XCP_on_CAN *and* XCP_on_UDP.
LIN	0 – 1 per module	The LIN interface uses the same hardware connectors as the CAN3 (ES89x) or CAN5 (ES88x) interface. With a suitable cable, e.g. CBCFI100, you can use CAN and LIN simultaneously.
System Device	0 – 1	
FlexRay	0 – 1 per ES89x	The ES88x and ES892 do not offer FlexRay interfaces. To actually use the FlexRay interface of an ES891, you have to set the **CAN4/FLX1** and/or **CAN5/FLEX2** ports to FlexRay in the ES800 web interface. *In that case, only 3 CAN ports can be used.* In addition, you need suitable cables, e.g., CBCFI100, to use both ports, which share a socket.
Ethernet and Daisychain (IO interface)	0 – 1 per module	A chain of ES4xx and/or ES63x and/or ES930 modules.

	ES830	**Remarks**
Ethernet and XCP_on_UDP	0 – 4	See section 5.3.3 on page 60 for details. 4 is the maximum number of **all** XCP interfaces, i.e. XCP_on_CAN **and** XCP_on_UDP.
Ethernet and X/FETK Bypass	0 – 4 for details, see Tab. 5-6	Can be used as hook-based bypass or service-based bypass. The **X/FETK bypass device is used** for XETK, BR_XETK and FETK. *ES882/ES886 support XETK and BR_XETK. ES891/ES892 support XETK and FETK.*

NOTE

INTECRIO supports FETK and XETK on ES800 systems. X/FETK bypass is supported via the Ethernet controller with an X/FETK bypass device in the INTECRIO hardware configuration.

To connect the **XETK** hardware, the FE port of the ES891/ES892 or ES882/ES886 is used.

To connect the **BR_XETK** hardware, the AE port of the ES882/ES886 is used.

To connect the **FETK** hardware, the FETK1/GE or FETK2/GE port of the ES891 or ES892 is used. These ports must be set to FETK mode In the ES800 Web interface.

See the INTECRIO online help for details on X/FETK configuration.

See the ES800 System user's guide for more information on the ES800 Web interface.

Tab. 5-3 Number of interfaces/elements per ES800 hardware system

- For the CAN interfaces, you must make sure that each interface uses a unique ID.

  For the remaining interfaces, the ID is automatically assigned.

Interfaces, devices and other sublevels can be inserted in the hierarchy, and deleted when these points are taken into account.

The interfaces, devices, signal groups and signals of the hardware system can be configured in the Hardware Configurator. The following points must be observed during the configuration:

- While a series of interface parameters are preset, the tasks and processes associated with the signals/signal groups are defined in the OS configurator. All signals of a signal group are processed at the same time.
- During the configuration of individual signals, conversion formulas for sensors and actuators can be specified. The following formulas are available:
  - Identity: `f(phys) = phys`
  - linear: `f(phys) = a*phys + b`
- An implementation (i.e. a conversion formula and a valid value range) can be specified for CAN signals.

- The maximum number of devices per ES89x or ES88x module is given in the INTECRIO online help. The maximum number in the hardware system depends on its consistency and setup of your ES800 stack.

  To access all controllers at runtime, you need suitable cables.

Parts of the hardware system can be copied via **Copy** and **Paste**. The settings of the target parts are overwritten; if no target part is selected, a new one is created.

Import: As an alternative to manual configuration, it is possible to import a hardware description (`*.hwx` file); see "HWX Import/Export" on page 59.

5.5.2 Interface Types and Supported Interfaces

Tab. 5-4 contains the interface classes for the ES800 and the names of the interface supported by INTECRIO. The listed interfaces of the ES800 can be configured using the Hardware Configurator.

Interface class	**Name**	**Description**
Simulation controller	ES830	
Communication interfaces (ES891, ES892, ES882, ES886)	CAN_Controller + CAN_IO	CAN IO interface
	CAN_Controller + XCP_on_CAN	XCP bypass on CAN
	LIN_Controller	LIN interface
	FlexRay	FlexRay interface (ES891 only)
	Ethernet_Controller + X_FETK_Bypass	Interface for XETK/BR_XETK/ FETK bypass *ES88x support XETK and BR_XETK. ES89x support XETK and FETK.*
	Ethernet_Controller + XCP_on_UDP	XCP bypass on UDP
IO interface	Ethernet_Controller + Daisychain	A chain of ES4xx and/or ES63x and/or ES930 modules; connected to the Fast Ethernet controller
System interface	SystemDevice	controls display and monitoring modes

Tab. 5-4 Interface classes of the ES800 and names of supported interfaces/elements

Tab. 5-3 on page 75 indicates how many interfaces of a type can be used with an ES830 per ES891, ES892, ES882, or ES886. The maximum number in the hardware system depends on its consistency and setup of your ES800 stack.

Fig. 5-8 shows the schematic structure of the interfaces in the WS browser.

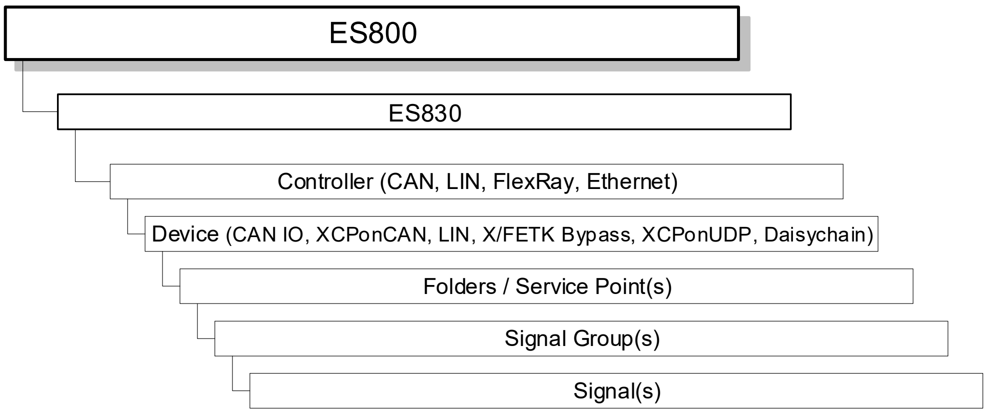

ES800
ES830
Controller (CAN, LIN, FlexRay, Ethernet)
Device (CAN IO, XCPonCAN, LIN, X/FETK Bypass, XCPonUDP, Daisychain)
Folders / Service Point(s)
Signal Group(s)
Signal(s)

Fig. 5-12 Display of the ES800 interfaces in the WS browser

Simulation controller: The simulation controller ES830 is connected to up to four ES891 or ES892 or ES882 or ES886 interface modules. The ES89x/ES88x have no separate node in the WS browser.

Communication interfaces: An ES891 or ES892 or ES882 or ES886 is equipped with the following interfaces:

Interface	Modules
5 interfaces to the CAN bus of the vehicle	ES89x, ES88x
1 interface to the FlexRay bus of the vehicle (replaces 2 CAN interfaces)	ES891
1 interface to the LIN bus of the vehicle	ES89x, ES88x
1 Fast Ethernet connection that can be used for XETK or daisychain	ES89x, ES88x
2 Gigabit Ethernet connections that can be used for FETK	ES89x
1 Automotive Ethernet connection with 3 (ES882) or 4 (ES886) ports; can be used for BR_XETK	ES88x

Tab. 5-5 Interfaces per ES89x/ES88x hardware module. The maximum number in the hardware system depends on its consistency and setup of your ES800 stack.

INTECRIO supports the following combinations of X/BR_X/FETK per ES89x/ES88x module in an ES800 hardware system.

ES891/ES892	- one or two FETK - one XETK - one or two FETK and one XETK
ES882/ES886	- up to three BR_XETK and/or XETK

NOTE

The maximum number of X/FETK devices in an ES800 hardware system is 4.

Tab. 5-6 Max. number of X/BR_X/FETK per ES89x/ES88x module

Two of the ES891 ports can be used either as CAN ports or as FlexRay ports. INTECRIO supports one FlexRay controller in an ES800 hardware system.

CAN Controller + CAN IO

- In the tree view, the first hierarchy level (i.e. the one underneath the ES830) is occupied by the CAN controller.
- The second hierarchy level is occupied by the CAN node (device, CAN IO).
- The third hierarchy level is occupied by folders for CAN frames (signal groups) and CAN signals.

  Underneath the folder for *CAN frames*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by CAN frames (signal groups).
  - The fifth hierarchy level is occupied by simple CAN signals and/or CAN signals of type *multiplexor*.
  - Underneath a CAN signal of type *multiplexor,* the sixth hierarchy level is occupied by CAN multiplex groups.
  - The seventh hierarchy level under the CAN multiplex group is occupied by CAN signals of type *multiplexed*.

  Underneath the folder for *CAN signals*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by CAN signals of type *standard*.

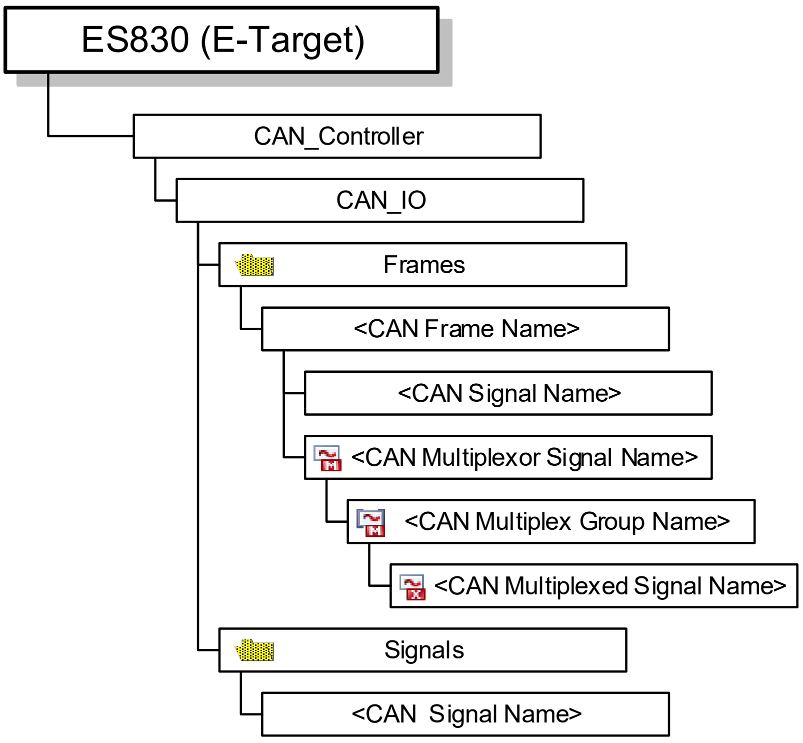


Fig. 5-13 Display of the CAN IO interface (ES800) in the WS browser

CAN Controller + XCP bypass

- In the tree view, the first hierarchy level (i.e. the one underneath the ES830) is occupied by the CAN controller.
- The second hierarchy level is occupied by the XCP on CAN node (device).

- The third hierarchy level is occupied by folders for rasters and status.

  Underneath the folder for *rasters*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by XCP rasters (signal groups).
  - The fifth hierarchy level is occupied by XCP signals.

  Underneath the *Status* folder, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by status signal groups.
  - The fifth hierarchy level is occupied by status signals.

LIN interface

> **NOTE**
>
> Instead of configuring the LIN interface manually, you can import a cluster configuration from a LIN description file.

- In the tree view, the first hierarchy level (i.e. the one underneath the ES830) is occupied by the LIN controller.
- The second hierarchy level is occupied by the LIN node (device, LIN I/O).

  A LIN node can be used either as *master* or as *slave*. The selected node type determines availability and direction of several items below the node level.
- The third hierarchy level is occupied by folders for schedule tables (only available for *Master* nodes), status display, frames, diagnostic frames, and signals.

  Underneath the folder for *schedule tables*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by schedule tables.
  - The fifth level is occupied by frames of the various types.
  - For *unconditional frames*, the sixth level is occupied by signals.
  - For *event-triggered* and *sporadic frames*, the sixth level is occupied by references to unconditional frames.
  - For *event-triggered* and *sporadic frames*, the seventh level is occupied by references to signals of unconditional frames.

  Underneath the folder for *status display*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by status signal groups.
  - The fifth hierarchy level is occupied by status signals.

  Underneath the folder for *frames*, the hierarchy levels are occupied as follows:

  - The fourth hierarchy level is occupied by folders for event-triggered frames, sporadic frames (only available for *Master* nodes), and unconditional frames.
  - The fifth level is occupied by frames of the various types.
  - For *unconditional frames*, the sixth level is occupied by signals.
  - For *event-triggered* and *sporadic frames*, the sixth level is occupied by references to unconditional frames.

- For *event-triggered* and *sporadic frames*, the seventh level is occupied by references to signals of unconditional frames.

Underneath the folder for *diagnostic frames*, the hierarchy levels are occupied as follows:

- The fourth hierarchy level is occupied by diagnostic frames (signal groups).
- The fifth hierarchy level is occupied by diagnostic signals.

Underneath the folder for *signals*, the hierarchy levels are occupied as follows:

- The fourth hierarchy level is occupied by LIN signals of type *standard*.

FlexRay interface

> NOTE
>
> Only ES891 offers a FlexRay interface.

- The first hierarchy level is occupied by the FlexRay device.
- The second hierarchy level is occupied by folders for status display, channels, FlexRay frames, FlexRay PDUs, and FlexRay signals.

Underneath the folder for *status display*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by status signal groups.
- The fourth hierarchy level is occupied by status signals.

Underneath the folder for *channels*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by two channels.
- The fourth hierarchy level is occupied by slots. Up to 2047 slots can belong to one channel.
- The fifth hierarchy level is occupied by frames. Up to 64 frames can belong to one slot.
- The sixth hierarchy level underneath a frame is occupied by the frame's PDUs.

  The levels below a PDU are described on Page 80.

Underneath the folder for *frames*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by FlexRay frames.
- The fourth hierarchy level is occupied by FlexRay PDUs (signal groups).
- The fifth hierarchy level is occupied by simple FlexRay signals and/or FlexRay signals of type *multiplexor*.
- Underneath a FlexRay signal of type *multiplexor*, the sixth hierarchy level is occupied by FlexRay multiplex groups.
- The seventh hierarchy level under the FlexRay multiplex group is occupied by FlexRay signals of type *multiplexed*.

Underneath the folder for *PDUs*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by FlexRay PDUs (signal groups).
- The fourth hierarchy level is occupied by simple FlexRay signals and/or FlexRay signals of type *multiplexor*.

- Underneath a FlexRay signal of type *multiplexor*, the fifth hierarchy level is occupied by FlexRay multiplex groups.
- The sixth hierarchy level under the FlexRay multiplex group is occupied by FlexRay signals of type *multiplexed*.

Underneath the folder for *FlexRay signals*, the hierarchy levels are occupied as follows:

- The third hierarchy level is occupied by FlexRay signals of type *standard*.

See Fig. 5-10 on page 70 for a schematic display of the FlexRay interface.

Ethernet interface: The Gigabit Ethernet interfaces and/or the Fast Ethernet interface of the ES891 or ES892 can be used to configure an X/FETK bypass.

The Fast Ethernet interface of the ES882 or ES886 can be used to configure an XETK bypass, and the Automotive Ethernet interface of the ES882 or ES886 can be used to configure a BR_XETK bypass.

NOTE

The ES800 hardware system supports only X/FETK bypass.

Tab. 5-6 lists the max. number of bypass devices that can be used simultaneously on a particular ES89x/ES88x module, and the possible X/BR_X/FETK type combinations.

For a description of the XCP bypass (XCP on UDP and X/FETK), see section 5.3.3 on page 60.

X/FETK Bypass

- In the tree view, the first level (i.e. the one underneath the ES830) is occupied by the Ethernet Controller.
- The second hierarchy level is occupied by the X/FETK bypass device.
- The third hierarchy level is occupied by the service points and hooked service points.

  The ASAM-MCD-2MC file contains service point descriptions. Number and configurations of the service points actually used in the bypass are determined in the service point selection and hooked service point selection editors.
- The fourth hierarchy level is occupied by the signal groups for sending and receiving.

  The available signal groups depend on the settings made in the service point selection and hooked service point selection editors.
- The fifth hierarchy level is occupied by individual signals.

IO interface / Daisy Chain: An ES4xx/ES63x/ES930 daisy chain can be connected to the Fast Ethernet port of the ES800 target. The WS browser in INTECRIO does not display the individual elements of the chain, it displays only the chain as a whole, with one signal group for each chain element and sample period.

NOTE

Different from the other interfaces, the daisy chain cannot be configured in INTECRIO. Instead, an externally created configuration file is imported.

If the configuration file is edited, the changes must be imported, via the **Update** context menu, into INTECRIO.

- The first hierarchy level contains the Ethernet controller.
- The second hierarchy level contains the daisy chain device.
- The third hierarchy level is occupied by the signal groups for the different sample periods and chain elements.
- The fourth hierarchy level is occupied by the individual signals assigned to the sample periods and chain elements. The actual signals depend on the daisy chain.

System interface: The system interface is used to configure the monitoring and display modes of the ES830. Signal groups for the different modes can be activated independently.

- The first hierarchy level is occupied by the system interface device.
- The second hierarchy level is occupied by the signal groups for the different modes.
- The third level is occupied by the individual signals of the different modes. The signals of a mode are predetermined.

5.6 PC Connectivity

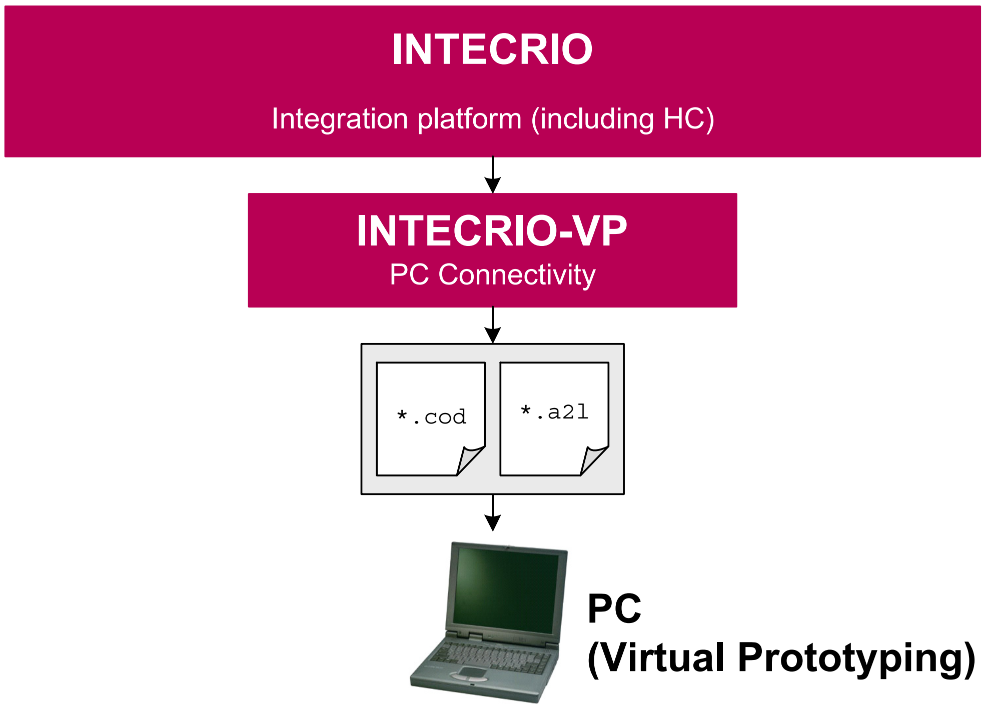


Fig. 5-14 INTECRIO-VP: VP-PC connectivity

With its PC connectivity, INTECRIO-VP offers the possibility to use INTECRIO for virtual prototyping purposes, i.e. validation and pre-calibration of application software. The possibility to verify and validate software as early in the V cycle as possible is the main motivation for virtual prototyping.

INTECRIO-VP provides the functionality required for virtual prototyping with INTECRIO. This means in detail:

- Providing the VP-PC target. This target can be selected in the WS browser just like ES900 or ES800.
- The possibility to execute models with adaptive simulation time (i.e. the shortest possible computation time given the computational power and the complexity of the model).
- The possibility to configure the RTA-OSEK for PC operating system in the OSC (see section 5.8),
- The possibility to generate executable file and ASAM-MCD-2MC description just as for rapid prototyping (see section 5.9).
- The possibility to use RTA-TRACE and INCA-EIP in the virtual prototyping experiment. This includes the VP service, available in the Windows task bar.
- The possibility to use back animation of ASCET and MATLAB and Simulink models during the virtual prototyping experiment.

  Back animation means that the model variables can be displayed on the BMT display devices and that calibration variables can be calibrated directly from within the model.

- The possibility to connect to a Microsoft® Visual Studio® debugger during the virtual prototyping experiment.

  The debugging possibility is limited to the following use case: Build process and experiment are performed on the same workstation, and the experiment is started immediately after the build process.

  In order to simulate interrupts in a virtual ECU, the virtual machine has to manipulate the stack of the application thread asynchronously. Since many functions cannot cope with asynchronous stack changes, stepping is not possible in every line of code.

> **NOTE**
>
> It is recommended that you set multiple breakpoints and jump from breakpoint to breakpoint. For further details, see the RTA-OSEK for PC documentation.

5.7 Project Configurator

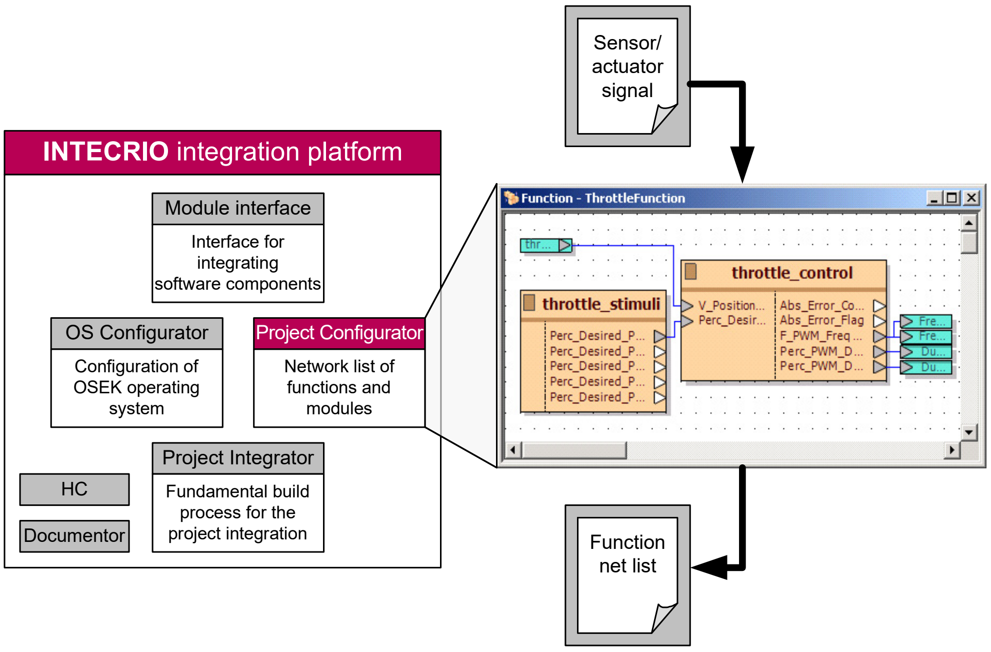


Fig. 5-15 Project configurator

The project configurator is part of the integration platform of INTECRIO. It is used to specify software systems and system projects. It contains a graphical editor (on the right in Fig. 5-15) that can be used in offline and online mode.

5.7.1 Offline Mode

In *offline mode*, modules and AUTOSAR software components (SWC) can be displayed, and functions, software systems and system projects can be created and configured.

5.7.1.1 Modules and SWC

In the workspace, modules and SWC (see also “Modules and AUTOSAR Software Components” on page 31) are saved in the folders `Software\Modules` or –modules only – `Environment\Modules`.

In the graphical editor of the project configurator, modules/SWC are represented as blocks, together with the name of the module.

The signal sinks or inputs are arranged on the left side of the block, the signal sources or outputs on the right side. The color denotes either the BMT used to create the module (defaults: light red – MATLAB and Simulink, green – ASCET, dark red – AUTOSAR SWC) or the usage as environment module (slightly different green).

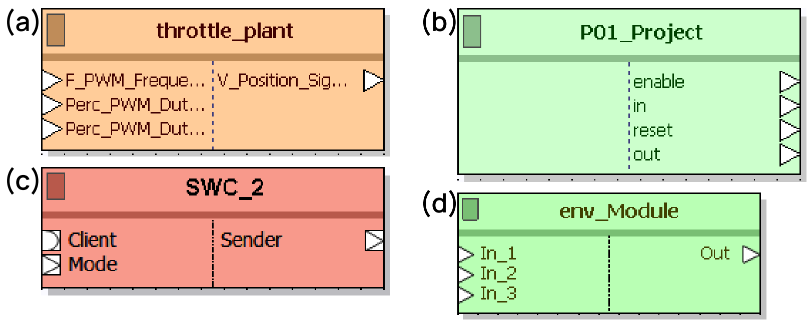


Fig. 5-16 Standard layout of a module/SWC (a: Simulink module, b: ASCET module, c: AUTOSAR SWC, d: environment module)

The standard size of the block is designed so that all interface elements are visible. The names of the signal sources and sinks are abbreviated, if required; complete names appear as tooltips.

The color of the block can be adjusted; SWC/modules created with the same BMT always have the same color. Size and layout of each block can be adjusted individually.

If the description of the module is updated by importing a new version of the SCOOP-IX file, all user settings are retained.

5.7.1.2 Functions

Functions (see also the section “Functions” on page 33) are created in the project configurator and placed in the folders `Software\Functions` or `Environment\Functions` in the workspace. Their names can be randomly selected.

The interface of a function – signal sinks, signal sources – is also created in the project configurator. Implementations, signal type, etc., are adopted by the elements that are connected to the inputs and outputs.

The standard layout for the external view of a function is designed just like that of a module/SWC: the signal sinks of the function are arranged on the left side, signal sources on the right side. The icons are derived from the connected module/SWC ports. The block size is selected automatically, according to the number of signal sinks and sources. The size of the function and the positions of the signal sinks and sources on their respective sides can be adjusted.

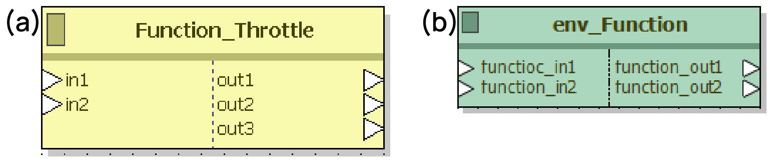


Fig. 5-17 Standard layout (external view) of a function (a) and an environment function (b)

Any number of modules can be assigned to a function, but each module can be assigned only once. This restriction notwithstanding, a module can appear more than once in the graphical display of a function. Other functions *cannot* be assigned to a function.

The interface elements of the modules can be connected with each other in the graphical editor or the connection wizard of the project configurator or with interface elements of the function. Unused module interface elements can be removed from the graphical representation (not from the module). The following rules apply to the connections:

- *Modules*: A source (output) can be connected with any number of sinks (inputs).

  A sink (input) can be connected with exactly one source (output).
- *SWC*: A sender can be connected with several receivers, a server can be connected with several clients.

  Scalar senders and receivers with primitive typization can be connected with inputs and outputs of modules.
- Disconnected sources and sinks are allowed.
- A connection between modules can be either static or dynamic. Dynamic connections can be changed during the runtime of the program. For SWC, only static connections are possible.

5.7.1.3 Software Systems and Environments

Software systems (see also the section “Software Systems” on page 34) and environment systems are created in the project configurator and placed in the `Software\Software Systems` or `Environment\Environment Systems` folder in the workspace. Their names can be randomly selected.

The interface of a software or environment system is created the same way as the interface of a function (see "Functions"). The standard layout of a software or environment system corresponds to that of a function. The block size is selected automatically, according to the number of signal sinks and sources. The size of the software or environment system and the positions of the signal sinks and sources on their respective sides can be adjusted.

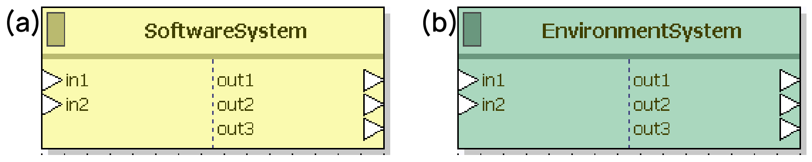


Fig. 5-18 Standard layout of a software system (a) and environment system (b)

Any number of modules, SWC or functions can be assigned to a software or environment system. For assignment and connection, the following applies:

- In INTECRIO, modules and SWC cannot be multiply instantiated, i.e. each module or SWC can be used only once in a particular software or environment system. If several functions containing the same module/SWC are inserted in a software or environment system, the code generation issues an error message. The same happens if a module/SWC is inserted into a software or environment system both directly and as part of a function. This restriction notwithstanding, a module/SWC can appear more than once in the graphical display of a software or environment system.
- Modules, SWC and functions can be used *either* for software systems *or* for environment systems. It is not possible to use a module/SWC/function imported/created for a software system in an environment system, and vice versa.

5.7.1.4 System Projects

Similar to functions and software or environment systems, system projects (see also “System Projects” on page 36) are created and configured in the project configurator. A system project can be assigned a hardware system, a software system, and an environment system (i.e. any number of modules and functions).

In the graphical editor, software system, environment system and each hardware device are displayed as separate blocks. Unused signals can be removed from the graphical representation.

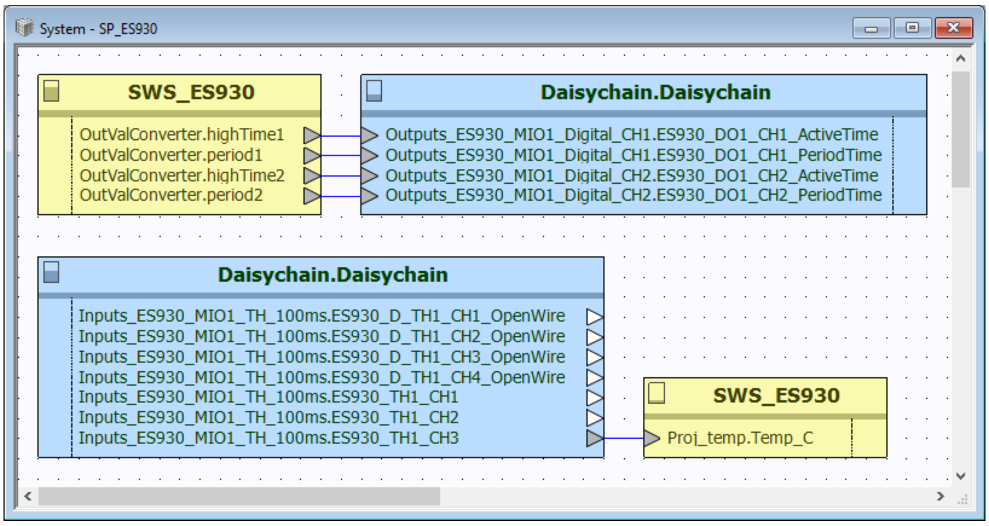

System - SP_ES930
SWS_ES930
OutValConverter.highTime1
OutValConverter.period1
OutValConverter.highTime2
OutValConverter.period2
Daisychain.Daisychain
Outputs_ES930_MIO1_Digital_CH1.ES930_DO1_CH1_ActiveTime
Outputs_ES930_MIO1_Digital_CH1.ES930_DO1_CH1_PeriodTime
Outputs_ES930_MIO1_Digital_CH2.ES930_DO1_CH2_ActiveTime
Outputs_ES930_MIO1_Digital_CH2.ES930_DO1_CH2_PeriodTime
Daisychain.Daisychain
Inputs_ES930_MIO1_TH_100ms.ES930_D_TH1_CH1_OpenWire
Inputs_ES930_MIO1_TH_100ms.ES930_D_TH1_CH2_OpenWire
Inputs_ES930_MIO1_TH_100ms.ES930_D_TH1_CH3_OpenWire
Inputs_ES930_MIO1_TH_100ms.ES930_D_TH1_CH4_OpenWire
Inputs_ES930_MIO1_TH_100ms.ES930_TH1_CH1
Inputs_ES930_MIO1_TH_100ms.ES930_TH1_CH2
Inputs_ES930_MIO1_TH_100ms.ES930_TH1_CH3
SWS_ES930
Proj_temp.Temp_C

Fig. 5-19 System project in the graphical editor

The required connections between the signal sources and sinks of hardware and software must be created by the user. The same rules apply as for the connections within a function (see Page 86), expanded to software and hardware components.

The size of the hardware blocks and the positions of the signal sinks and sources on their respective sides can be adjusted.

A workspace can contain several system projects. The user can activate only one system project at a time. For each system project, build options can be set that affect the creation of the executable file. If the build process is invoked not from the context menu of a system project, but from the menu or the toolbar, it uses the active system project.

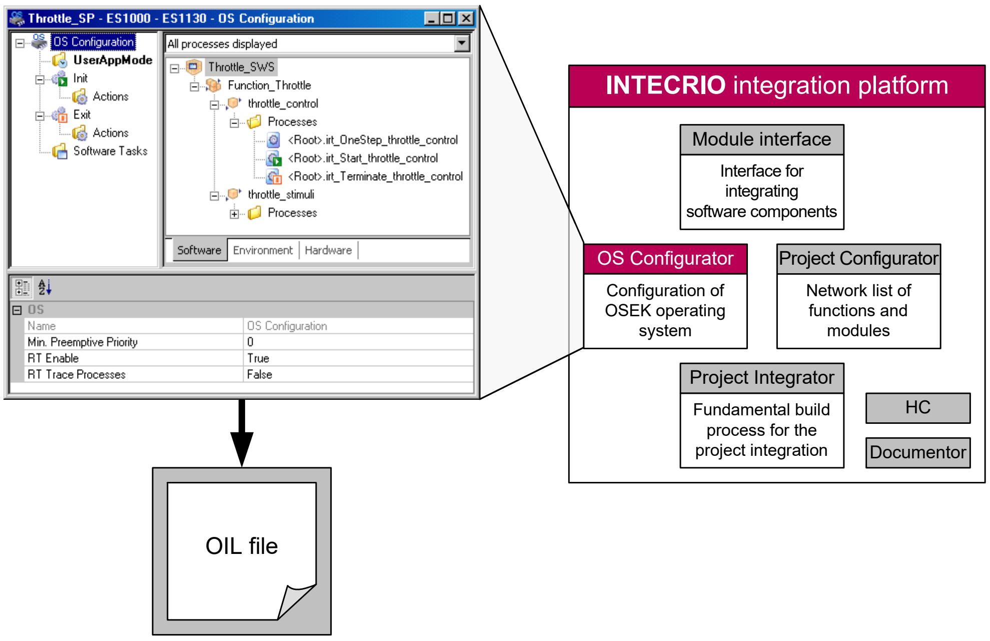
5.7.2 Online Mode

Dynamic connections can be changed in *online mode*, i.e. during the running experiment. In general, changes are allowed that do not lead to a change in structure. Changes to the description or display of modules, functions or software systems (e.g. removing or adding signal sources/sinks, modules or functions) are not possible in online mode.

The implementation characteristic of the newly connected signal sources and sinks is adjusted via changes in the copying process on the target. A conversion is performed in the case of different value ranges or quantizations. The value assignment to the signal sink is always limited; this limitation cannot be deactivated.

The mechanism for editing connections is the same as in the offline mode. In addition, the online mode offers the option of connecting a stimuli signal with a signal sink.

5.8 OS Configurator


Throttle_SP - ES1000 - ES1130 - OS Configuration
OS Configuration
UserAppMode
Init
Actions
Exit
Actions
Software Tasks
All processes displayed
Throttle_SWS
Function_Throttle
throttle_control
Processes
<Root>.irt_OneStep_throttle_control
<Root>.irt_Start_throttle_control
<Root>.irt_Terminate_throttle_control
throttle_stimuli
Processes
Software
Environment
Hardware
OS
INTECRIO integration platform
Module interface
Interface for integrating software components
OS Configurator
Configuration of OSEK operating system
Project Configurator
Network list of functions and modules
Project Integrator
Fundamental build process for the project integration
HC
Documentor
OIL file

Name	OS Configuration
Min. Preemptive Priority	0
RT Enable	True
RT Trace Processes	False

Fig. 5-20 OS configurator

The configuration of the operating system is a very important task in the context of creating a real-time prototype. Inside of INTECRIO, this task is handled by the *OS configurator* (another component of the integration platform).

Section 5.8.1 provides an overview of the tasks of the operating system, section 5.8.2 describes the OS configurator.

5.8.1 Tasks of the Operating System

The OSEK consortium[1] developed standards for the real-time operating systems used in the automobile industry, among them the OSEK implementation language OIL. An operating system that meets the OSEK standards is referred to as OSEK operating system.

The ES910 and ES830 use the OSEK-compatible and AUTOSAR[2]-compatible operating system RTA-OSEK, the PC uses, in case of virtual prototyping, RTA-OSEK for PC.

OSEK operating systems support the coordinated execution of many processes and – when using AUTOSAR – runnable entities (RE). On systems with a single CPU, different processes/RE cannot be executed at exactly the same time since the CPU is capable of executing only one instruction at a time. For this reason, the operating system is responsible for performing a quasi-parallel processing or multitasking. That is, the operating system determines the processing sequence of the tasks and processes/RE that compete for the processor and, if necessary, toggles between the executions of different tasks.

1) Working group for Open Systems and their Interfaces for Electronics in Motor Vehicles (German: **O**ffene **S**ysteme und deren Schnittstellen für die **E**lektronik im **K**raftfahrzeug)
2) **Aut**omotive **O**pen **S**ystem **Ar**chitecture, see https://www.autosar.org

5.8.1.1 Scheduling

Scheduling is a core function of an OSEK operating system. The scheduler must decide which process is started first from a group of activated processes/RE. The decision strategy, the so-called *scheduling algorithm*, is very important since it affects the real-time capabilities and the efficiency of the system. To meet the strict requirements of efficiency and real-time behavior, OSEK operating systems use a combination of static and dynamic scheduling, together with a combination of cooperative and preemptive scheduling.

Static scheduling: For *static scheduling*, the scheduling algorithm has all the information about the processes/RE to be scheduled and their limitations. Custom limitations are calculation time, deadline, future execution times, priority relationships and mutual exclusion. Since all limitations of the processes and RE are known before the system starts, it is possible to determine the processing sequence of these processes/RE up front (offline). If such an offline schedule exists, it is sufficient to start the processes/RE at runtime at the predefined times in the predefined order.

Dynamic scheduling: For *dynamic scheduling* on the other hand, the algorithm only knows the activated processes/RE and does not have any knowledge of future activations. Since new processes/RE can be activated spontaneously, the scheduler must determine at runtime which one of the processes/RE must be selected.

The advantage of dynamic scheduling over static scheduling lies in the flexibility with which external events can be addressed. In particular, the effectiveness of static scheduling decreases with decreasing latency period. Disadvantages of dynamic scheduling are higher demands on the computing power and need for increased memory for managing the processes/RE. Since dynamic as well as static scheduling are supported, OSEK operating systems allow for the application of combined strategies which were optimized with respect to the demands concerning response time and memory capacity.

5.8.1.2 Tasks

An operational sequence or *Task* is defined as the result of static scheduling. It contains a sequence of processes or RE that must be executed in the specified order and with a defined priority if a certain activation event occurs.

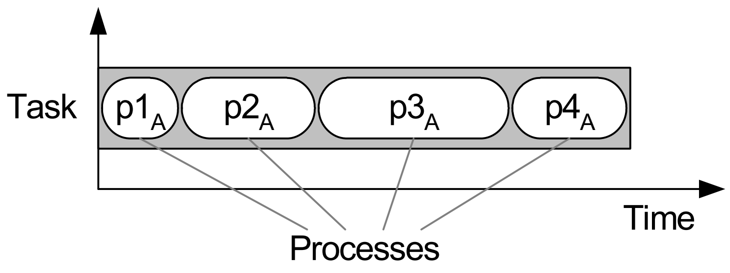


Fig. 5-21 Task scheme

Dynamic task scheduling (or multitasking) only applies to tasks as a whole, not the individual processes/RE. Within a task, the scheduler does not have to make a decision since the processing sequence is statically specified. This reduces the required computing power at runtime and the memory requirement since it is not necessary to manage a high number of processes/RE but only a much smaller number of tasks.

Each task is assigned a static *priority*. Tasks activated at runtime are handled according to their respective priority. A task with a higher priority takes precedence over a task with a lower priority. Different tasks can have the same priority. If these tasks are scheduled for execution at the same time, they are arranged in a FIFO queue and processed based on the principle "First come, first served."

Dynamic scheduling is handled in accordance with a status model for the tasks. Upon activation, a task is changed to the status *activated*. If its priority is higher than that of the *running* task and if switching is possible, it is started (the latter translates to a direct transition from the status "inactive" to the status "running") while the execution of the current task is interrupted (the task is changed to the status "activated"). At the end of the running task, i.e. when it changes to the status *inactive*, the activated task with the highest priority and at the first position of the respective FIFO queue is started or continued (if this task was previously interrupted). Fig. 5-22 shows the existing task states and all possible transitions.

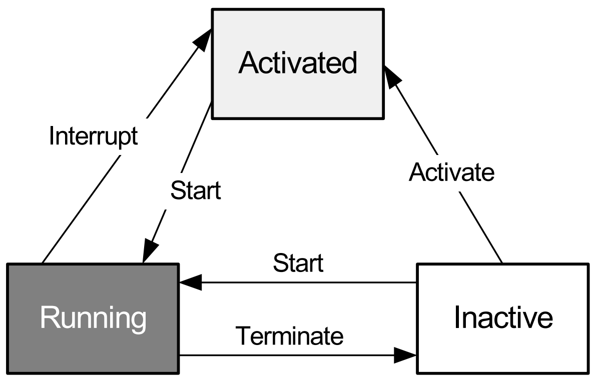


Fig. 5-22 Task states and transitions

5.8.1.3 Cooperative and Preemptive Scheduling

There are two possible methods for switching between a running task and an activated task with higher priority. The first switches the execution at predefined locations of the software. These predefined locations are the boundaries between the processes/RE of a task. Since the task with the higher priority is waiting until the running process/RE finishes, this method is referred to as *cooperative scheduling* (see Fig. 5-23).

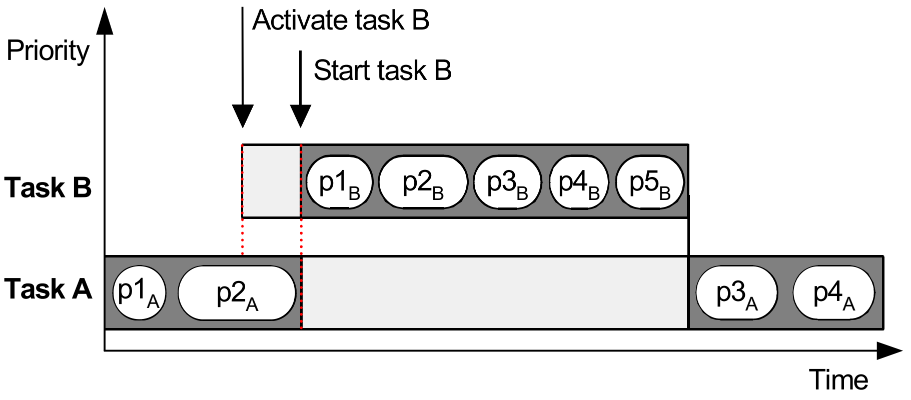


Fig. 5-23 Cooperative scheduling

NOTE

Cooperative scheduling is not available for RTA-OSEK.

The advantage of cooperative scheduling is the efficient utilization of resources. The design ensures that access to resources, such as stack, register or messages, is exclusive. In addition, there is no need to secure the process/RE context when switching takes place; all processes/RE can be executed using the same register bank. The disadvantage of cooperative scheduling is the relatively slow response time that is dependent upon the longest execution time of the processes/RE.

The second strategy–*preemptive scheduling*–allows for switching the execution inside the processes/RE at the boundaries of machine instructions (provided that the interrupts are not deactivated).

The scheduler is, therefore, capable of interrupting the currently running process/RE of a task and starting the execution of a task with higher priority (see Fig. 5-24).

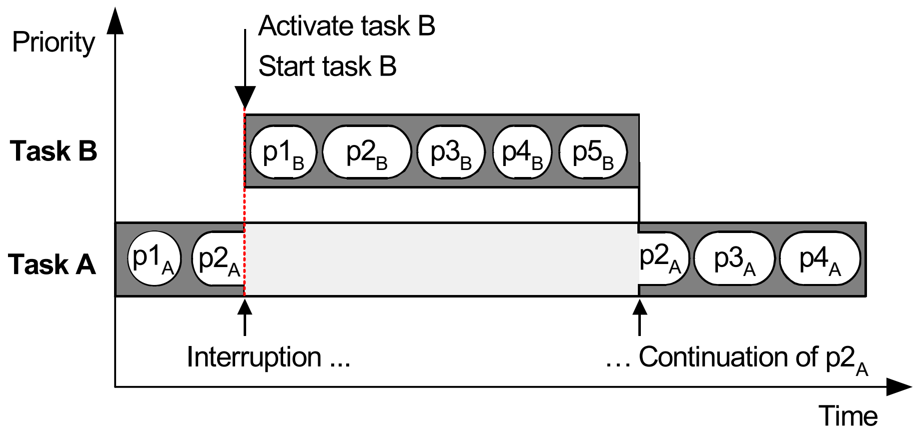


Fig. 5-24 Preemptive scheduling

External events (interrupts) and periodic activations with controlled variations require short response times. Preemptive scheduling can meet these requirements. The disadvantage of preemptive scheduling is higher memory capacity since it is necessary to secure the context of interrupted processes/RE and ensure data consistency.

Preemptive scheduling also offers flexibility for handling external events or *interrupts*. It is possible to assign an interrupt source to a priority level, thereby starting the task with a very fast response time. This mechanism is represented by the direct transition from the status *inactive* to *running* (see Fig. 5-22 on page 91). The tasks called by the occurrence of interrupts and planned by the interrupt controller are referred to as *hardware tasks*.

Preemptive and cooperative tasks have different priority ranges that do not overlap. Preemptive tasks always have a higher priority than cooperative tasks.

5.8.1.4 Data Consistency with Preemptive Scheduling

In preemptive scheduling, it is possible that a process or RE with low priority is interrupted by a process/RE with higher priority. If the interrupted process/RE reads a variable and the interrupting process/RE describes the same variable, inconsistencies may occur if the interruption occurs between to successive read operations as illustrated in Fig. 5-25. The diagram shows what happens of the program code is interrupted during the processing and no resource protection is implemented.

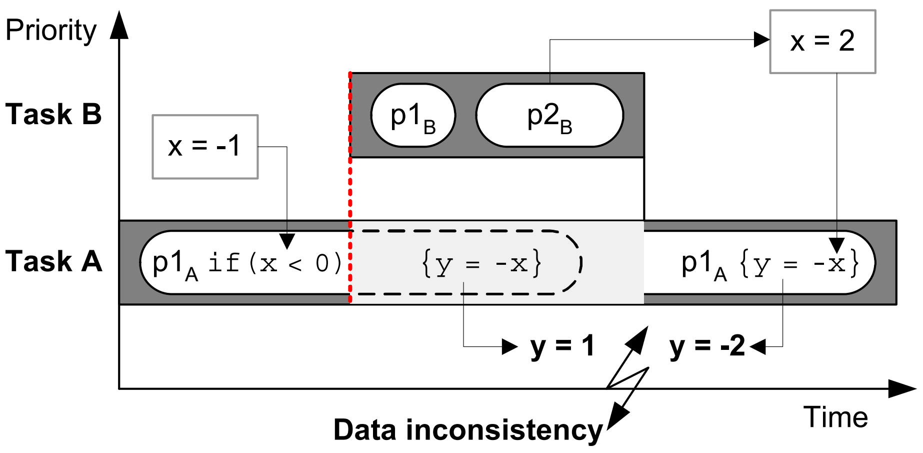


Fig. 5-25 Data inconsistency

Process $p1_A$ of task A calculates the absolute value of `x`:

```
if (x<0)
  {y = -x;}
else
  {y = x;}
```

Process $p1_A$ reads the input value `-1`. The condition of the first line of the algorithm is met, so that the assignment `y = -x` is scheduled for execution. Before the assignment can be executed, process $p1_A$ is interrupted. Process $p2_B$ of task B assigns `x` the value of `2`. If $p1_A$ is taken up again after the end of task B, the algorithm uses the pending assignment `y = -x` and the new value `x = 2` instead of `x = -1`, i.e. $p1_A$ furnishes an incorrect result: $|-1| \neq 2$.

This is merely a simple example to illustrate data inconsistency; however, in a real application, data inconsistency can lead to a system crash.

The correctness of the system therefore depends on the time sequence and the order of interruptions in the system. To avoid system and timing-dependent software errors, data consistency must be guaranteed.

NOTE

For the time between start and termination of a process P1 or RE R1, it must be ensured that all data stored in memory accessed by P1/R1 may change their value if and only if they are changed by P1/R1.

Messages: To solve the problem of data consistency, the *messages* concept is supported by the crossbar (cf. section 3.5.5). These are protected global variables. The protection is achieved by working with copies of the global variables. The system analyzes whether a copy is required and ensures an optimum data consistency scheme without detrimental effects on the core of the runtime.

While a process is being started, all input messages in its private area are copied for message copies. After the process is finished, all output messages that are located in the private area as copies, are copied into the global message area. The operating principle of messages is represented in Fig. 5-26.

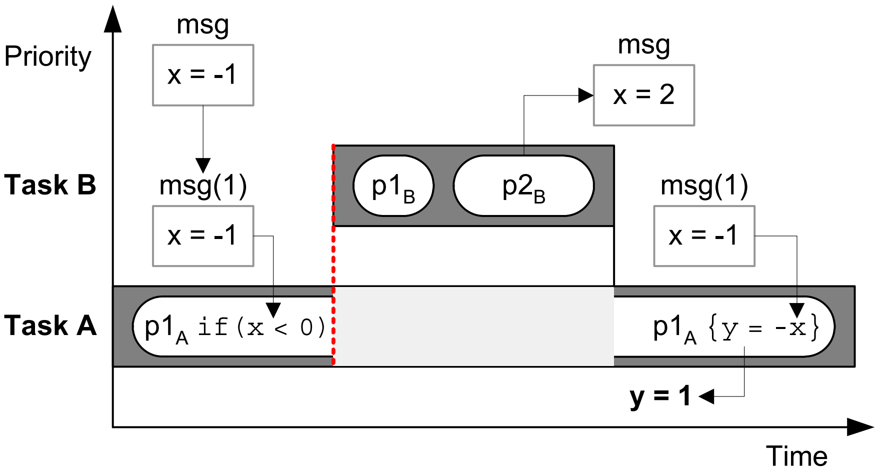


Fig. 5-26 Handling of messages

At the start, process $p1_A$ of task A copies the incoming message `msg` to the private message copy `msg(1)`. All subsequent read operations to the message access this private copy. Although process $p1_A$ is interrupted by task B, which sets the value of `msg` from `-1` to `2`, this change does not affect process $p1_A$. This ensures that process $p1_A$ works with the private copy throughout the entire execution time. This ensures the data consistency since the algorithm

```
if (x<0)
```

```
  {y = -x;}
else
  {y = x;}
```

is correctly executed in any case.

When working with AUTOSAR SWC, an AUTOSAR runtime environment (RTE, cf. section 4.2) is used instead of the crossbar. If necessary, the RTE uses suitable means of the OS (resources, interrupt blocks) to ensure consistency of the transmitted data.

5.8.1.5 Application Modes

Application Modes were developed to support different runtime configurations of the complete system at different times. They allow for a simple and flexible design and the management of system statuses of completely different functions. Examples of such application modes are *Startup*, *Normal Operating Mode*, *Shutdown*, *Diagnosis*, and *EEPROM Programming*. Each application mode can be equipped with its own tasks, priorities, timer configurations, etc.

> NOTE
>
> RTA-OSEK, and thus INTECRIO, supports only one application mode.

An application mode consists of two successive phases: an initialization and a normal sequence phase. During initialization, all interrupts are deactivated. This is used, for example, for the set-up of hardware registers and variables. At the end of the phase, interrupts are activated and the normal processing of the tasks begins.

5.8.2 Design of the OS Configurator

The design of the OS configurator of INTECRIO is shown in Fig. 5-27.

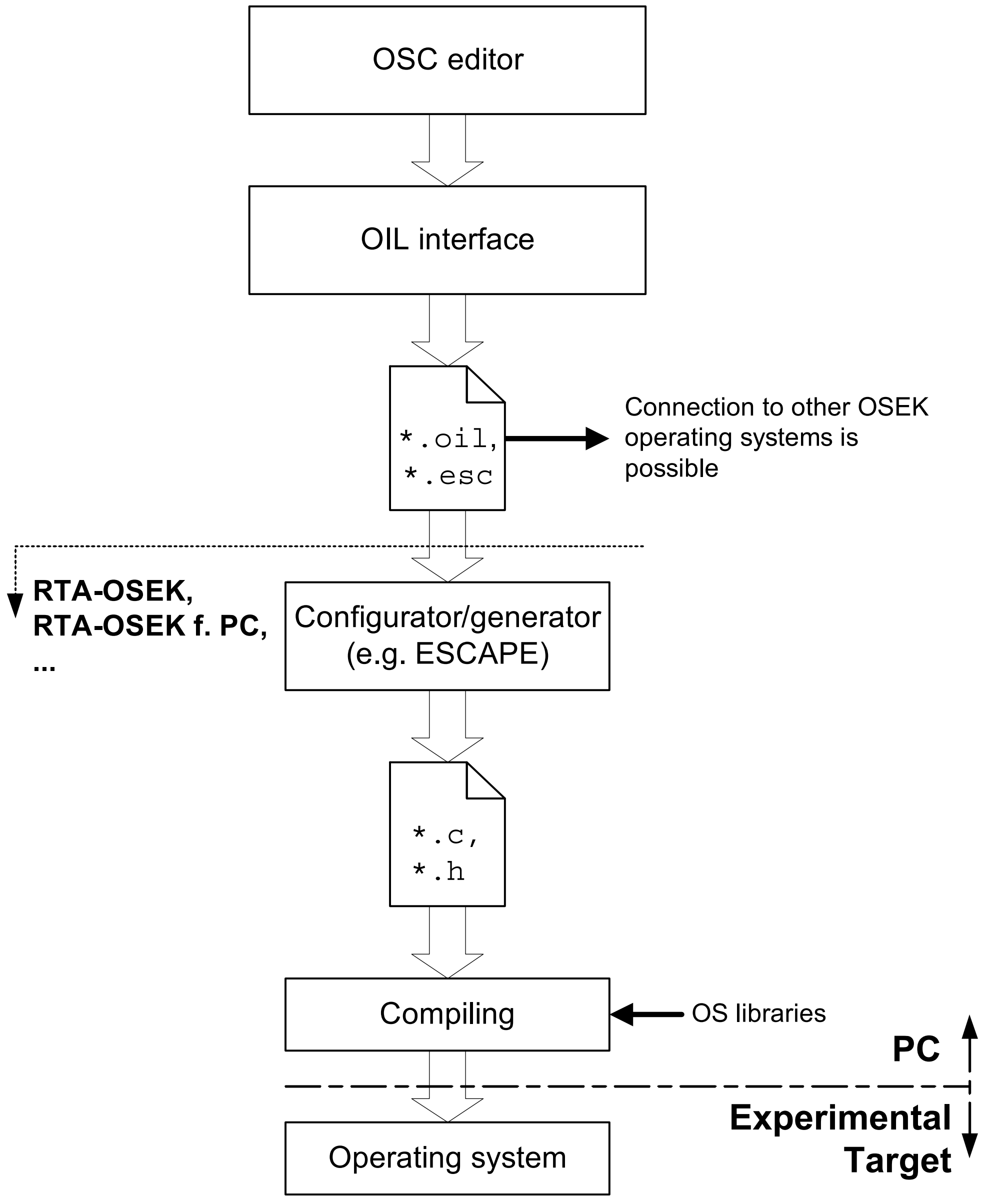


Fig. 5-27 OS configurator: Design

The figure replicates the process sequence during the configuration of the operating system.

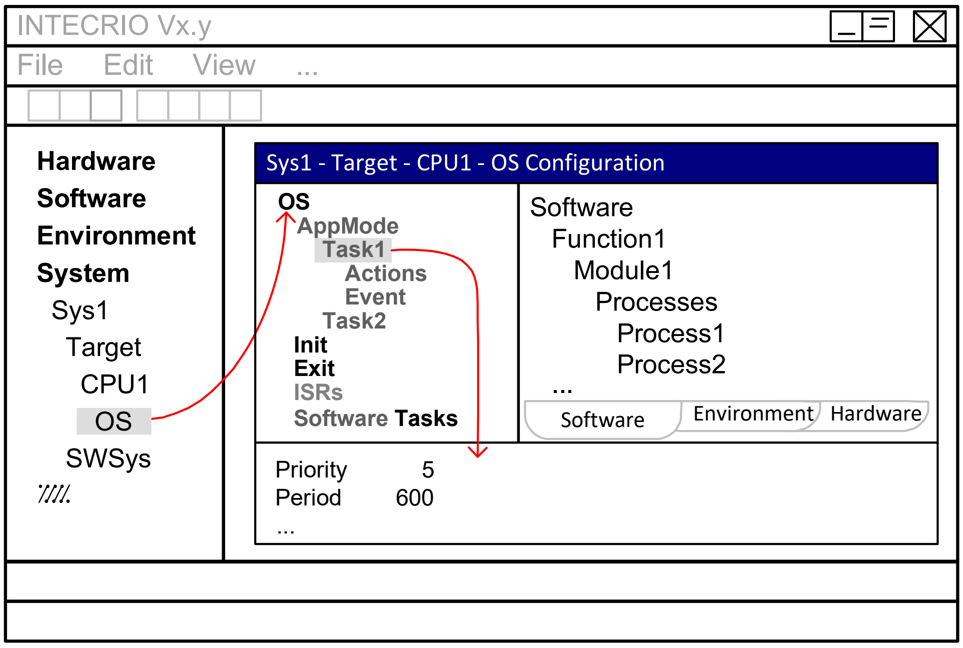
The *OSC* editor is an easy to handle editor that provides the user with a quick overview of the system and allows for editing the configuration in an application-oriented display.

After completed configuration, the *OIL interface* creates the required configuration files in the OIL language (`*.oil` files).

However, only the OSEK *conformance classes* BCC1 and BCC2 are directly supported. The OIL configuration files can be processed further with any OSEK operating system. The further processing in INTECRIO is based on the operating systems RTA-OSEK or RTA-OSEK for PC of ETAS.

The *configurator/generator* generates C-code files from the `*.oil` files which, in turn, are used to compile the operating system while linking the operating system library. Only the completed operating system is loaded onto the experimental target, all previous levels are executed on the PC.

5.8.3 The OSC Editor



The interface of the OSC is divided into three parts: The top left field contains the OS configuration view, at the top right are three tabs that show the hierarchical structures of software, environment and hardware system. You can select whether the tabs show all processes or only those that are not assigned to a task. Below these two fields if the input field for the attributes of the object selected in the OS configuration view. The attributes relevant for the object and the operating system are shown.

The OSC has two modes:

- Offline mode

  The operating system is configured in offline mode. The minimal priority of preemptive tasks can be set for the operating system. It can also be defined whether tracing the runtime behavior should be handled using the tool RTA-TRACE (global or on the process level).

  For ASCET models, you have the additional option to configure the OS in ASCET, and then import the configuration (`*.oil` file) into INTECRIO.

- Online mode

  In online mode, i.e. with running experiment, the setting options of the OSC are blocked. You can use the OS configurator only as display.

5.8.3.1 Creating Tasks

The operating system is located on the top level of the OS configuration view.

With legacy AUTOSAR SWC: No application mode is shown in the display. One *Init* and *Exit* task each are automatically created directly below the operating system. In addition, tasks can be created in the `Software Tasks` folder. The type of these tasks is defined by the assigned runnable entities.

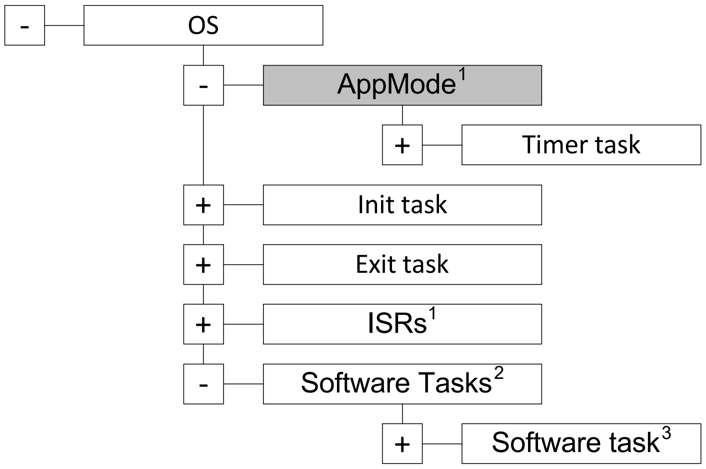


Fig. 5-28 OSC: Tree structure
(1: not for AUTOSAR SWC, 2: with AUTOSAR-SWC: `Tasks`, 3: with AUTOSAR SWC: task type defined by assigned RE)

Without AUTOSAR SWC: The application mode (see “Application Modes” on page 95) is created directly below the operating system.

The tasks of type *Timer* are created on the next level below the application mode. One *Init* and *Exit* task each are automatically created directly below the operating system; they are used by all application modes. In addition, tasks of type *Software* can be created in the `Software Tasks` folder. When working with RTA-OSEK, you can also create interrupt service routines in the `ISRs` folder. The task types are explained in Tab. 5-7.

The possible task types have the following meaning:

Timer	These tasks are periodically activated. They can have different periods.
Software	These tasks are non-periodically activated via commands of the operating system or via certain events.
Init	Automatically created task that is executed once when an application mode is executed. Interrupts are deactivated during the runtime of the task.
Exit	Automatically created task that is executed once at the end of the simulation. Interrupts are deactivated during the runtime of the task.
ISR	Interrupt service routines (RTA-OSEK only).

NOTE

The RTA-OSEK operating system does not support init/exit tasks. In that case, INTECRIO automatically generates code that calls these tasks at the start or end of an application mode via C function calls.

Tab. 5-7 Task types

Below the application mode, timer tasks can be created, deleted and renamed. Each task features the folders `Actions` and `Event` for processes and events.

NOTE

For virtual prototyping (target PC), the `Event` folder is omitted.

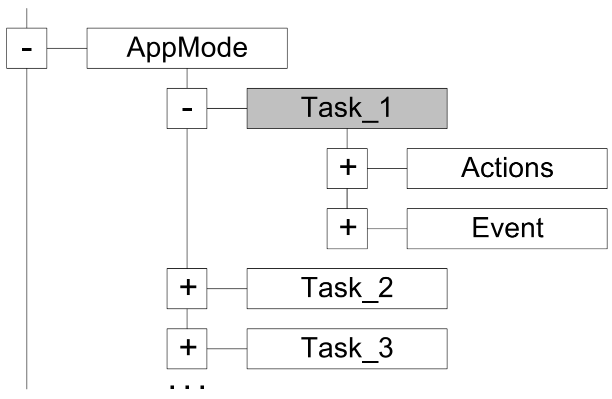


Fig. 5-29 OSC: Application mode with assigned timer tasks

Software tasks can only be created in the `Software Tasks` folder. These tasks do not belong to any application mode and are not included in the scheduling of the operating system. They can still be called during an experiment, e.g. with an event from the Hardware Configurator.

Interrupt service routines (ISRs) can only be created in the `ISRs` folder. The ISR sequence has no influence on the runtime behavior.

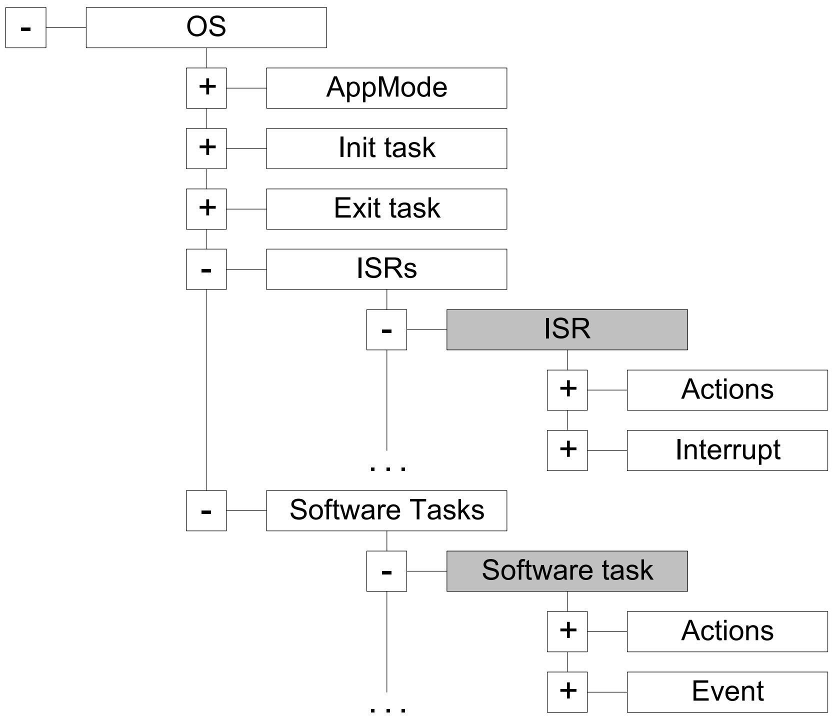


Fig. 5-30 OSC: Software task and ISR (Neither ISRs nor events exist for virtual prototyping. The respective folders are omitted in that case.)

5.8.3.2 Task Properties

The properties of timer and software tasks can be edited. In case of incorrect entries, warnings or error messages are issued, and the old value is kept.

NOTE

The properties of the Init and Exit tasks *cannot* be edited. For ISRs, only the priority can be edited.

With legacy AUTOSAR SWC:

- Priority

  The activation of tasks is determined by their priority if several tasks are scheduled for execution at the same time. Tasks are interrupted if a task with a higher priority than the currently running task is activated.

  Possible minimum and maximum values depend upon the target as well as the scheduling; Fig. 5-31 on page 101 shows the scheme of possible values.

- Maximum number of simultaneous activations (Task Activation)

  This value determines how often a task can be activated for scheduling. If a task is activated again before the execution is finished after its previous activation, the task is then activated twice. To save system resources, the number of simultaneous activations can be limited.

Without AUTOSAR SWC:

- TaskID

  Unique number as identifier.

- Priority

  The activation of tasks is determined by their priority if several tasks are scheduled for execution at the same time. For example, if several periodic tasks were scheduled for simultaneous activation, the task with the highest priority is executed first. Tasks are interrupted if a task with a higher priority than the currently running task is activated.

  Possible minimum and maximum values depend upon the target as well as the scheduling; Fig. 5-31 shows the scheme of possible values.

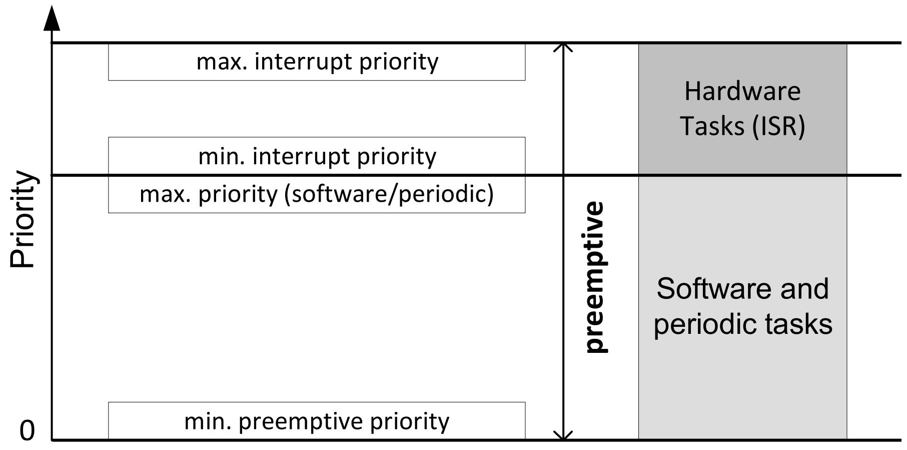


Fig. 5-31 Priority scheme

NOTE

RTA-OSEK supports only preemptive scheduling.

- Period

  It determines after what time in seconds the task is activated again.

  This option is only available for timer tasks.

- Delay

  The task is activated for the first time after the time in seconds defined in this option. If the delay value is 0, the task is activated as soon as the program starts, and afterwards at the beginning of every period.

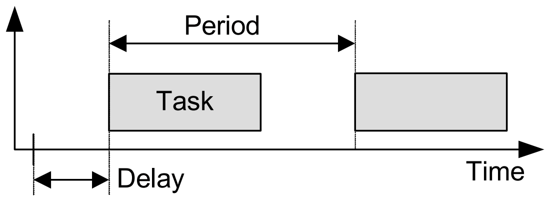


Fig. 5-32 Delay of a task

  This option is only available for timer tasks.

- Execution Budget

  This value contains the maximum execution time (in seconds) of a task. Values between 0.000001 s and 128 s are permitted; the value 0 disables runtime monitoring.

- Maximum number of simultaneous activations (Max. number of activation)

  This value determines how often a task can be activated for scheduling. If a task is activated again before the execution is finished after its previous activation, the task is then activated twice. To save system resources, the number of simultaneous activations can be limited.

- Monitoring

  This option determines whether monitoring information is collected for this task (`True`) or not (`False`). If the option is activated, additional signal sources, e.g. for the entire runtime of the task, are created. These signal sources are part of the ASAM-MCD-2MC description and can be measured in the ETAS Experiment Environment or in INCA/INCA-EIP.

  If monitoring is enabled, the following monitoring variables are created for each task:

Variable	Meaning
`actTime`	Activation time of the task
`startTime`	Start time of the task
`grossRunTime`	Total runtime of the task
`netRunTime`	Net runtime of the task
`minRunTime`	Minimum runtime of the task
`maxRunTime`	Maximum runtime of the task
`dT`	Time difference between the last and the current activation of the task

  The monitoring variables are measured in systems ticks. They must be converted to seconds for the user.

- Exclude from Tracing

  This option determines whether a task is excluded (`True`) from monitoring with RTA-TRACE or not (`False`).

5.8.3.3 Setting Up Timer and Software Tasks

Finally, the processes/RE available in the modules, SWC and functions of software and environment system are inserted in the `Actions` folders of the tasks. You can also assign processes/RE that were furnished by the hardware configuration, e.g. for the hardware initialization or signal processing. Each process/RE can be assigned exactly to one task.

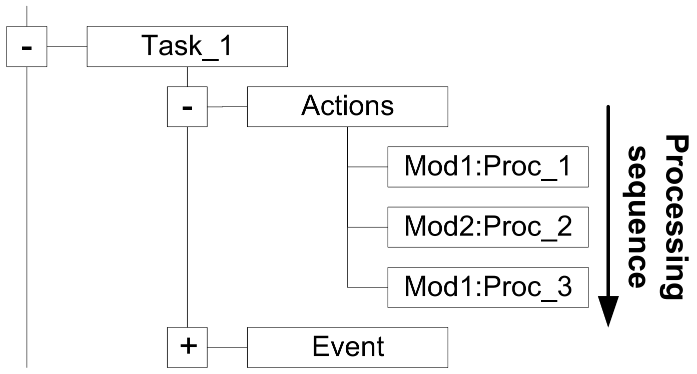


Fig. 5-33 OSC: Task with assigned processes

> **NOTE**
>
> The RTA-OSEK and RTA-OSEK for PC operating systems do not support processes. Instead, INTECRIO automatically generates code for the tasks that invokes the assigned processes/RE as C functions.

The sequence in which the processes/RE are displayed corresponds to the processing sequence; the top process/RE is processed first, the bottom one last. The processes/RE can be moved within a task to change the processing sequence.

In a similar way, exactly one event can be assigned to the `Event` folder of a task (exception: RTA-OSEK for PC/PC). Events are driven by interrupts and serve for triggering actions. The `Event` folder contains the event that, upon occurrence, triggers the one-time execution of the respective task. Events can be hardware-driven (e.g. watchdog alarm) or non-periodic (e.g. upon receipt of a trigger signal).

> **NOTE**
>
> Only interrupt-triggered signals can be assigned to the `Event` folder. Only one event can be assigned to each task.

The configurations described can be performed manually or automatically via the automapping function.

5.8.3.4 Setting Up Interrupt Service Routines

Interrupt service routines are set up in a similar way as tasks. A hardware interrupt is inserted in the `Interrupt` folder of an ISR; each HW interrupt can be assigned to exactly one ISR. The processes belonging to the ISR are inserted to the `Actions` folder. As for tasks, the process sequence in the `Actions` folder corresponds to the processing sequence.

Some HW interrupts have the *AnalyzeCapable* property (this property is set automatically by Hardware Configurator). In this case, the triggering event, i.e. the interrupt, can have sub-events that are analyzed at runtime. Each sub-event has a set of processes which are executed if required.

If such a HW interrupt is assigned to an ISR, the `Event Dependencies` sub-folder is created automatically in the `Actions` folder. The `Event Dependencies` folder contains the sub-events; these are displayed as further sub-folders that contain the respective processes.

Semantics is as follows: If the ISR is executed at runtime, and the analysis recognizes one or more events from the `Event Dependencies` folder, the process lists for those events are executed.

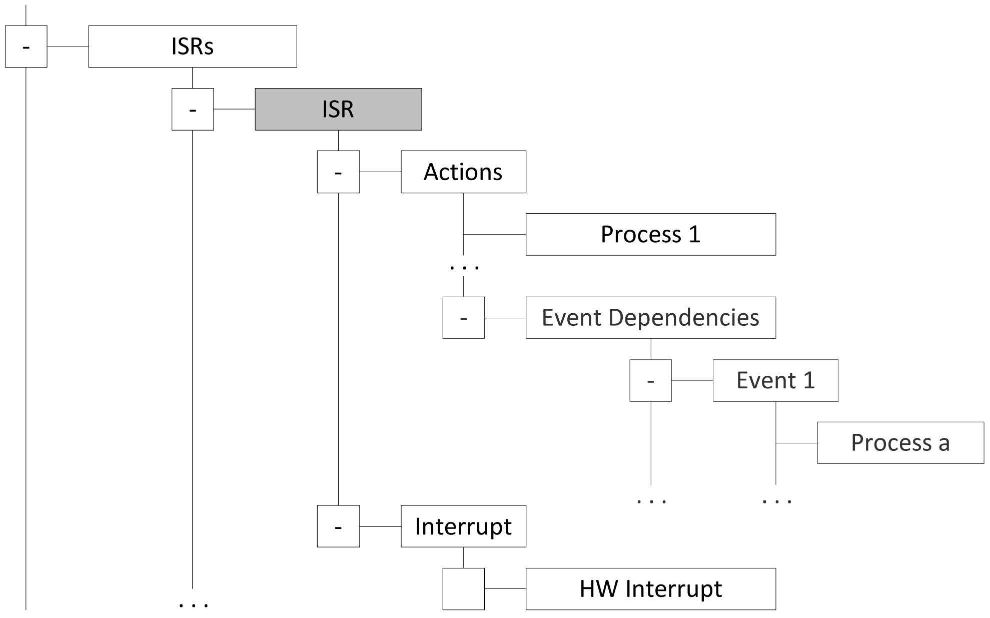


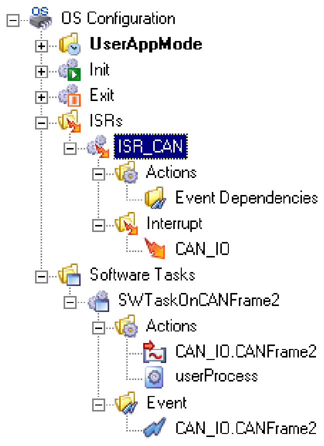
Fig. 5-34 OSC: ISR

Two procedures exist for ISR configuration. The automapping function for ISRs uses the default procedure.

A Default

This procedure should always be used, unless urgent scheduling requirements must be met.

A HW interrupt is assigned to a newly created ISR. Within the high-priority ISR, only the analysis is executed. If required, the analysis task activates further tasks. These software tasks (with lower priority than the ISR) contain the processes to be executed (signal groups and user-defined processes).

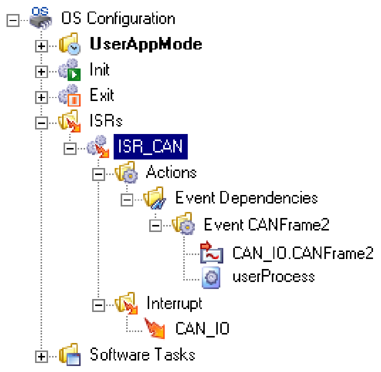


B Fastest response time

This procedure should only be used if signals must be evaluated as fast as possible.

After the ISR was created and the HW interrupt assigned, the event belonging to the signal is assigned to the `Event Dependencies` folder. The signal group, as well as the user-defined processes, are inserted in the `Event <event name>` subfolder.

The disadvantage is that the user-defined processes are executed with the high priority of the ISR and thus block most other actions in the system.



5.9 Project Integrator

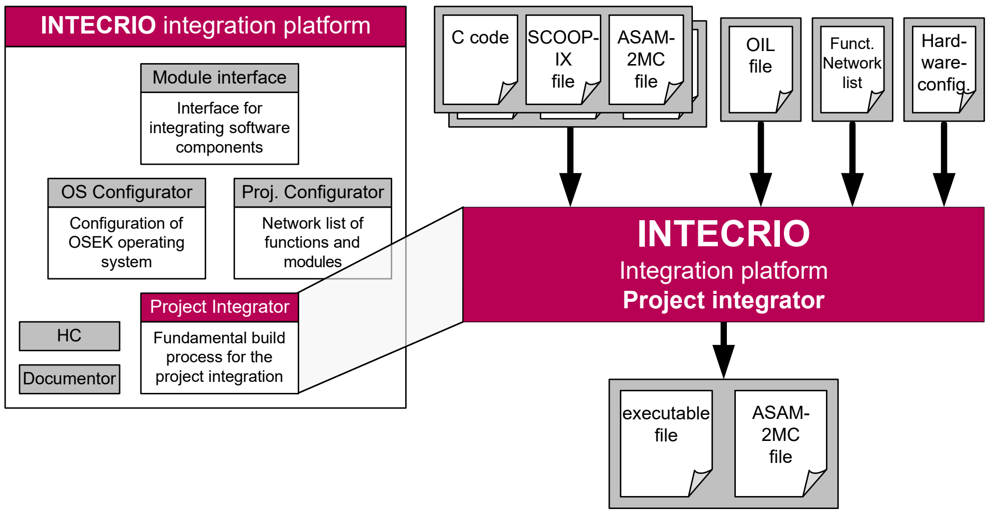


Fig. 5-35 Project integrator

The project integrator (PI) combines all the components of the system – modules and functions, hardware interfacing, OS configuration, etc. – into an executable file. It essentially consists of a tool chain. The frame of this chain, i.e. the components, that provides the Make functionality is the PI build system.

Additional components are the PI plugin, which provides the variables parts of the build configuration, compiler, linker, etc.

Besides the executable file, an ASAM-MCD-2MC file is created for the experiment's project in which the ASAM-MCD-2MC files of the individual modules and additional information about the total project are combined. Optionally, the project integrator also creates a configuration file for RTA-TRACE.

In contrast to the configurators, the project integrator does not have its own editors. In the graphical framework, it only reveals itself by using the **Integration** menu.

5.9.1 Build Process

For a successful build process, all necessary files (`*.six`, `*.c`, `*.h`, `*.a2l`, ...) must be available for all modules. An installation of the BMT that generated these files is not necessary.

5.9.1.1 Overview

Fig. 5-36 schematically displays the phases of the build process and the file types concerned. Each one of the phases, in turn, can be subdivided into individual steps.

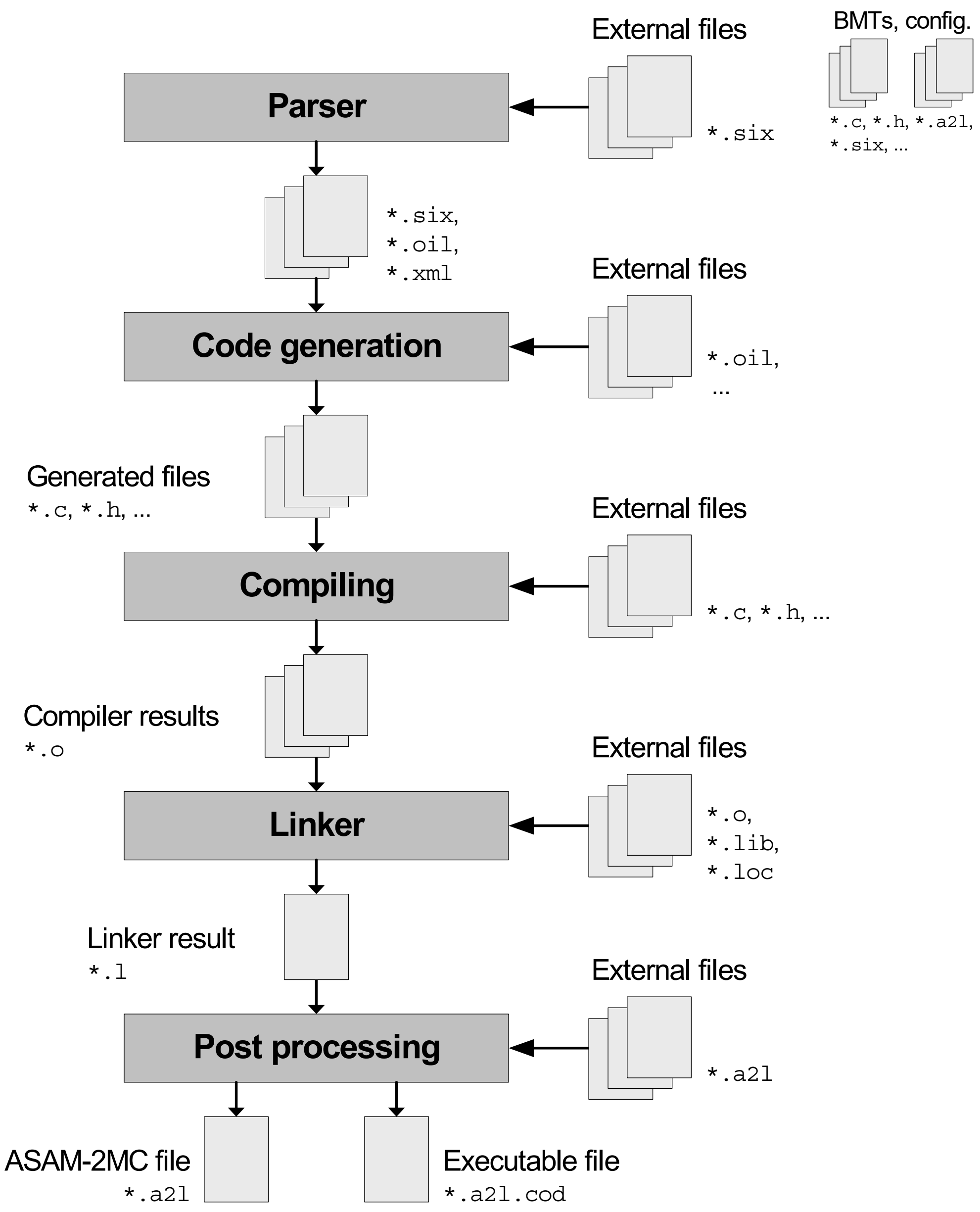


Fig. 5-36 Build process

At the start of the build process, the *parser* analyzes the configurations of all components and the total project, as well as the interface descriptions provided by the behavioral modeling tools (`*.six`).

For the *code generation*, the interface descriptions (`*.six`) and the configurations (`*.oil`, ...) created with different INTECRIO components are transferred to C code. This code contains the information required in addition to the functional code of the modules.

For the *compiling*, object files are created from the files created during the code generation and the C code of the behavioral modeling tools. External C code files or header files can be added here. Only one compiler can be used for a system project.

The compiling results are linked into a binary file by the *linker*. External object files or libraries can be added here. Only one linker can be used for a system project.

In *post-processing*, the final executable file and the ASAM-MCD-2MC description file for the complete project is created from the binary file. The ASAM-MCD-2MC files generated by the behavioral modeling tools are included here.

5.9.1.2 Sequence

Before the build process can run, it must be ensured that the system project contains the following components:

- A configuration of the hardware (see section 5.3),
- A configuration of the software (see section 5.7),
- A completely configured system project (see section 5.7, subsection "System Projects"), and
- An OS configuration (see section 5.8).

Once it is started, the build process runs automatically. Information about the current status and warnings or error messages are displayed. If a warning occurs, the process is continued; in case of a normal error, the current phase is completed before the process is canceled. In case of a severe error or a missing source file, the build process is canceled immediately, if necessary in the middle of a phase.

Code is created that can be executed in RAM with the option for a dynamic reconfiguration at runtime, and optionally code that can be executed in FLASH. This FLASH code does not offer dynamic reconfiguration. The latter can be executed in standalone mode on the rapid prototyping hardware. It is also possible to run only the code generation phase.

The files created in the build process are written to a directory that was specifically created for this system project, `<workspace>\cgen\system<n>`. This directory contains subdirectories for compiled files and other, temporary files. The final executable file and the ASAM-MCD-2MC description are written to the `Results` subdirectory of the project directory (`...\<workspace>`), if nothing else is specified. The basic name for the executable file (`<basic name>.a2l.cod`) and the ASAM-MCD-2MC file (`<basic name>.a2l`) can be predefined; the name of the system project is used by default.

If nothing else is specified, the build process is incremental, i.e. only modified input files are included and only missing output files or output files created with other input files than the current ones are generated. Upon request, it is possible to delete all INTECRIO system files, except for the generated code from the behavioral modeling tools and the SCOOP-IX files, prior to the start of the build process. This forces a complete rebuild of the entire project. This cleanup can also be performed without subsequent build process.

5.9.2 ASAM-MCD-2MC Generation

The build process of the project integrator generates an ASAM-MCD-2MC description (`*.a2l` file) of the project that meets the specifications of the working group for standardization of automation and measuring systems, version 1.4[1]. Such a description is required for the ETAS Experiment Environment to identify the model elements that must be measured or calibrated.

During the creation of this ASAM-MCD-2MC file, the `*.a2l` files provided by the behavioral modeling tools for the modules contained in the project are combined. Furthermore, additional entries are added that describe the project as a whole.

In general, an ASAM-MCD-2MC file contains the following components:

- Project information
- Descriptions of data structures used in the project
- Descriptions of variables and parameters
- Descriptions of external interfaces
- Descriptions of communication protocols
- Descriptions of conversion formulas

1) The current specification can be obtained here: https://www.asam.net/

5.10 ETAS Experiment Environment

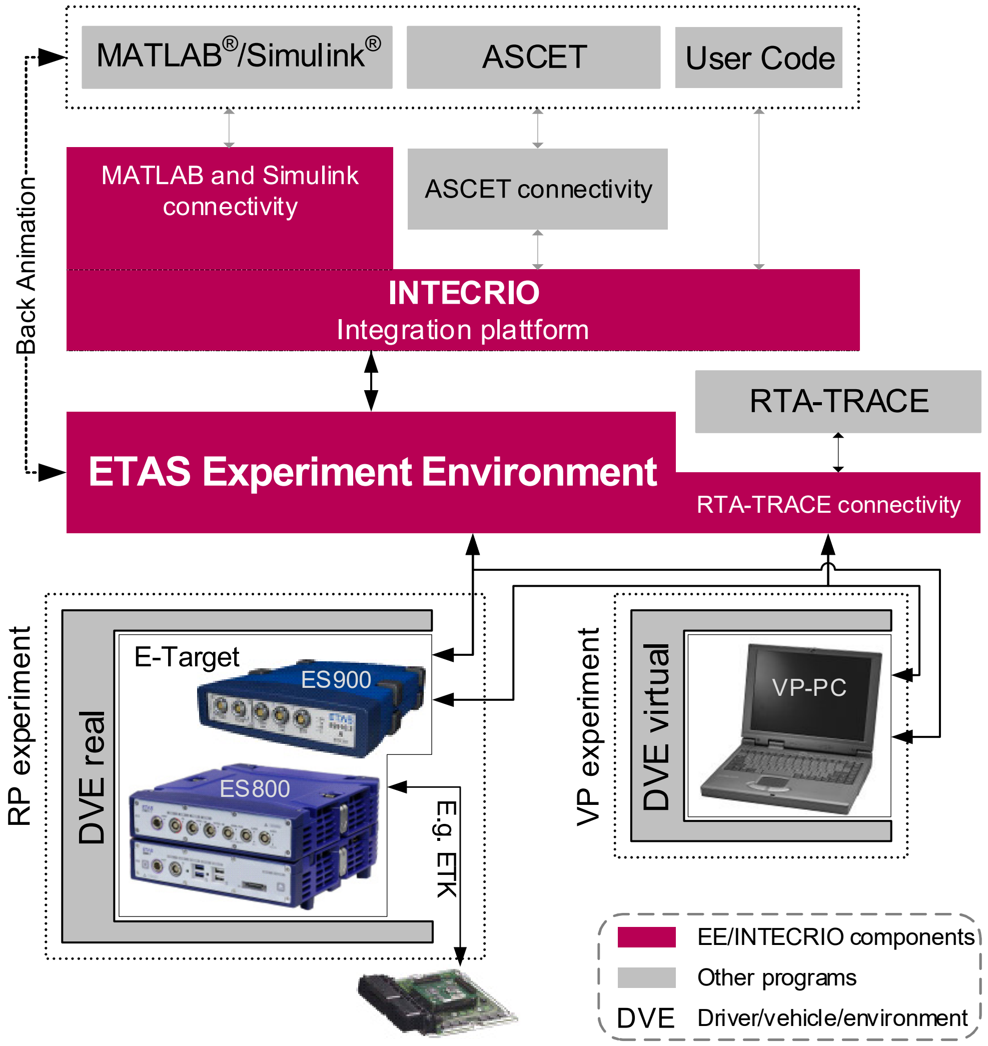


Fig. 5-37 ETAS Experiment Environment used with INTECRIO

This section provides an introduction to experiments in general and the ETAS Experiment Environment in particular. Using the ETAS Experiment Environment is described in the online help.

Experimenting can generally be subdivided into three steps:

- Preparing the experiment
- Performing the experiment
- Analysis after the experiment

Preparing the experiment contains creating a prototype that is specifically suited for this special experiment, as well as the creation of a suitable environment for the experiment. The analysis following the experiment essentially contains the analysis of recorded data with suitable tools[1]. However, only the performance of experiments is dealt with at this point.

1) for example, the ETAS Measure Data Analyzer (MDA)

Prototypes that use a VP-PC target contain one memory page, prototypes that use an ES910 or ES830 target contain two memory pages. To make use of both memory pages, you have to use INCA/INCA-EIP as experiment environment; the ETAS Experiment Environment does not support multiple memory pages. See the INCA and INCA-EIP documentation for details on using memory pages.

NOTE

Beginning with V5.0.4, INTECRIO supports ETAS Experiment Environment V3.8.4. ETAS Experiment Environment V3.7 is *no longer supported*.

ETAS Experiment Environment V3.9 is *not supported*.

Experimenting with an ES800 hardware system requires INCA V7.4 or higher with INCA-EIP, or ETAS Experiment Environment V3.8.4.

5.10.1 Validation and Verification

If the software components or the complete application software must be validated and verified in the function development phase (see also section 3.4 "INTECRIO in the Development Process"), it generally requires an experiment environment. It must provide all the functions required for the validation and verification.

In general, an experiment environment must deal with the following tasks:

- Loading code and data onto the target
- Starting, stopping and interrupting the experiment
- Measuring and calibrating different elements with different means
- Use of stimuli, if necessary

The tasks vary with the targets used.

It is also necessary that all the settings required for the validation and verification during the creation of the prototype are performed so that it is possible to perform a useful experiment.

5.10.2 Measuring and Calibrating

In general it can be said that the main task of an experiment environment consists of two items: measuring and calibrating. Measuring means that the current status of an element is read and made visible in an environment-dependent form. Calibrating means that the current status of an element is changed or adjusted in a suitable way. For this reason, an experiment environment is characterized by two different capabilities: measurement and visualization of element statuses as well as calibration (adjustment) of element statuses.

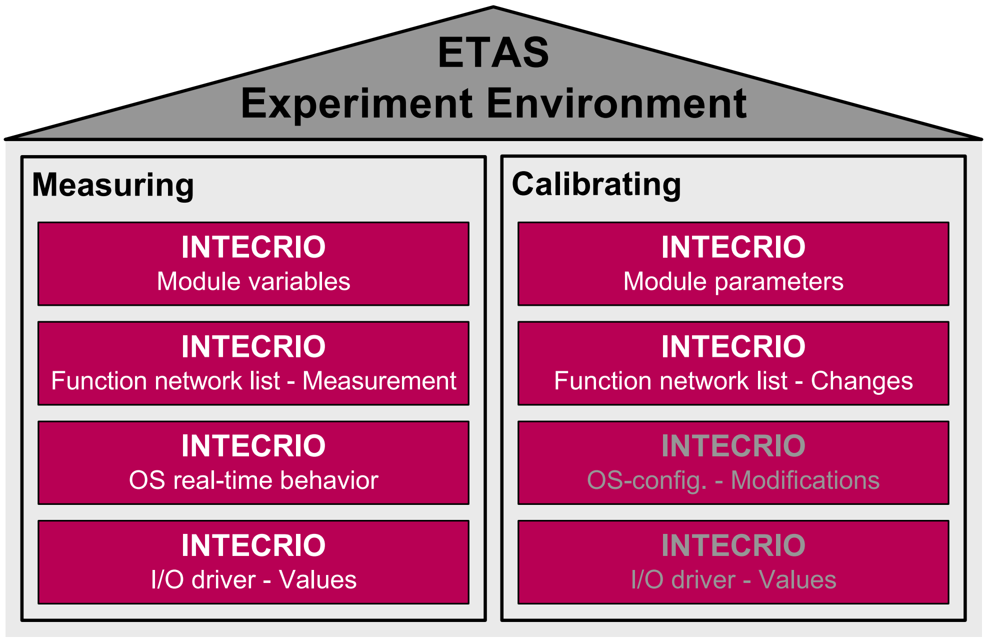

ETAS
Experiment Environment
Measuring
INTECRIO Module variables
INTECRIO Function network list - Measurement
INTECRIO OS real-time behavior
INTECRIO I/O driver - Values
Calibrating
INTECRIO Module parameters
INTECRIO Function network list - Changes
INTECRIO OS-config. - Modifications
INTECRIO I/O driver - Values

Fig. 5-38 Main tasks of the ETAS Experiment Environment

The following elements can be measured in the ETAS Experiment Environment:

- *Module variables* – Variables within the modules specified with BMTs
- *Function network list* – The values of the connections between the different software and hardware modules can be measured to obtain information about the current signal value exchange between the components.
- *Real-time behavior of the operating system* – The current status of the operating system, i.e. the current task, execution times, etc., can be displayed.
- *I/O driver* – The values provided or consumed by a driver are of interest just like the current driver configuration.

The following elements can be calibrated in the ETAS Experiment Environment:

- *Module parameters* – The parameters in the various modules can be calibrated.
- *Function network list* – The connections between software and hardware modules can be changed at runtime. This is an essential capability for validation and verification.

Calibrated parameters can be saved and loaded.

5.10.3 Experimenting with Different Targets

In order for experiments to run on a target, the target must support different interfaces. These properties depend on the requested functionality, as discussed in section 5.10.1 "Validation and Verification". Therefore, the target must be prepared to allow for the combination of the different tasks of the experiment environment as well as the measuring and calibrating of the relevant elements.

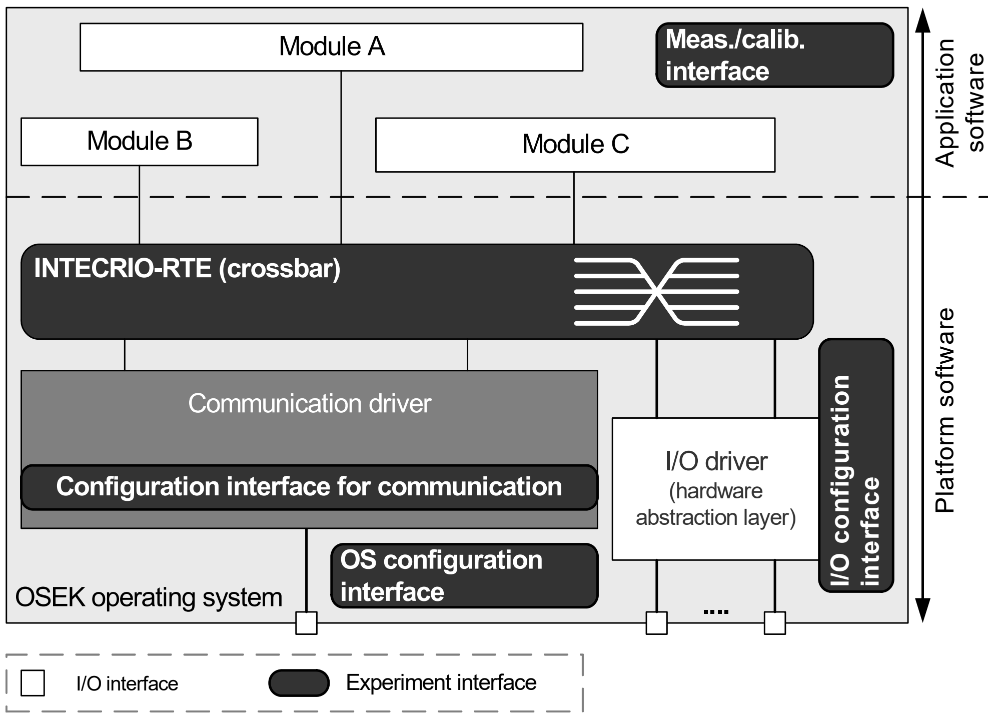


Fig. 5-39 Experiment interfaces

Fig. 5-39 shows the different experiment interfaces that are required so that all the measuring and calibrating tasks displayed in Fig. 5-38 can be performed.

- The *measuring and calibrating interface* – for access to variables and parameters,
- *INTECRIO-RTE (Crossbar)* – for access to the function network list,
- The *configuration interface for communication* – for access to the I/O driver values,
- The *I/O configuration interface* – for access to the configuration of the I/O drivers,
- The *OS configuration interface* – for access to the OS configuration.

However, not every target has to feature all of these interfaces; it is sufficient if the interfaces required for the respective task are available.

Real-time targets for rapid prototyping should support all listed interfaces since this type of experiment requires the possibility for quick changes for verification and validation.

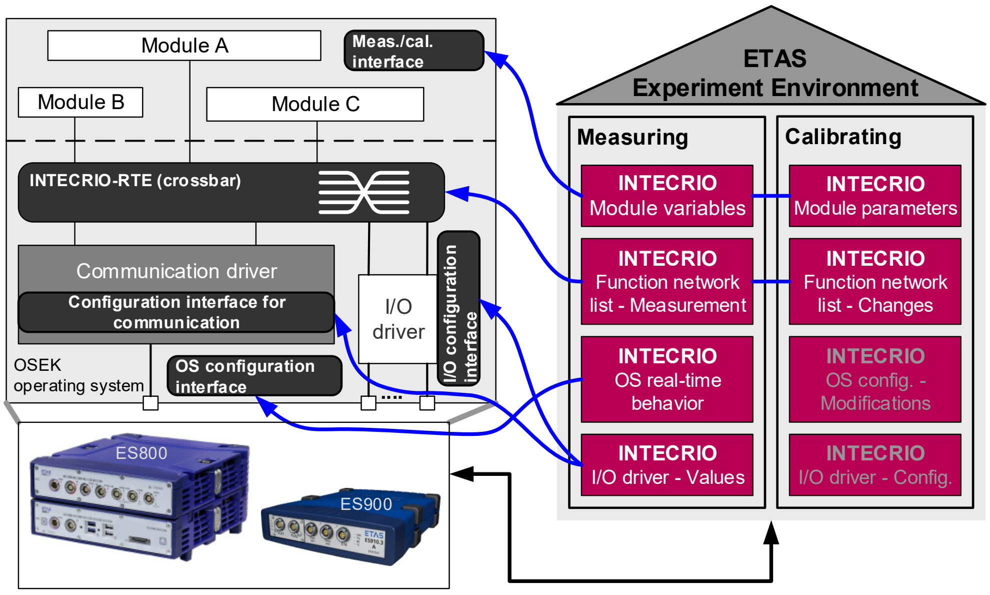

Module A
Meas./cal. interface
Module B
Module C
INTECRIO-RTE (crossbar)
Communication driver
Configuration interface for communication
I/O driver
I/O configuration interface
OSEK operating system
OS configuration interface
....
ES800
ES900
ETAS Experiment Environment
Measuring
Calibrating
INTECRIO Module variables
INTECRIO Module parameters
INTECRIO Function network list - Measurement
INTECRIO Function network list - Changes
INTECRIO OS real-time behavior
INTECRIO OS config. - Modifications
INTECRIO I/O driver - Values
INTECRIO I/O driver - Config.

Fig. 5-40 Experiment interfaces for rapid prototyping targets

Fig. 5-40 shows which interface takes on what measuring and calibrating tasks for a rapid prototyping system.

However, for experiments on the production electronic control unit there is no possibility to calibrate the configurations during the running experiment or – except for the real-time behavior of the operating system – to measure. For this reason, only the measuring and calibrating interface as well as the OS configuration interface are required, the others can be omitted (see Fig. 5-41).

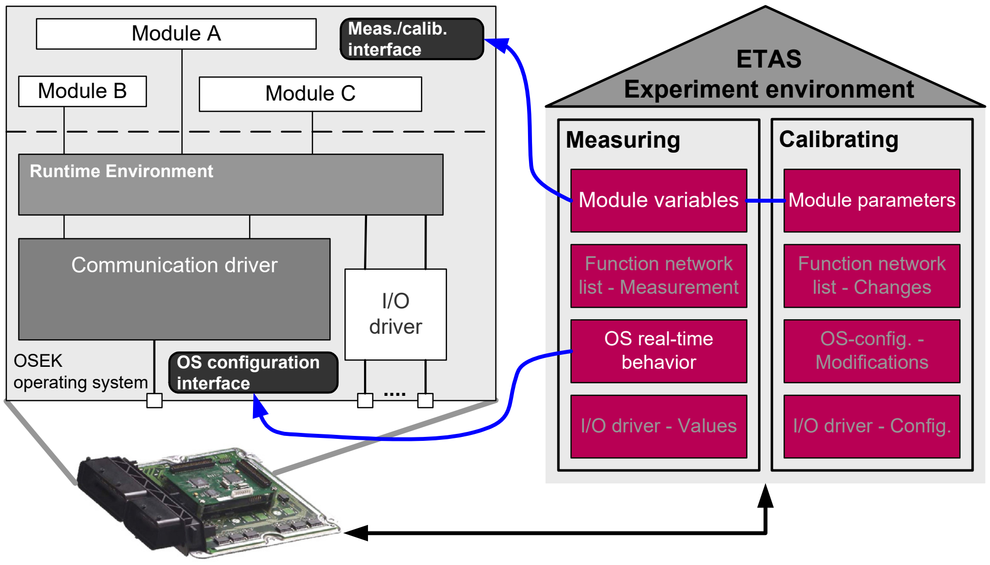


Fig. 5-41 Experiment interfaces for production electronic control units

5.10.4 Rapid Prototyping Experiment with the ETAS Experiment Environment

In principle, there are two types of experiments with rapid prototyping systems: bypass and fullpass experiment. The performance of an experiment is roughly the same in both cases; the user wants to execute the prototype, measure values and calibrate parameters. Nevertheless, there are clear differences which are described in the following sections.

5.10.4.1 Bypass Experiment

A *bypass experiment* exists if only parts of the application software are computed on the rapid prototyping hardware.

Bypass experiments are preferably used if only a few software functions must be developed and an electronic control unit with validated software functions – perhaps from a predecessor project – is already available. This electronic control unit then needs to be modified so that it supports a bypass interface. The necessary software modifications with respect to the electronic control unit are referred to as *bypass hooks*. The effort for creating a bypass experiment is low.

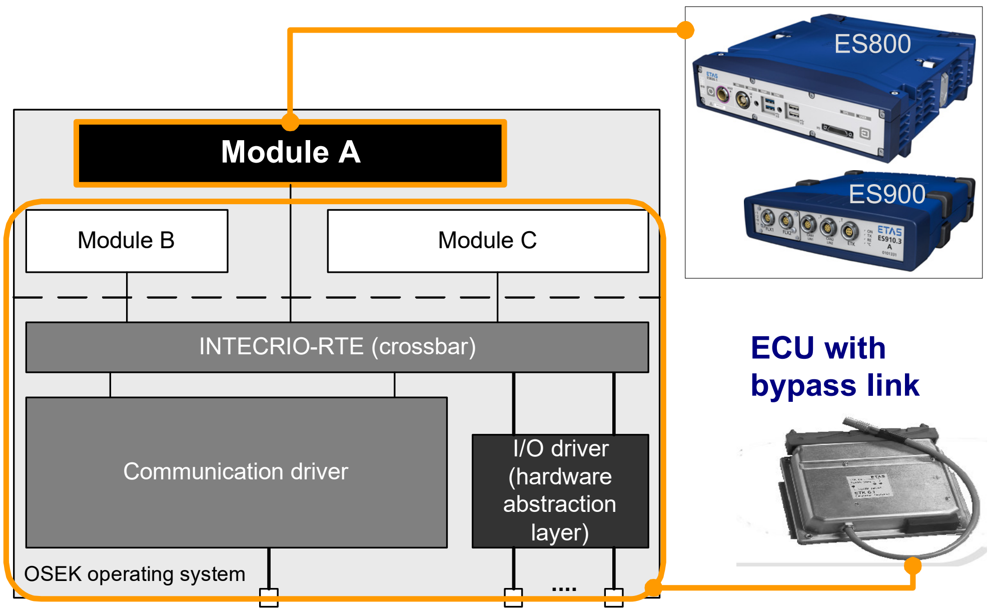


Fig. 5-42 Bypass experiment: Scheme

A bypass system can be considered as a system with two processors: The electronic control unit with bypass link is one processor, the other processor is the rapid prototyping system. The application software (sometimes even a part of the platform software) is distributed to these two processors which are linked with each other by means of a bypass synchronization mechanism (e.g. ETK or CAN bus).

The calculation of the bypass function is generally initiated by the electronic control unit via a control flow interface or trigger; the output values of the bypass function are monitored in the electronic control unit for plausibility. In this case, electronic control unit and rapid prototyping system operate synchronously. Alternatively, it is also possible to implement an unsynchronized communication without trigger.

Since the two processors are forming a system, it is necessary that the controlling PC views them as one system. This means that access to both processors is assigned by a control application. This is easy to implement by using INCA since INCA allows access to the rapid prototyping target as well as the electronic control unit target.

INTECRIO and the ETAS Experiment Environment support bypass experiments, too. During a bypass experiment with INTECRIO, you can access the experimental target from the ETAS Experiment Environment, i.e. you can measure and calibrate the bypass hook variables. However, you have no direct access to the ECU.

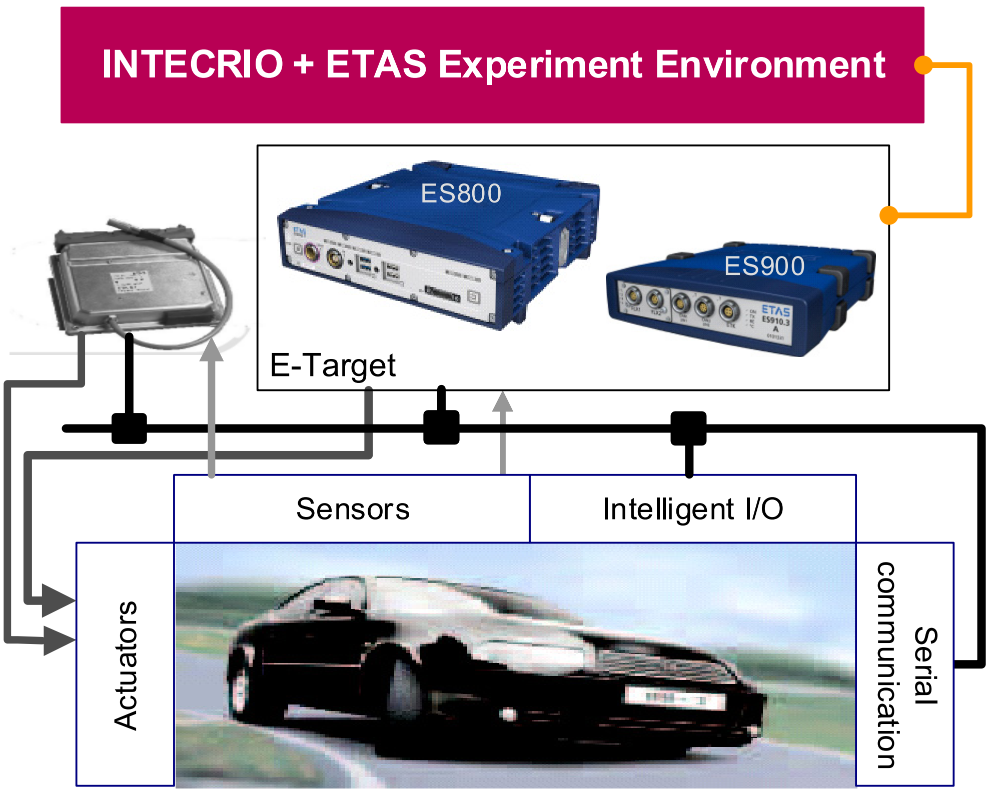


Fig. 5-43 Bypass experiments with INTECRIO + ETAS Experiment Environment

5.10.4.2 Fullpass Experiment

If an electronic control unit with validated software functions and bypass interface is not available or if additional sensors and actuators must be validated, fullpass experiments are frequently preferred. The real-time behavior must be guaranteed by the rapid prototyping hardware and possibly monitored; all sensor and actuator interfaces required by the function must be supported.

The environment of INTECRIO refers to a *fullpass experiment* if the entire application software (the control algorithm) runs on the rapid prototyping hardware. The hardware runs in standalone mode (without electronic control unit); the I/O interfaces form the connection to the outside world (see Fig. 5-44); sensors and actuators are directly connected to the hardware.

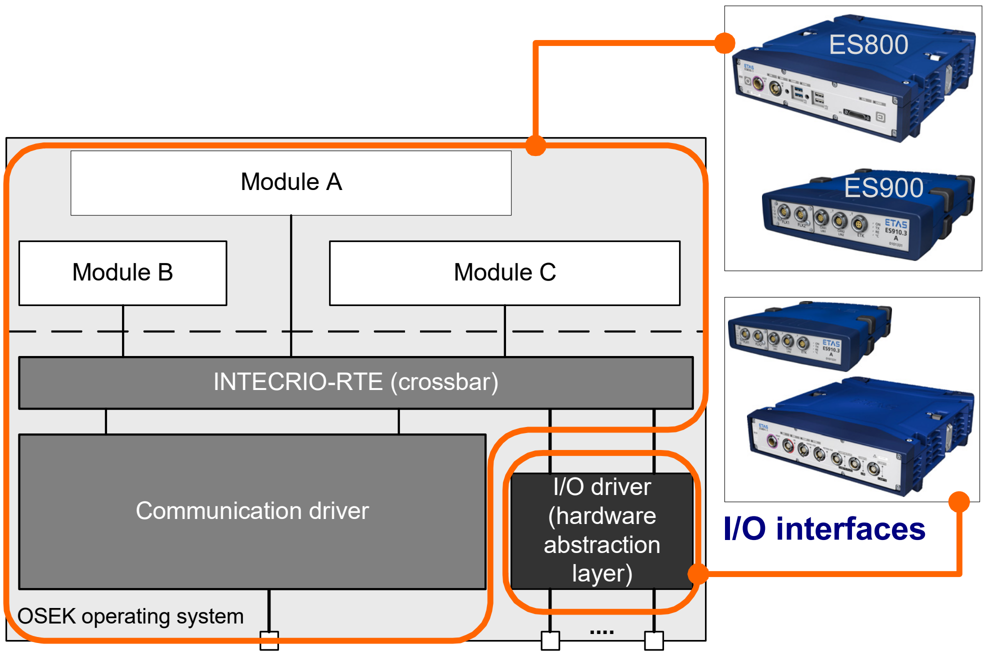


Fig. 5-44 Fullpass experiment in standalone mode

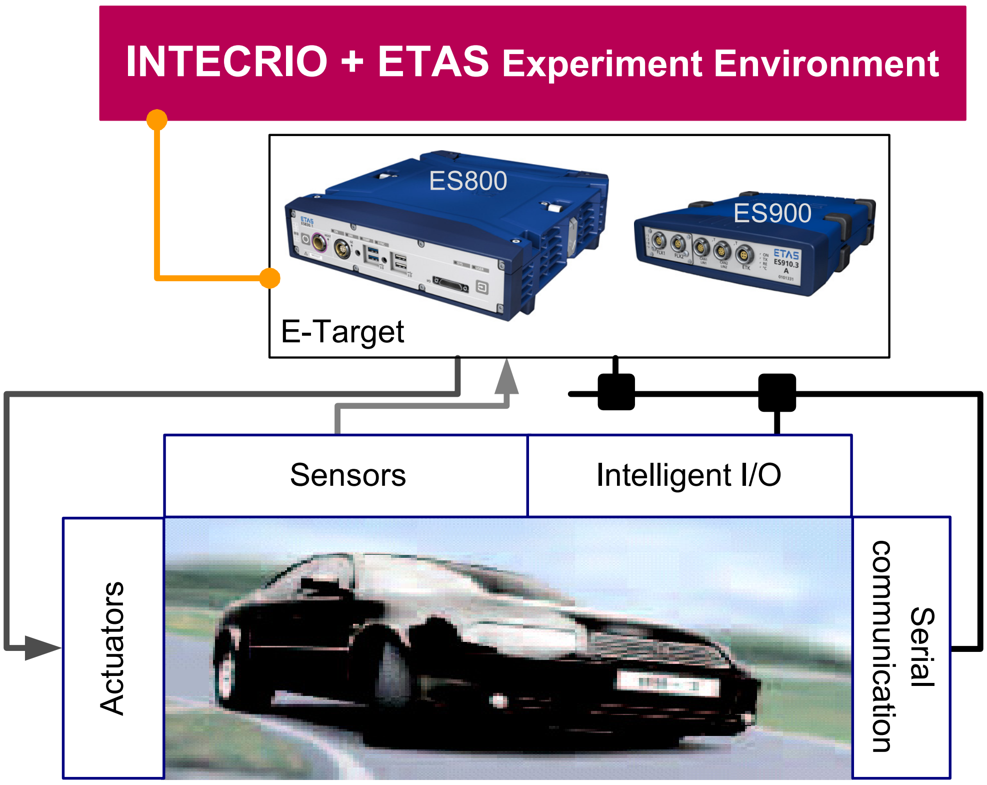


Fig. 5-45 Fullpass experiment with INTECRIO + ETAS Experiment Environment

The other option consists of using INCA/INCA-EIP instead of the ETAS Experiment Environment.

5.10.4.3 X-Pass Experiment

The X-pass experiment is a mixture of bypass and fullpass experiment. The rapid prototyping hardware utilizes the electronic control unit with bypass hooks as interface to the outside world (see Fig. 5-46).

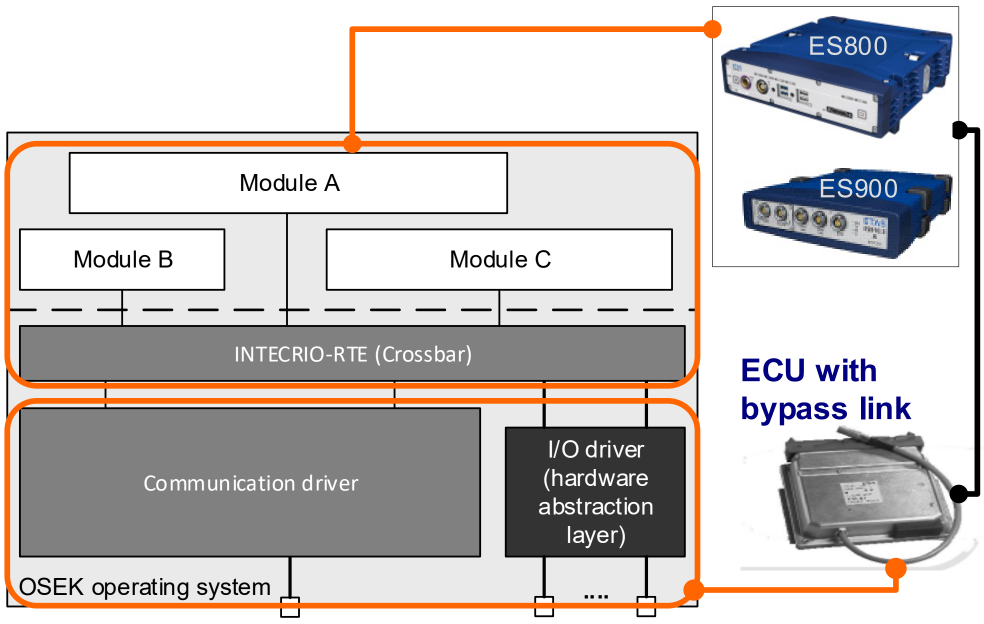


Fig. 5-46 X-pass experiment with electronic control unit as I/O

5.10.5 Virtual Prototyping Experiments with the ETAS Experiment Environment

The ETAS Experiment Environment offers the same options for virtual prototyping as it does for rapid prototyping, e.g. to view variables and to change parameters. In parallel, this is possible directly in MATLAB and Simulink or in ASCET, as well. In addition, users can change parameters and module connections on the running prototype in order to compare various model configurations.

5.11 Documentor

The INTECRIO documentor offers the possibility to generate documentation for the components of a system project. The documentation can be generated in HTML or PDF format, and the be printed or used in other documents.

Besides general information on the system project, the documentation file contains information on the software and hardware systems and the OS configuration. The exact content can be configured; the following specifications are possible:

System Project

- general information (INTECRIO version, creation date, etc.)
- workspace information
- system-level connections (i.e. between hardware and software)

Software System

- information on the software system (general information, signal sources/ sinks of software system and functions, connections on software system level, etc.)
- information on the contained modules (general information, information regarding module code and files, signal sources/sinks of modules, parameter, processes, etc.)

Environment System

- information on the environment system (general information, signal sources/sinks of environment system and functions, connections on environment system level, etc.)
- information on the contained modules (general information, information regarding module code and files, signal sources/sinks of modules, parameter, processes, etc.)

Hardware System

- information on the hardware system (general information, ECU, CPU, signal sources/sinks of hardware, connections on hardware system level, etc.)
- information on devices (name, signal groups, signals, etc.)

OS Configuration

- general information
- information on application modes and tasks
- information on OS actions (i.e. processes)
- information on events

Details regarding the setup and generation of documentation can be found in the online help.

5.12 RTA-TRACE Connectivity

NOTE

RTA-TRACE is discontinued. However, *existing* installations can still be used.

RTA-TRACE connectivity is an add-on to the ETAS Experiment Environment. It allows for connecting RTA-TRACE with the rapid prototyping hardware or the PC in case of virtual prototyping. By using RTA-TRACE, the time behavior (VP) or the real-time behavior (RP) of the experiment on the target (ES910, ES830, VP-PC) can be displayed.

Additional information about RTA-TRACE and how to operate this tool can be found in the RTA-TRACE documentation.

6 SCOOP and SCOOP-IX

This chapter contains a concept for the description, management and exchange of C code interfaces. The description and exchange of code interfaces is a very important topic in the context of INTECRIO since the interfaces for integration are of significant importance.

In the framework of the embedded control software, the smooth integration of simple C code is affected by the fact that certain semantic pieces of information are not part of the standard C code:

- Implementation data, such as conversion formula, minimum, maximum and limitation for C variables as well as return values and arguments of C functions,
- Grouping information for characteristic values (lookup tables) represented by several C arrays with disjointed definitions or embedded in C structures (`struct`),
- Information about use that indicate whether an element is intended for measurements or calibration with running experiment, and
- Origin of the model and specific data (e.g. model name, physical unit, embedded component or block, notes, use as message, process, signal or parameter), particularly for automatically generated source files.

Furthermore, additional information is more or less obviously "hidden" in the C code and cannot easily be extracted:

- Memory classes that are written to by non-standard target-specific `#pragma` instructions
- Attributes of C variables or C functions that are written to by non-standard target-specific modifiers such as `inline` or `far`.

The concept introduced in this chapter that is used to collect all the necessary interface information and make it available, is referred to as *SCOOP* (***S****ource* ***Co****de,* ***O****bjects, and* ***P****hysics*).

The approach of SCOOP essentially consists of an interface description language (roughly comparable with known interface description languages such as ARXML1) or that of CORBA2) and COM from Microsoft) and tools for creating, managing and using the interface descriptions.

The interface description language *SCOOP-IX* (see also section 6.2 "SCOOP-IX Language" on page 121) is intended for the detailed collection of all the information about interfaces in a wider sense. SCOOP-IX descriptions can be used for the data exchange between tools or supplied together with open or compiled C code for later integration.

1) AUTOSAR XML
2) Common Object Request Broker Architecture, developed by the Object Management Group (OMG, see https://www.omg.org/)

6.1 SCOOP Concept

The approach of SCOOP aims at providing a uniform description of the aforementioned information, together with the actual interfaces of the code on C level. Besides the initially mentioned semantic information, a SCOOP-IX interface description essentially consists of the following information:

- Name, type and magnitude of C variables
- Name, return value and signature of C functions
- File origin of C elements

The combination of this information to an interface description language offers a very powerful tool for the following applications:

- Representation of interface inside of INTECRIO and its components, particularly the following:
  - Experimental target configurator
  - OS configurator
  - Project configurator
  - Project integrator
- Representation of interfaces for communication between different tools and the interfacing of ASCET and MATLAB and Simulink to INTECRIO.

SCOOP provides a formal interface description that is suitable for the following purposes:

- Distribution of object files or libraries together with a comprehensive interface description on the levels of C code, physics and semantics with the support of know-how protection (IP protection).
- Check for compatibility of interfaces of different software modules, not only on the level of C code (name, type, signature), but also on the physical (implementation, unit) and semantic (record layout, use as message or process) level.
- Generation of connection code or wrapper functionality to adjust nonconforming module interfaces to each other for integration.
- To provide tools (such as the OS configurator) with the opportunity of using information further that is transferred by code generators (e.g. all C elements that represent ASCET processes and messages).

6.2 SCOOP-IX Language

SCOOP-IX is short for *SCOOP Interface Exchange Language*; this language is the basis of the SCOOP concept. As mentioned earlier, SCOOP-IX provides means for describing the interfaces of C modules to enable their integration with INTECRIO.

The SCOOP-IX language is based on XML and, therefore, well suited for use in INTECRIO, ASCET, Simulink®, or similar tools.

NOTE

INTECRIO V5.0 supports SCOOP-IX versions V1.0, V1.1, V1.2, V1.4, and V1.5.

6.2.1 Modules and Interfaces

SCOOP views a module either as an individual compiling unit (usually a C file) or as a combination of several compiling units (a group of C code or object files, libraries, etc.) with a common interface. Exactly one SCOOP-IX file belongs to a module.

Global C variables as well as C functions can be part of a module interface. If this is the case, they are referred to as *interface elements* below.

Interface elements are characterized as partners in an access or call relationship beyond module boundaries. For this reason, a C declaration or definition is considered to be the correspondence of an interface element of the module in the following cases:

- *Export interface*: A C variable or C function is globally defined in the module and available for external linking (not declared as `static`). The exact definition of the element can be determined directly. Elements that cannot be accessed from outside the module should be omitted from the SCOOP-IX description.
- *Import interface*: A C variable is accessed from within the module (read, write or address operation) or a C function is called within the module (directly or via address operation), but the element is defined outside of the module. The exact definition of the element can be determined by examining the associated declaration (whose existence is guaranteed with MISRA[1] compatibility).

6.2.2 Description of the C Code Interface

The description of the C code interface consists of information that is contained in the source code. The elements of the code interfaces fall into two categories, variables and functions, and they each contain specific descriptions of the interface elements.

Additional general information about the elements and the modules are also addressed by SCOOP-IX and are described below.

The interface description of a C *variable* (`<dataElement>` block, see Page 136, 137, and 138) essentially consists of the following information:

- The name of the variable (`<dataCInterface>` block, see Page 137, among others)
- The C type of the variable (`<type>` block, see Page 137, among others)
- The number of entries in x (and y) direction if the variable is an array (matrix)
- Information for storage in memory (such as `extern`, `static`, `const` and `volatile`, `far` or `huge`, `#pragma` instructions)
- An optional initialization value (`<initValue>` block, see Page 137, among others)

Accordingly, the interface description of a C *function* (`<functionElement>` block, see Page 139) essentially consists of the following information:

- Name of the function (`<functionCInterface>` block, see Page 139)

1) Motor Industry Software Reliability Association

- Information for storing the function in memory (such as `extern` and `static` (general), `inline` (target-specific), `#pragma` instructions)
- Arguments and return values of the function, such as:
  - Names of all arguments
  - C types of all arguments and the return value (`<return>` block, see Page 139)
  - Information for storage in memory (such as `const`, `far` or `huge`)
  - Sequence in which the arguments appear

In addition to the specific information described so far about C variables and C functions, *general information* about each element are important, such as the following:

- Type of interface element (import vs. export; `interfaceKind` parameter, see Page 137 and Page 139),
- File origin (`<fileOrigin>` block, see Page 137 and Page 139)

Each module interface is described not only by its elements, but also by the following *general information*:

- File origin of elements (`<fileContainer>` block, see Page 135).
- C header files to be integrated (also `<fileContainer>` block).
- Status of the module (source code, object file or library; `<constitution>` block and `mode` parameter, see Page 134).
- Hardware target (`<target>` block, see Page 134) and compiler (`<tool>` block, see Page 135) that the module requires.
- Compiler options and similar settings that were used for the creation or must be used for further processing (`<configuration>` block, see Page 135).

6.2.3 Description of Semantic Information

In contrast to the information about the C code interface, semantic information cannot be extracted from source code through analysis. Instead, this type of interface information must be created manually or automatically by a code generator together with the actual code generation. ASCET and MATLAB and Simulink connectivity offer the latter option.

Semantic information about elements is divided into the categories "Model Origin" , "Implementation" and "Use" . These categories are explained in the following sections. Additional module-specific information is also considered (see “Module Data” on page 126).

6.2.3.1 Model Origin

If the C source code described was automatically generated or manually created from a more or less formal model (such as block diagram, state machine, control or data flow diagram), the origin of each interface element can be described in the model.

The model origin is used primarily for documentation purposes and for improved orientation of the user. Configuration tools, such as the project configurator, can display this information, thereby providing the user a means for identifying model elements.

In addition, the information about the model origin can be used to forward specific information to other tools. For example, if ASCET marks the C elements that were generated for processes and messages, it allows the OS configurator to locate precisely these elements out of the entire interface description and to present to the user as possible candidates for the configuration of the operating system.

In addition to that, the description of the origin allows for enabling semantic checks in the model at the highest level with respect to consistency or plausibility across domain and tool boundaries.

Information about the model origin are divided into general and model-specific information. The latter are explained using examples of ASCET and MATLAB and Simulink.

General information about the model origin (`<modelOrigin>` block, see Page 137 and Page 139) can consist of the following elements:

- A model name such as the displayed name of the interface element (`<name>` block, see Page 137 and Page 139) or the element name of a memory element, signal, method, etc.
- A unique identifier in the model (`identifier` option, see Page 137 and Page 139)
- A model path within a hierarchical model structure (`<modelLink>` block, see Page 137 and Page 139)
- Model type such as `continuous`, `discrete`, `Boolean`, `array`, etc. for C variables, return values and arguments of functions (`<modelType>` block, see Page 138)
- Model form such as variable, parameter or constant for C variables (`<modelKind>` block, `kind` option, see Page 138 and Page 140)
- Visibility in other models, either `public` or `private` (`visibility` option, see Page 138 and Page 140)

  `public` visibility corresponds to the ASCET scope *exported*,
  `private` visibility corresponds to the ASCET scope *local*.
- Logical flow direction for C variables, such as input port or output port (`<flowDirection>` block, see Page 137)
- Physical unit for C variables, return values and arguments of functions
- Value range on the model level for C variables, return values and arguments of functions
- Textual notes, such as user comments, additional non-specific model information, etc. (`<annotation>` block, see Page 138 and Page 140)

Depending on the BMT used, certain *domain-specific information* is important for the integration of SCOOP-IX modules.

The following information is of special interest for code that was generated with ASCET:

- The ASCET component in which the equivalent of the respective interface element is embedded
- The type of component (class, module or project; `<pathNode>` block with `kind="asd:module"` option, see Page 137)
- The type of equivalent of the interface element (element, message, resource, method, process, task; `<pathNode>` block with `kind="asd:element"` option, see Page 138)

In real-time operating systems, such as RTA-OSEK, processes on C code level are represented by means of `void/void` functions. With respect to the OS configuration and project integration, the following information is of interest, among others:

- Messages that are accessed within the process or any C function that is called inside of them (`<messageAccess>` block, see Page 140), as well as the respective access mode (send, receive; `send` option, see Page 140).
- Resources that are accessed within the process or any C function that is called inside of them (`<resourceAccess>` block, see Page 140).
- Time requirements on the model level (`<constraint>` block, see Page 140), such as
  - Period (`<period>` block, see Page 140), offset, deadline and priority (`priority` option, see Page 140) of the execution,
  - Type of trigger (initialization, timer, interrupt or software; `trigger` option, see Page 140) and
  - Scheduling mode (preemptive, cooperative or non-preemptable; `<scheduling>` block, see Page 140).

  Since the actual priority levels are dependent upon the operating system and the CPU, imprecise priorities such as `background`, `low`, `normal`, `high` and `scheduler` are allowed.

The following information is of special interest for code that was generated with MATLAB and Simulink:

- MATLAB and Simulink subsystem or block that contains the counterpart to the respective interface element, as well as the type of subsystem or block.
- Type of counterpart to the interface element (signal or parameter).

The scan rates of a MATLAB and Simulink model can be formulated by means of comparable time restrictions such as the aforementioned ones.

6.2.3.2 Implementation

To allow for data consistency checks and the generation of connection code, information about the implementations of the C code interfaces is required. This applies to C variables, return values and arguments of functions.

Implementation information (`<implementation>` block, see Page 138) is comprised of

- A conversion formula that describes the relationship between the data of a model element and those of its C code equivalent (`<conversion>` block, see Page 136, and `<conversionRef>` block, see Page 138),
- Minimum and maximum values on the C code level (`<valueRange>` block, see Page 138) and
- The use of ASCET limiters and (in SCOOP-IX V1.2) resolution scheme if the boundaries of the value range are exceeded (`<saturation>` block, see Page 138).

  The `<saturation>` block contains the options `value`, `resolution` and `assignment`. Depending on the settings in the ASCET implementation editor, the options are set as follows.

  - `value` is set to `true` (`false`) if *Limit to maximum bit length* is activated (deactivated)
  - `resolution` is set to `automatic`, `keep`, or `reduce`, depending on the selection in the combo box next to *Limit to maximum bit length*.
  - `assignment` is set to `true` (`false`) if *Limit Assignments* is activated (deactivated).

  For Simulink models, or for ASCET variables that use no limiter, the `<saturation>` block is omitted.
- For SCOOP-IX files generated with ASCET V6.4: The `<zeroExcluded>` block (see Page 138) always contains `value="false"`.

  For SCOOP-IX files generated with ASCET V5.0 - V6.3: The `<zeroExcluded>` block contains information whether zero is explicitly excluded from the interval.

6.2.3.3 Use

The following semantic information about the use of interface elements is important (only data elements):

- The relationship between characteristic values and the respective C variables from which they are formed, as well as information about the characteristic value, such as axes, dimensions and record layout
- Use for measurement or calibration: `<usage>` block, see Page 138 (measurement) or Page 139 (calibration)
- Pseudo addresses for the simulation interface to the experimental target or ECU addresses with the corresponding bit masks

6.2.3.4 Module Data

The following add-on information may be contained in the SCOOP-IX description of a module (`<moduleInfo>` block, see Page 133):

- Module name (`<name>` block, see Page 133)
- The module version concerning the contents of the interface description (`<version>` block, see Page 133)
- Date and time of the creation (`<dateTime>` block with the `kind="created"` option, see Page 133)
- Date and time of the last modification (`<dateTime>` block with the `kind="lastModified"` option, see Page 133)

- Degree of completion of the interface description (`<completion>` block, see Page 133), i.e. one of the following statuses:
  - `basic` (only pure C code interface data, no semantic information)
  - `in progress` (intermediate format, semantic information partially completed)
  - `full` (document is considered to be stable, semantic information not compulsorily complete)
- Information about user and company (blocks `<company>`, `<user>` and `<creators>`, see Page 134)
- Name and version of the generating BMT (`<tool>` blocks, see Page 134)
- Textual notes (`<annotation>` block, see Page 134)

6.2.4 Referenced Models

Beginning withV5.0.4, INTECRIO supports the Model Referencing feature of Simulink. If you generate code for a Simulink model with referenced models, the following happens:

- A **`*.six`** file of SCOOP-IX V1.5 is generated for the main model. See section 6.2.4.1 "Extract from a `*.six` File" on page 127 for an extract.

  This `*.six` file contains all necessary links to all referenced models, i.e. models referenced by the main model and models referenced by other referenced models.

  The `*.six` file is the only file that needs to be selected during model import into INTECRIO.
- For each referenced model, a separate SCOOP-IX file named *`<referenced_model_name>`*`.ref_six` of SCOOP-IX V1.5 is generated. See section 6.2.4.2 "Extract from a `*.ref_six` File" on page 130 for an extract.

  A `*.ref_six` file does not contain links to other `*.six` or `*.ref_six` files. If a referenced model contains other referenced models, these are linked in the main `*.six` file.

6.2.4.1 Extract from a `*.six` File

This section contains an extract from the `*.six` file of a main model, i.e. a Simulink model that contains a referenced model.

References to main model and referenced model are set in blue font.

```
...
<module
  xmlns="http://www.etas.com/scoop-ix/1.5"
  xmlns:ix="http://www.etas.com/scoop-ix/1.5"
  xmlns:mlsl="http://www.etas.com/scoop-ix/1.5/
    modelDomain/matlab-simulink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.etas.com/scoop-ix/1.5
    file://C:\ETAS\INTECRIO5.0\SCOOP-IX\1.2/schemas/
    scoop-ix-domain-mlsl.xsd"
  xmlns:html="http://www.w3.org/1999/xhtml">
  <directoryLocations scheme="MATLAB 9.3">
    ...
  </directoryLocations>
  <moduleInfo identifier="MyMainModel">
    <name>MyMainModel</name>
    <modelLink href="mlsl://&quot;{{modelDir}}
      MyMainModel.slx&quot;"/>
    <version major="1" minor="9"/>
    ...
    <creators>
      <user lastName="MOL9FE" role="creator"/>
      <tool kind="environment" vendor="The Mathworks, Inc."
        name="MATLAB">
        ...
      </tool>
      <tool kind="modeler" vendor="The Mathworks, Inc."
        name="Simulink">
        ...
      </tool>
      <tool kind="modeler" vendor="The Mathworks, Inc."
        name="Stateflow">
      </tool>
      <tool kind="codeGenerator" vendor="The Mathworks, Inc."
        name="Simulink Coder">
        ...
      </tool>
      <tool kind="codeGenerator" vendor="The Mathworks, Inc."
        name="MATLAB Coder">
        ...
      </tool>
      <tool kind="codeGenerator" vendor="ETAS GmbH"
        name="Connector for Simulink (IRT)"
        family="INTECRIO Tool Suite">
        <version major="4" minor="7" year="2019"
          month="1" day="1"/>
        <configuration>
          <option identifier="SCOOPIXFileName">
            <![CDATA[MyMainModel.six]]></option>
          ...
        </configuration>
      </tool>
    </creators>
  </moduleInfo>
  <codeInfo>
    <constitution mode="sourceCode"/>
    <dateTime kind="created" year="2019" month="5" day="16"
      hour="11" minute="20" second="37"/>
    <target>
      <board vendor="ETAS GmbH" model="INTECRIO Generic
        Experimental Target"/>
```

```
        <tool kind="compiler" vendor="GNU Project"
          family="GNU Compiler Collection" name="GNU C Compiler">
          <configuration>
            <optionKind name="macroDefine" prefix="-D"/>
            <optionKind name="includeDirectory" prefix="-I"/>
            <!-- RTW specific defines -->
            <option kind="macroDefine" name="USE_RTMODEL"/>
            <option kind="macroDefine" name="MODEL">
              MyMainModel</option>
            ...
            <!-- RTW specific include directories -->
            <option kind="includeDirectory">
              <![CDATA[{{codeDir}}]]></option>
            ...
            <!-- S-Function specific include directories -->
            <!-- Referenced models local include
              directory -->
            <option kind="includeDirectory">
              <![CDATA[{{codeDir}}
              referenced_model_includes]]></option>
          </configuration>
        </tool>
      </target>
    </codeInfo>
    <!-- Model specific files -->
    <fileContainer constitution="sourceCode">
      <pathBase path="{{codeDir}}"/>
      <!-- Model specific source files -->
      <file name="MyMainModel_types.h" kind="header"/>
      <file name="MyMainModel.h" kind="header"/>
      <!-- used through rtwShared.lib:
        zero_crossing_types.h -->
      <file name="MyMainModel.c" kind="body"/>
      <file name="MyMainModel_private.h" kind="header"/>
      <file name="rtmodel.h" kind="header"/>
      <!-- used through rtwShared.lib: rtGetInf.h -->
      <!-- used through rtwShared.lib: rtGetInf.c -->
      <!-- used through rtwShared.lib: rtGetNaN.h -->
      <!-- used through rtwShared.lib: rtGetNaN.c -->
      <file name="MyMainModel_main.c" kind="body"/>
      <!-- Additionally registered model specific source files -->
      <file name="rt_sim.c"
        path="{{codeDir}}external\rtw\c\src\" kind="body"/>
      <!-- Target specific libraries -->
      <file name="rtwStaticLib.lib" kind="symbolicLibrary"/>
      <file name="rtwSharedLib.lib" kind="symbolicLibrary"/>
      <!-- Additional files -->
    </fileContainer>
    <fileContainer constitution="referencedModels">
```

```
        <!-- SCOOP-IX files for referenced models -->
        <file name="MySub.ref_six"
          path="D:\ETASData\INTECRIO5.0\User\ModelRef\
          modules\mysub\" kind="SIX" format="SCOOP-IX"/>
    </fileContainer>
...
```

NOTE

The `<fileContainer constitution="referencedModels">` section in the `*.six` file of a main model contains links to *all* referenced models, i.e. models referenced by the main model and models referenced by other referenced models.

6.2.4.2 Extract from a `*.ref_six` File

This section contains an extract from the `*.ref_six` file of a referenced model.

References to the model described in `*.ref_six` are set in blue font.

```
...
<module
    xmlns="http://www.etas.com/scoop-ix/1.5"
    xmlns:ix="http://www.etas.com/scoop-ix/1.5"
    xmlns:mlsl="http://www.etas.com/scoop-ix/1.5/
      modelDomain/matlab-simulink"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.etas.com/scoop-ix/1.5
      file://C:\ETAS\INTECRIO4.7\SCOOP-IX\1.2/schemas/
      scoop-ix-domain-mlsl.xsd"
    xmlns:html="http://www.w3.org/1999/xhtml">
    <directoryLocations scheme="MATLAB 9.3">
      ...
    </directoryLocations>
    <moduleInfo identifier="MySub">
      <name>MySub</name>
      <modelLink
        href="mlsl://&quot;{{modelDir}}MySub.slx&quot;"/>
      <version major="1" minor="26"/>
      ...
      <creators>
        <user lastName="MOL9FE" role="creator"/>
        <tool kind="environment" vendor="The Mathworks Inc."
          name="MATLAB">
          ...
        </tool>
        <tool kind="modeler" vendor="The Mathworks, Inc."
          name="Simulink">
          ...
        </tool>
```

```
         <tool kind="modeler" vendor="The Mathworks, Inc."
           name="Stateflow">
         </tool>
         <tool kind="codeGenerator" vendor="The Mathworks, Inc."
           name="Simulink Coder">
           ...
         </tool>
         <tool kind="codeGenerator" vendor="The Mathworks, Inc."
           name="MATLAB Coder">
         </tool>
         <tool kind="codeGenerator" vendor="ETAS GmbH"
           name="Connector for Simulink (IRT)"
           family="INTECRIO Tool Suite">
           <version major="4" minor="7" year="2019" month="1"
             day="1"/>
           <configuration>
             <option identifier="SCOOPIXFileName">
               <![CDATA[MySub.ref_six]]></option>
             ...
           </configuration>
         </tool>
       </creators>
     </moduleInfo>
     <codeInfo>
       <constitution mode="sourceCode"/>
       <dateTime kind="created" year="2019" month="5" day="16"
         hour="11" minute="20" second="19"/>
       <target>
         <board vendor="ETAS GmbH" model="INTECRIO Generic
           Experimental Target"/>
         <tool kind="compiler" vendor="GNU Project"
           family="GNU Compiler Collection" name="GNU C Compiler">
           <configuration>
             <optionKind name="macroDefine" prefix="-D"/>
             <optionKind name="includeDirectory" prefix="-I"/>
             <!-- RTW specific defines -->
             <option kind="macroDefine" name="USE_RTMODEL"/>
             <option kind="macroDefine" name="MODEL">
               MySub</option>
             ...
             <!-- RTW specific include directories -->
             <option kind="includeDirectory">
               <![CDATA[{{codeDir}}]]></option>
             ...
             <!-- S-Function specific include directories -->
             <!-- Referenced models local include
               directory -->1)
               ...
```

1) Only present if the referenced model contains another referenced model.

```
          </configuration>
        </tool>
      </target>
    </codeInfo>
    <!-- Model specific files -->
    <fileContainer constitution="sourceCode">
      <pathBase path="{{codeDir}}"/>
      <!-- Model specific source files -->
      <file name="MySub_types.h" kind="header"/>
      <file name="MySub.h" kind="header"/>
      <!-- used through rtwShared.lib: rtwtypes.h -->
      <!-- used through rtwShared.lib: multiword_types.h -->
      <file name="MySub.c" kind="body"/>
      <file name="MySub_private.h" kind="header"/>
      <!-- Additionally registered model specific source files -->
      <file name="rt_sim.c"
        path="{{codeDir}}external\rtw\c\src\" kind="body"/>
      <!-- Target specific libraries -->
      <file name="rtwStaticLib.lib" kind="symbolicLibrary"/>
      <file name="rtwSharedLib.lib" kind="symbolicLibrary"/>
      <!-- Additional files -->
    </fileContainer>
    <fileContainer constitution="referencedModels">
    </fileContainer>
...
```

NOTE

The `<fileContainer constitution="referencedModels">` section in a `*.ref_six` file is always empty, even if the referenced model contains further referenced models.

All links to referenced models are provided in the `*.six` file of the main model.

6.3 Creation of SCOOP-IX and Example

Tools that are either a part of INTECRIO or are coupled to INTECRIO create SCOOP-IX descriptions if C code is created for the integration. In the case of ASCET and MATLAB and Simulink, the SCOOP-IX generation is performed by the respective connectivity tool.

An example for a simple SCOOP-IX file created with ASCET can be found below. The example is used exclusively for representing an interface description in SCOOP-IX, it does not claim to be meaningful or correct.

```
<?xml version="1.0" encoding="iso-8859-1"?>
<!DOCTYPE module [
  <!ENTITY szlig "&#223;">
  <!ENTITY copy "&#169;">
  <!ENTITY baseTypes-asd SYSTEM
    'c:\ETAS\ASCET6.4\Formats\SCOOP-IX\1.2\common\
      baseTypes-asd.xml'>
  ]>
<?xml-stylesheet type="text/xsl" href="c:\ETAS\ASCET6.4\Formats\
  SCOOP-IX\1.2\common\showSCOOP-IX.xsl"?>
<!--
<h1>SCOOP-IX</h1>
<p>
  <strong>Copyright &copy; 2002-2004 ETAS GmbH</strong>
    Borsigstra&szlig;e 14, D-70469 Stuttgart.
    <em>All rights reserved.</em>
</p>
-->
<module
  xmlns="http://www.etas.de/scoop-ix/1.2"
  xmlns:ix="http://www.etas.de/scoop-ix/1.2"
  xmlns:asd="http://www.etas.de/scoop-ix/1.2/modelDomain/ascet"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.etas.de/scoop-ix/1.2
    c:\ETAS\ASCET6.4\Formats\SCOOP-IX\1.2\Schemas\
      scoop-ix-domain-asd.xsd"
  xmlns:html="http://www.w3.org/1999/xhtml" >

  <directoryLocations scheme="ASCET 6.4">
    <directory identifier="integratorDir"
      path="E:\ETAS\INTECRIO5.0\" ></directory>
    <directory identifier="toolDir"
      path="c:\ETAS\ASCET6.4\" ></directory>
    <directory identifier="modelDir"
      path="c:\ETASData\ASCET6.4\Database\INTECRIO\" >
      </directory>
    <directory identifier="codeDir"
      path="c:\ETASData\ASCET6.4\Database\INTECRIO\
      Project\CGen\" ></directory>
  </directoryLocations>

  <moduleInfo identifier="_040VSM3H60001KO7102G5GFA1O5G0">
    <name>ASDSimpleModel</name>
    <modelLink href="asd://{{modelDir}}?Training/
      ASDSimpleModel" ></modelLink>
    <version major="1" minor="0" ></version>
    <dateTime kind="created" year="2011" month="02" day="13"
      hour="15" minute="37" second="04" ></dateTime>
    <dateTime kind="lastModified" year="2011" month="03"
      day="04" hour="17" minute="14" second="44" > </dateTime>
    <completion degree="full" ></completion>
    <suitability>
      <application domain="rapidPrototyping"
        addressesAvailable="true"
        instanceTreeRootIdentifier=
          "_040VSM3H60001KO7102G5GFA1O5G0instance"
        setGetDeltaTIdentifier=
          "__040VSM3H60001KO7102G5GFA1O5G0">
        </application>
    </suitability>
    <company name="ETAS GmbH" department="ETAS/PAC-F1"
      city="Stuttgart" country="Germany" />
    <user lastName="Doe" firstName="John" title="Dr" ></user>
    <creators>
      <user lastName="Doe" firstName="John" title="Dr" ></user>
      <tool kind="modeler" vendor="ETAS GmbH" name="ASCET">
        <version major="6" minor="1" revision="1" ></version>
        <configuration >
          <option identifier="ignoreInternalMessages"
            > false</option>
        </configuration>
      </tool>
      <tool kind="codeGenerator" vendor="ETAS GmbH"
        name="ASCET">
        <version major="6" minor="1" revision="1" >
          </version>
        <mode name="experiment" value="Implementation" ></mode>
        <configuration>
          <option identifier="Code Generator" >
            Implementation Experiment</option>
          <option identifier="Target" >Prototyping</option>
          ...1)
        </configuration>
      </tool>
    </creators>
    <annotation>
      <ix:documentation xmlns="http://www.w3.org/1999/xhtml">
        <p>This is a sample module interface description file.
          It is used for demonstrating an interface
        description in the <b>SCOOP-IX</b> language.</p>
        <p>Neither is its content supposed to make any sense at
          all, nor has its correctness been checked by
          compilation.</p>
      </ix:documentation>
    </annotation>
  </moduleInfo>

  <codeInfo>
    <constitution mode="sourceCode" ></constitution>
    <dateTime kind="created" year="2011" month="02" day="13"
      hour="15" minute="38" second="4" ></dateTime>
    <target>
```

1) A SCOOP-IX file contains all settings from the project properties. For documentation purposes, only the first two are listed.

```
            <processor vendor="Motorola" model="MPC750" ></processor>
            <board vendor="ETAS GmbH" model="Prototyping" ></board>
            <tool kind="compiler" vendor="GNU Project"
              family="GNU Compiler Collection"
              name="GNU C Compiler for Embedded PowerPC target">
              <configuration>
                <optionKind name="macroDefine" prefix="-D">
                  </optionKind>
                <optionKind name="includeDirectory" prefix="-I" >
                  </optionKind>

                <!-- ASCET specific defines -->
                <option kind="macroDefine" name="EXT_INTEGRATION" >
                  </optionKind>

                <!-- ASCET specific include directories -->
                <option kind="includeDirectory">
                  <![CDATA[{{codeDir}}]]></option>
              </configuration>
            </tool>
          </target>
          <target >
            <board vendor="ETAS GmbH" model="INTECRIO Generic
              Experimental Target" >
            </board>
            <tool kind="compiler" vendor="GNU Project"
              family="GNU Compiler Collection"
              name="GNU C Compiler" >
              <configuration >
                <optionKind name="macroDefine" prefix="-D">
                  </optionKind>
                <optionKind name="includeDirectory"prefix="-I" >
                  </optionKind>
                <option kind="macroDefine" name="EXT_INTEGRATION" >
                  </option>
                <option kind="includeDirectory" >
                  <![CDATA[{{codeDir}}]]></option>
              </configuration>
            </tool>
          </target>
        </codeInfo>

        <fileContainer complete="false">
          <pathBase path="{{codeDir}}" ></pathBase>
          <!-- model specific C files -->
          <file name="_asd_pid.c" kind="body" ></file>
          <file name="asdsmpm.c" kind="body" ></file>
          <file name="conf.c" kind="body" ></file>
          <file name="modulem.c" kind="body" ></file>
          <file name="asdsmpm.h" kind="header" ></file>
          <file name="conf.h" kind="header" ></file>
          <file name="modulem.h" kind="header" ></file>
          <!-- additional files -->
          <file name="ASDSimpleModel.a2l"
            content="dataDescription" format="ASAM-2MC"
            formatVersion="1.5" ></file>
        </fileContainer>

        <interface>
          <modelLinkBase href="asd://
            {{modelDir}}?Training/ASDSimpleModel/" >
            </modelLinkBase>

          <pathBase path="{{codeDir}}" ></pathBase>
          <headerFile name="asdsmpm.h" ></headerFile>
          <headerFile name="conf.h" ></headerFile>
          <headerFile name="modulem.h" ></headerFile>
          <usage layoutFamily="asd:standardLayout" ></usage>
          &baseTypes-asd;

          <definitions>
            <conversion name="ident">
              <rationalFunction>
                <numerator bx="1" ></numerator>
                <denominator f="1" ></denominator>
              </rationalFunction>
            </conversion>
          </definitions>

          <dataElement interfaceKind="export">
            <dataCInterface identifier=
              "MODULE_IMPL_ClassObj.Out1->val">
              <type><typeRef name="real64" ></typeRef></type>
              <fileOrigin name="MODULEM.c" ></fileOrigin>
              <initValue value="0.0" ></initValue>
            </dataCInterface>
            <modelOrigin identifier="ASDSimpleModel.Module.Out1">
              <name>Out1</name>
              <modelLink href="Module.Out1" ></modelLink>
              <modelLocation>
                <pathNode name="Module" kind="asd:module">
                  <pathParameter name="asd:implementation"
                    value="Impl" ></pathParameter>
                  <pathParameter name="asd:dataSet" value="Data" >
                    </pathParameter>
                </pathNode>
                <pathNode name="Out1" kind="asd:element" >
                  </pathNode>
              </modelLocation>
              <modelKind kind="message" visibility="public">
                <flowDirection in="false" out="true" >
                  </flowDirection>
              </modelKind>
              <modelType type="continuous" ></modelType>
              <annotation>
                <ix:documentation xmlns=
                  "http://www.w3.org/1999/xhtml" lang="en-US">
                  This is output message <i>Out1</i> of
                    continuous type.
                </ix:documentation>
              </annotation>
            </modelOrigin>
            <implementation>
              <conversionRef name="ident" ></conversionRef>
              <valueRange min="-2147483648" max="2147483647" >
                </valueRange>
              <saturation value="true" resolution="reduce"
                assignment="true" ></saturation>
              <zeroExcluded value="false" ></zeroExcluded>
            </implementation>
            <usage measurement="true" virtual="false"
              variant="false" >
              <address kind="pseudo" >
                <BLOB kind="KP_BLOB" device="E_TARGET" >
                  <![CDATA[2 1001 1 1001 1]]></BLOB>
              </address>
            </usage>
          </dataElement>

          <dataElement interfaceKind="export">
            <dataCInterface identifier=
              "ASDSIMPLEMODEL_IMPL_ClassObj.Module->
              myProduct->val">
              <type><typeRef name="sint32" ></typeRef></type>
              <fileOrigin name="MODULEM.c" ></fileOrigin>
              <initValue value="0" ></initValue>
            </dataCInterface>
            <modelOrigin identifier=
              "ASDSimpleModel.Module.myProduct">
              <name>myProduct</name>
              <modelLink href="ASDSimpleModel.Module.myProduct" >
                </modelLink>
              <modelLocation>
                <pathNode name="Module" kind="asd:module">
                  <pathParameter name="asd:implementation"
                    value="Impl" ></pathParameter>
                  <pathParameter name="asd:dataSet"
                    value="Data" ></pathParameter>
                </pathNode>
                <pathNode name="myProduct" kind="asd:element" >
                  </pathNode>
              </modelLocation>
              <modelKind kind="variable" visibility="private" >
                </modelKind>
              <modelType type="continuous" >
                <valueRange min="-2147483648.0" max="2147483647.0" >
                  </valueRange>
              </modelType>
              <annotation>
                <ix:documentation xmlns=
                  "http://www.w3.org/1999/xhtml" lang="en-US">
                  This is variable <i>myProduct</i> of
                    continuous type.
                </ix:documentation>
              </annotation>
            </modelOrigin>
            <implementation>
              <conversionRef name="ident" ></conversionRef>
              <valueRange min="-2147483648" max="2147483647">
                </valueRange>
              <saturation value="true" resolution="reduce"
                assignment="true" ></saturation>
              <zeroExcluded value="false" ></zeroExcluded>
            </implementation>
            <usage measurement="true" virtual="false"
              variant="false" >
              <address kind="pseudo" >
                <BLOB kind="KP_BLOB" device="E_TARGET" >
                  <![CDATA[2 1001 1 1000 0]]></BLOB>
              </address>
            </usage>
          </dataElement>

          <dataElement interfaceKind="export">
            <dataCInterface identifier=
              "ASDSIMPLEMODEL_IMPL_ClassObj.Module->myPar->val">
              <type><typeRef name="real64" ></typeRef></type>
              <fileOrigin name="MODULEM.c" lines="23" > </fileOrigin>
              <initValue value="3.2" />
            </dataCInterface>
            <modelOrigin identifier="ASDSimpleModel.Module.myPar">
              <name>myPar</name>
              <modelLink href="ASDSimpleModel.Module.myPar">
                </modelLink>
              <modelLocation>
                <pathNode name="Module" kind="asd:module">
                  <pathParameter name=
                    "asd:implementation" value="Impl" >
                    </pathParameter>
                  <pathParameter name="asd:dataSet" value="Data" >
                    </pathParameter>
                </pathNode>
                <pathNode name="myPar"
                  kind="asd:element" ></pathNode>
              </modelLocation>
              <modelKind kind="parameter" visibility="private" >
                </modelKind>
              <modelType type="continuous" ></modelType>
              <annotation>
                <ix:documentation xmlns=
                  "http://www.w3.org/1999/xhtml" lang="en-US">
                  This is parameter <i>myPar</i> of continuous type.
                </ix:documentation>
              </annotation>
            </modelOrigin>
            <implementation>
              <conversionRef name="ident" ></conversionRef>
              <valueRange min="-1.e+037" max="1.e+037" >
                </valueRange>
              <zeroExcluded value="false" ></zeroExcluded>
            </implementation>
            <usage calibration="true" virtual="false"
              variant="false" >
              <address kind="pseudo" >
                <BLOB kind="KP_BLOB" device="E_TARGET"
                  ><![CDATA[2 1001 1 1000 1]]></BLOB>
              </address>
            </usage>
          </dataElement>

          <functionElement interfaceKind="export">
            <functionCInterface identifier="MODULE_IMPL_compute">
              <signature>
                <return>
                  <type><void /></type>
                </return>
                <void />
              </signature>
              <fileOrigin name="MODULEM.c" ></fileOrigin>
            </functionCInterface>
            <modelOrigin identifier="Module.compute">
              <name>compute</name>
              <modelLink href="Module.compute" />
              <modelLocation>
                <pathNode name="Module" kind="asd:module">
                  <pathParameter name="asd:implementation"
                    value="Impl" ></pathParameter>
```

```
                <pathParameter name="asd:dataSet" value="Data" >
                  </pathParameter>
              </pathNode>
              <pathNode name="compute" kind="asd:process" >
                </pathNode>
            </modelLocation>
            <modelKind kind="process" visibility="public" >
              </modelKind>
            <runTimeInfo>
              <FPUUsage value="true" ></FPUUsage>
              <TerminateTaskUsage value="false" >
                </TerminateTaskUsage>
              <messageAccess>
                <message identifier=
                  "MODULE_IMPL_ClassObj.Out1->val" send="true" >
                  </message>
              </messageAccess>
              <resourceAccess ></resourceAccess>
              <constraint>
                <period value="0.01" ></period>
                <execution trigger="timer" priority="0">
                  </execution>
                <scheduling mode="preemptive" > </scheduling>
              </constraint>
            </runTimeInfo>
            <annotation>
              <ix:documentation xmlns=
                "http://www.w3.org/1999/xhtml">
                This is process <i>compute</i> of module
                  <i>Module</i>.
              </ix:documentation>
            </annotation>
          </modelOrigin>
        </functionElement>
      </interface>
    </module>
```

7 Modeling Hints

This chapter provides an overview of the modeling philosophy of INTECRIO and describes how the behavioral modeling tools are used in conjunction with INTECRIO.

This chapter does *not* intend to provide the complete instructions for creating an effective executable model.

7.1 Modeling for INTECRIO

If you create a model to be integrated with INTECRIO, the model itself does not contain any target-dependent information. The configuration of the operating system and the hardware configuration (e.g. assignment of processes to tasks or mapping of signals to a CAN frame) are performed with INTECRIO.

A software module is the unit that can be imported in INTECRIO. It corresponds exactly to one SCOOP-IX description. In Simulink, this unit is a complete model that can contain any number of subsystems. As a special case, you can also generate code for a subsystem. This is treated as if it were a complete model. In ASCET, a complete project is considered to be the unit that can be imported. It can contain any number of classes and modules.

Several models can be imported in INTECRIO as software modules. The inputs and outputs can be connected with each other and with physical I/O systems. These connections can be changed dynamically, i.e. during the running experiment. A limitation is that these connections must be scalar. Vector connections can be measured as a whole, but only connected element by element in INTECRIO.

Several software modules with their connections, a hardware system and an OS configuration form a system project – the unit for which INTECRIO can generate executable code (an `*.a2l.cod` file).

7.2 Modeling with Simulink®

MATLAB and Simulink connectivity (see section 5.1) supports MATLAB® and Simulink® with versions R2016a – R2022a and their related service packs known at the time of the INTECRIO V5.0 release.

Unsupported MATLAB and Simulink versions cannot be used to create code for use with INTECRIO.

Model code created with MATLAB and Simulink R2006b – R2015b can still be imported and integrated in INTECRIO V5.0.

During the installation of MATLAB and Simulink connectivity, the MATLAB and Simulink installation is adjusted so that MATLAB and Simulink can interact with INTECRIO.

The following functions offered by Simulink and MATLAB® Coder™ + Simulink® Coder™ (+ Embedded Coder®) are supported:

- Almost all of the blocks supplied with Simulink

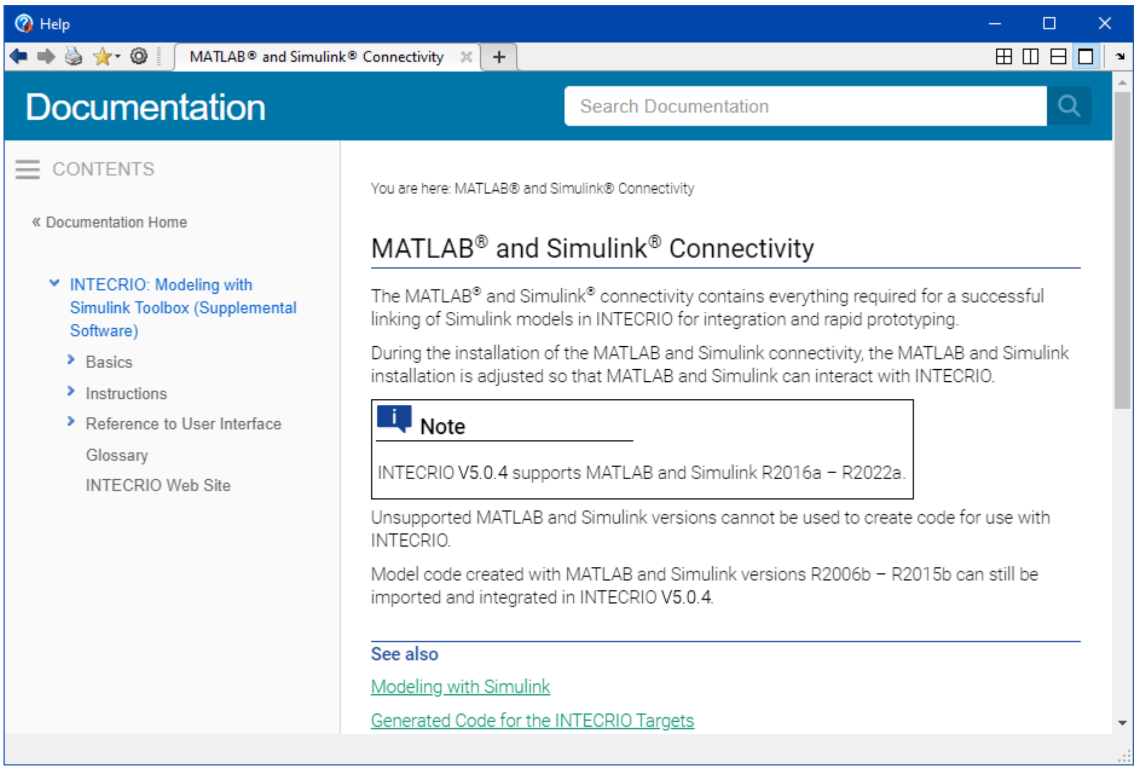
  (except the blocks `To File`, `From File`, `To Workspace` and `From Workspace` because they are not directly applicable to rapid prototyping targets)

  Only 1-D and 2-D lookup tables (but no higher-dimensional lookup tables) can be available as curve or map CHARACTERISTIC elements in the ASAM-MCD-2MC file.
- Different scanning times
- Single-tasking or multitasking (see Simulink documentation)
- Models containing continuous states (as well as all integration methods with fixed step size)
- Inlining of parameters and all the remaining optimizations offered by MATLAB Coder + Simulink Coder (+ Embedded Coder)
- The model verification blocks supplied with Simulink (model verification at runtime)
- Full fixed-point support (any data types with random scaling)
- User-defined S functions (no inlining, wrapper inlining, full inlining)
- Models with Stateflow® diagrams
- External mode
- Referenced models

Modeling with Simulink for INTECRIO is based on the MATLAB Coder + Simulink Coder/Embedded Coder code generation. By providing the *INTECRIO Real-Time Target* (IRT) and the *INTECRIO Embedded Coder Real-Time Target* (IER), code generation can be adjusted to the requirements of INTECRIO. During the installation of the MATLAB and Simulink interfacing, the path to the IRT or IER and to INTECRIO-specific blocks are added to the MATLAB path settings of he user.

Modeling is carried out according to the instructions in the documentation of Simulink, MATLAB Coder, Simulink Coder, and Embedded Coder, only target-dependent blocks of third parties must be avoided. IRT or IER must be selected as the target for the code generation.

Details about modeling with MATLAB and Simulink and about the joint use of MATLAB and Simulink and INTECRIO can be found in the INTECRIO section in the MATLAB and Simulink online help viewer.


Help
MATLAB® and Simulink® Connectivity
Documentation
Search Documentation
CONTENTS
« Documentation Home
INTECRIO: Modeling with Simulink Toolbox (Supplemental Software)
Basics
Instructions
Reference to User Interface
Glossary
INTECRIO Web Site

You are here: MATLAB® and Simulink® Connectivity

MATLAB® and Simulink® Connectivity

The MATLAB® and Simulink® connectivity contains everything required for a successful linking of Simulink models in INTECRIO for integration and rapid prototyping.

During the installation of the MATLAB and Simulink connectivity, the MATLAB and Simulink installation is adjusted so that MATLAB and Simulink can interact with INTECRIO.

Note

INTECRIO V5.0.4 supports MATLAB and Simulink R2016a – R2022a.

Unsupported MATLAB and Simulink versions cannot be used to create code for use with INTECRIO.

Model code created with MATLAB and Simulink versions R2006b – R2015b can still be imported and integrated in INTECRIO V5.0.4.

See also

Modeling with Simulink

Generated Code for the INTECRIO Targets

7.3 Modeling with ASCET

An ASCET project is considered to be the unit that is imported in INTECRIO. The OS configuration can partly be performed in ASCET, although this is not mandatory.

Details about modeling with ASCET and about the joint use of ASCET and INTECRIO can be found in the ASCET online help (V6.3 and higher) or in the INTECRIO-ASC and ASCET-RP documentation (V6.2 and lower).

7.4 Integration of User Code

If you want to import code in INTECRIO that is written by the user, a SCOOP-IX description must be created manually. It must contain the necessary include instructions as well as descriptions of the processes and values that you want to measure and calibrate.

8 Bypass Concept

8.1 ETK Bypass Concept Description

With an ETK equipped ECU, the ECU code must be prepared to set up data structures and communication with the ETK to enable communication between the rapid prototyping system used for the ETK bypass and the ECU itself.

Independent of the ECU implementation of these drivers, some safety issues common to the concept of the bypass must be considered.

8.2 Bypass Input

Like for measurement, the Distab13 (and Distab12 for hook-based bypass) mechanism is used to provide ECU variables as inputs for the bypass.

The DISplay TABle for the Distab13 contains a sorted list of addresses of variables in the ETK Flash. 8, 4, 2 and 1 byte values are supported. The addresses are ordered corresponding to the size of the values they point to. The ECU driver parses the table and writes the contents of the addresses to a table of return values in the ETK RAM. This table is ordered in the same manner as the address list: first, all 8 byte values, then the 4 byte values, etc.

With this approach, INCA and INTECRIO are given access to values of the internal memory of the microcontroller. Also, collecting the data in a table allows using block modes for transferring the data to the PC.

Fig. 8-1 gives an overview on the data layout for Distab13.

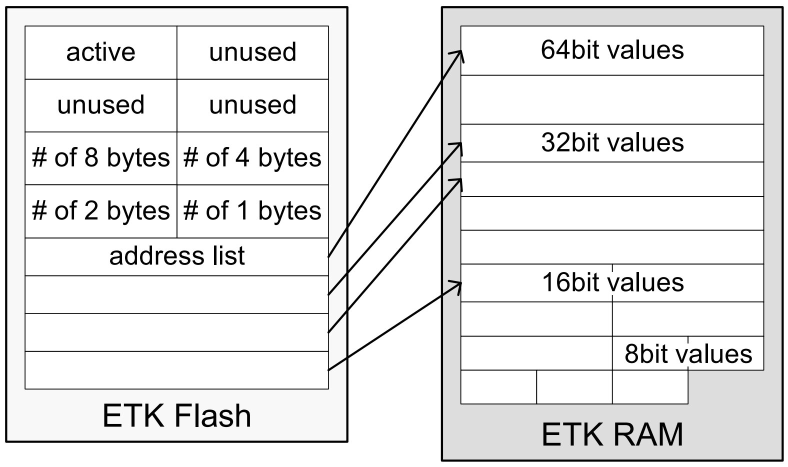


Fig. 8-1 Distab13 data structure

For each bypass raster that contains hooks for the hook-based bypass, an instance of the Distab is created and a Distab process is called. For the service-based bypass, one instance of the Distab data structure exists for each trigger where a service is provided and configured to read ECU values as input for the bypass calculation.

For the hook-based bypass, the number and name of Distabs implemented in the ECU code, and their size, e.g. the number of bytes per channel, is set by the ECU software setup and documented in the A2L description.

For service-based bypass, all tables are allocated dynamically in a given working memory.

8.3 Hook-Based Bypass

Classical

For the classical *hook-based bypass*, the input values of the bypass are gathered with the same Distab13 mechanism as the measurements. After the bypass input data is written to the ETK RAM, the bypass calculation is triggered. In addition, a channel for writing back bypass results to the ETK where they can be retrieved by the ECU is introduced.

For each bypass input channel, an output channel is provided. The size of these channels, as well as their names, also have to be documented in the A2L description. The prototyping tool (INTECRIO, INTECRIO-RLINK or ASCET-RP) can define the number of variables written back to the ECU, depending on the bypass experiment setup. Each variable written to by the bypass must be prepared in the ECU software by applying a hook to prevent the ECU from writing to this value if the bypass is active. The hook code is specific to the ECU and the variable it is applied to. No service is provided within this sample implementation for this task. The values prepared have to be documented in the A2L file by an `IF_DATA ASAP1B_BYPASS` description.

The following figure describes the hook-based bypass principle. The hook indicates the possibility to toggle between the results of the original function (Fn) and the bypass function (Fn*).

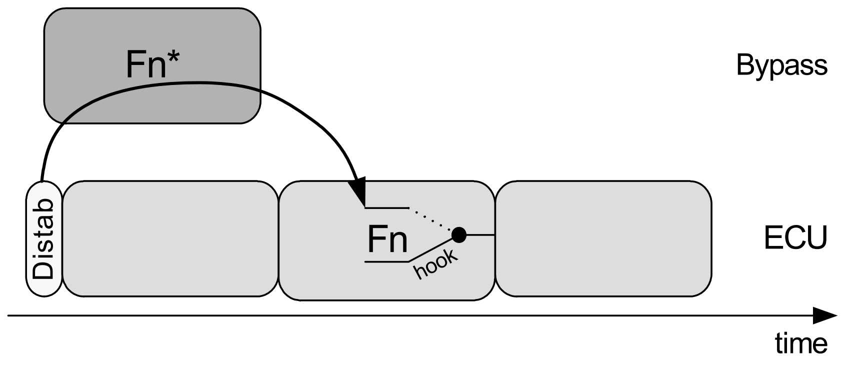


Fig. 8-2 Hook-Based Bypass: Principle

With Distab17

In connection with Distab17, the concept of service point configuration extends to the hook-based bypass. In this case, the hook-based bypass (HBB) is integrated with the service-based bypass (SBB): For hooked service points, the new signal values calculated in the rapid prototyping system are transferred to the ECU software by dedicated hook codes in the ECU functions instead of generically in a service point write action. Hooked service points are supported as of Distab17.

- In the following illustration, **Fn** denotes the original function that runs on the ECU.

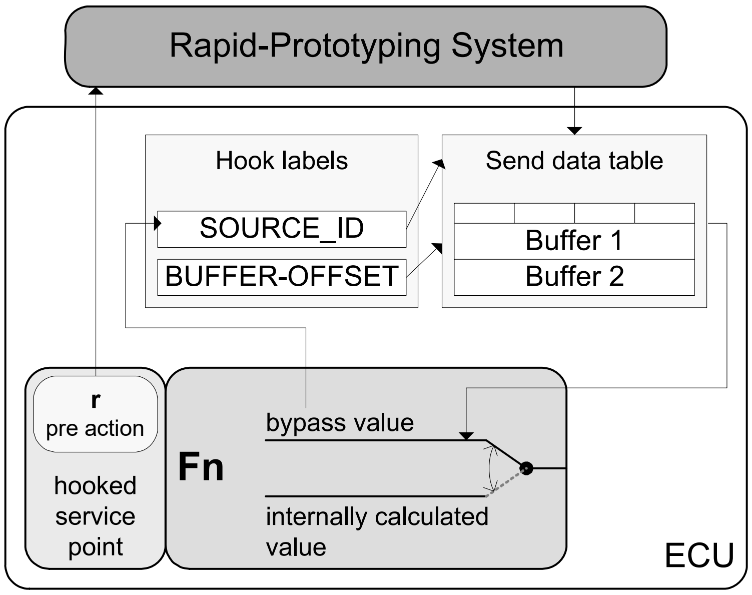


Fig. 8-3 Bypass with hooked service points

- Prior to the execution of the original function that runs on the ECU, hooked service points can be used to receive data from the ECU to the rapid prototyping system via a read or receive pre-action. The associated hook codes are usually implemented at the end of the original function. The hooks receive their source (i.e. SOURCE_ID) and offset (i.e. BUFFER_OFFSET) information from the associated hook labels.
- During the execution of the original function in the ECU, the rapid prototyping system writes data to a double-buffered send data table that can be accessed by these hooks in the original function. The two buffers are used alternately. Either the resulting bypass value or the value calculated internally by the original function is used.

8.4 Service-Based Bypass

NOTE

Service-based bypass on an ETK with 8 Mbit/s is not supported.

For the *service-based bypass*, both the input values and the output values of the bypass function are transmitted with the same Distab13 mechanism. After the bypass input data is written to the ETK RAM, the bypass calculation is triggered. In addition, a channel for writing back bypass results to the ETK where they can be retrieved by the ECU is introduced. Here, each bypassed ECU process uses and calls its own Distab.

This service also contains an inverted Distab mechanism to write back bypass outputs to the ECU. The ECU does not need to apply hooks to the variables written to, since the service simply overwrites the values with the bypass outputs. INTECRIO sets up a Distab-like sorted address table with the addresses of the ECU variables to be written to, and writes the corresponding values in a table of the ETK Flash. The part of the ECU service that writes the bypass outputs to the ECU parses the address table and gets the corresponding values from the data table and writes the values to the ECU addresses.

The following figure describes the service-based bypass principle.

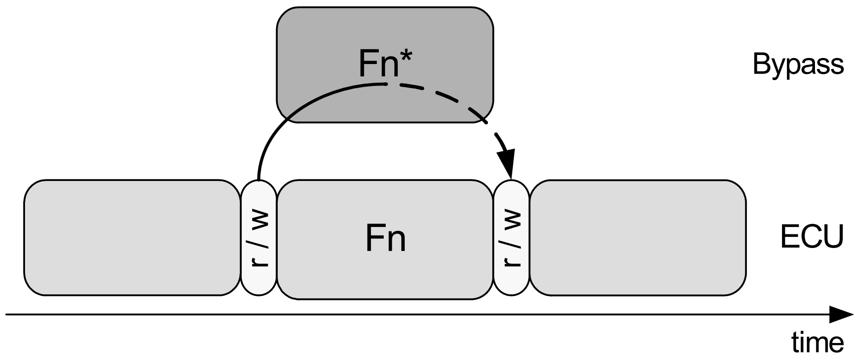


Fig. 8-4 Service-Based Bypass: Principle (The dashed line indicates that bypass data can be written back at a later time as well.)

INTECRIO V5.0 supports several versions of service-based bypass (SBB). Tab. 8-1 lists the supported SBB versions for each target (+: supported, –: not supported), and Tab. 8-2 lists the AML versions available in the SBB versions.

	SBB V2.0	**SBB V2.1**	**SBB V3.***
ES 910.2 / supported ETKs	+	+	–
ES 910.3 / supported ETKs	+	+	+
ES 8xx / supported ETKs	+	+	+

NOTE

Service-based bypass on an ETK with 8 Mbit/s is not supported.

Tab. 8-1 Supported SBB versions

SBB version	**supported AML versions**		**supported Distab types**
V2.0 + V3.0	ETK AML	1.2.0 – 1.7.0	Distab13 - Distab16
	XETK AML	≥ 1.0.0	
	SBB AML	≥ 2.0.0	
V2.1	ETK AML	not supported	Distab17
	XETK AML	≥ 2.0.0	
	SBB AML	≥ 3.1.1	
V3.1	ETK AML	not supported	Distab17
	XETK AML	≥ 2.0.0	
	SBB AML	≥ 3.1.0	

Tab. 8-2 SBB versions and AML versions

8.5 Bypass Safety Considerations

With calculating a bypass function on a rapid prototyping system and feeding data back into the ECU, the same care needs to be taken for development and use of bypass software as for ECU software. The bypass output may directly or indirectly influence the output channels of the ECU. The same applies, of course, if the rapid prototyping system uses own output channels.

Thus, it is highly recommended that the bypass functions include range checks and validations algorithms for the bypass outputs.

8.5.1 Bypass Input Data

To perform proper calculations, the bypass obviously needs consistent and valid input data. The ECU software must ensure this and prevent activation of the bypass if the ECU software detects incorrect or invalid inputs. This also includes ECU states like initialization and afterrun, or error modes the ECU might run in. In other words, activation of and data transfer to the bypass must be covered by the safety mechanisms of the ECU.

8.5.2 Bypass Calculation

The ECU software must be aware whether the bypass is active and must provide measures to react on bypass failures, for example missing calculations or unexpected shut off of the bypass system.

Failsafe measures might be using the alternative output values of the bypassed ECU functions, using constant fallback values, or even resetting the ECU, depending on the bypassed ECU function. This is entirely under responsibility of the ECU provider who integrates the bypass drivers.

Some implementations of the ECU bypass drivers, as for the service-based bypass, allow the deactivation of the bypassed ECU function by the bypass user. In this case, the results of the bypassed ECU function obviously cannot be used as fallback. This must be considered when setting up a safety strategy.

8.5.3 Bypass Output Data

The ECU provider must guarantee that any value sent back by the bypass system leads to a predictable behavior of the ECU – the bypass output values must undergo the same range check and validation as the values calculated within the bypass.

As said before, the implementation of the ECU drivers must, in any case, ensure that bypass failures can be detected by the ECU and valid and safe fallback values are available at any time.

8.5.4 Message Copies

If the ECU software contains message copies, the bypass must be aware of them.

The usual implementations of the *hook-based bypass* are an exception to that rule. Here, the hooks (and thus the messages written to) are known before compilation, so that the hook code can take care of and use message copies if needed—individual code and addresses are used at each hook.

With the *service-based bypass*, users cannot choose variables and decide which message to write to before they set up the bypass experiment in INTECRIO. Thus, the services in the ECU are generic code and do not know about specific message copies.

This requires two steps:

A The ECU software provider must provide this message copy information in the A2L file (usually in encrypted and password-protected form).

B If the message copy information is encrypted, the user of the bypass system receives a password from the ECU software provider. He must enter this password to decrypt the information and use it for system configuration.

If one of these two steps is missing (usually a wrong password is entered), the bypass system has no knowledge of message copies and reads from / writes to the original variable address, as it is declared in the `MEASUREMENT` declaration of the A2L file. For receive variables, this yields old data values. For send variables, the data value written by the bypass model may be overwritten by other parts of the ECU software. Both cases may cause bypass malfunction!

Another principal problem can arise with ECU software that contains message copies. The original code to create the message copies for an ECU task was based on the given message usage and generated appropriate code. By writing variable values into the ECU via bypass methods, the data flow changes, and a new or different message copy may become necessary. This can result in wrong variable values in the ECU software even at locations which are not directly related to the bypassed functions. Whether writing to a certain variable at a certain location (e.g. service point) may be dangerous or not, can be answered only by the ECU software supplier. This information cannot be declared in the A2L file.

8.6 Service-Based Bypass Specifics

Unlike the hook-based bypass where either the ECU or the bypass writes to the bypassed variable, the service-based bypass has an inherent possibility of data inconsistency, since both the ECU and the bypass write to the same value consecutively. Due to ECU real-time constraints, interrupts cannot be disabled to protect the sequence of writing the results of the ECU function and then writing the variable values of the bypass.

So, if a preemptive task of higher priority interrupts the tasks containing the bypass service, it will see the ECU value instead of the bypass value. The probability of this inconsistency depends on the distance between the two writes.

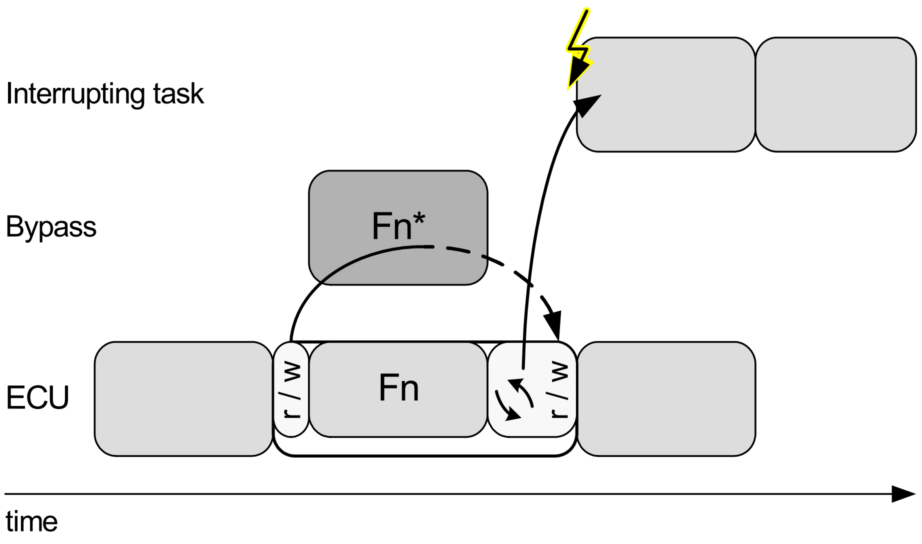


Fig. 8-5 Possible data inconsistency (the small arrows (⟳) indicate a waiting time for bypass results)

A countermeasure to this problem is disabling the ECU function, so that only the bypass is writing to the bypassed ECU values (see below). Be aware that disabling the ECU function implies other safety constraints in case of bypass failures as discussed below.

8.6.1 Service Processes for the SBB Implemented as Service Functions

For SBB, the way of ECU implementation is to replace the ECU process to be bypassed by a container process that contains service function calls before and after it calls the original ECU process. This allows to call the ECU process under certain conditions only, e.g. to deactivate it in case of possible data consistency problems. To simulate the timing behavior of the disabled ECU process, a delay time can be configured.

Therefore, the suggested ECU implementation looks like this:

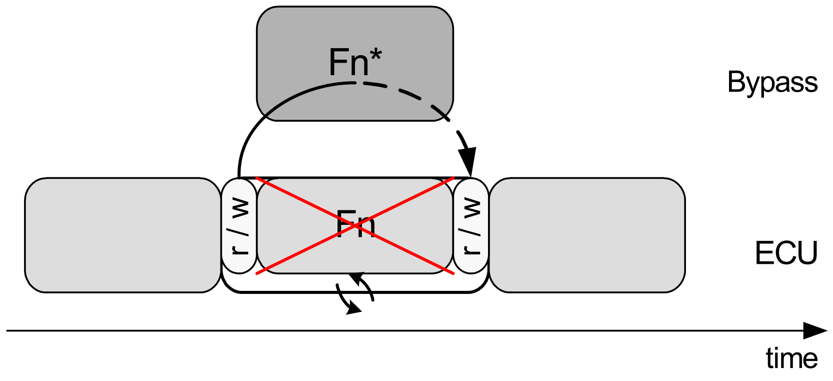


Fig. 8-6 Suggested SBB implementation

For setting up the bypass experiment in INTECRIO and implementing the service point in the ECU software as container process, a service point is defined as

A receiving data from the ECU (pre read action),
B waiting for data to be sent (a time-out is defined),
C sending data to the ECU (pre write action),
D conditionally executing the original ECU process,
E receiving data from the ECU (post read action),
F waiting for data to be sent (a time-out is defined),
G sending data to the ECU (post write action).

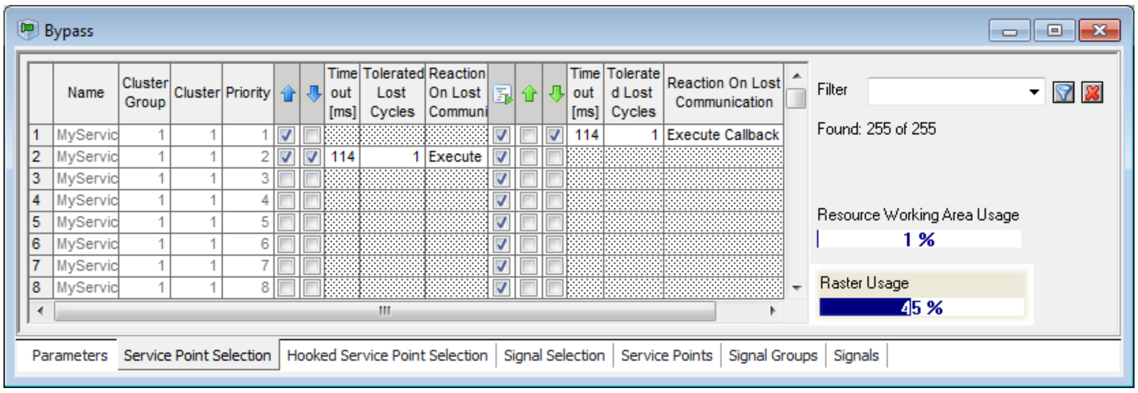
Each pre and post action can be freely configured or activated / deactivated.

8.6.2 Controlling the ECU Behavior from INTECRIO

Upon setting up the INTECRIO experiment, an initial setting of the control variables can be done in INTECRIO. These values are written to the ETK on experiment initialization.

The ECU function can be controlled by the INTECRIO user in several ways (if the ECU drivers also provide this functionality):

- The ECU function can be deactivated in the service point editor of INTECRIO (column, see Fig. 8-7)
- The detection of a bypass error can be defined
- The bypass error behavior of the ECU code can be influenced



Bypass

	Name	Cluster Group	Cluster	Priority	↑	↓	Time out [ms]	Tolerated Lost Cycles	Reaction On Lost Communi		↑	↓	Time out [ms]	Tolerate d Lost Cycles	Reaction On Lost Communication
1	MyServic	1	1	1	✓	☐				✓	☐	✓	114	1	Execute Callback
2	MyServic	1	1	2	✓	✓	114	1	Execute	✓	☐	☐			
3	MyServic	1	1	3	☐	☐				✓	☐	☐			
4	MyServic	1	1	4	☐	☐				✓	☐	☐			
5	MyServic	1	1	5	☐	☐				✓	☐	☐			
6	MyServic	1	1	6	☐	☐				✓	☐	☐			
7	MyServic	1	1	7	☐	☐				✓	☐	☐			
8	MyServic	1	1	8	☐	☐				✓	☐	☐			

Filter

Found: 255 of 255

Resource Working Area Usage
1 %

Raster Usage
45 %

Fig. 8-7 Controlling ECU function execution from INTECRIO (The columns "Cluster Group" and "Cluster" are only available for SBB V3.*. The "Raster Usage" display is only available for SBB V2.*.)

8.6.3 OS Configuration for Service-Based Bypass V3

This section explains some ways how to configure the operating system for a system project with service-based bypass V3.

8.6.3.1 Restrictions

The following restrictions are valid for OS configuration of a system project with service-based bypass V3:

- A read action (represented by a receive signal group,) is allowed only in an INTECRIO software task where the read action is mapped both as action and as event.

  Since an event can be mapped to only one task, this means that a read action can be mapped to only one INTECRIO software task.
- Read actions cannot be assigned to timer, init, or exit tasks, or ISR.
- Up to 247 read actions (255 minus 8 reserved for internal use) can be used per INTECRIO task priority and thus per ETK trigger.
- The currently used RTA-OSEK restricts the number of tasks available for service-based bypass to a maximum of 253 (the total number of available tasks is 256, and 3 system-internal tasks are necessary in any case).
- No restrictions apply to write actions (represented by send signal groups,).
  - Write actions can be mapped to all kinds of tasks (software, timer, init, exit, ISR).
  - A single INTECRIO task can contain write actions from different service points in different service point clusters.

Fig. 8-10 shows an example for an INTECRIO task that contains one read action and several write actions from various ECU tasks.

8.6.3.2 Classical ECU Function Bypass

In a classical ECU function bypass, the pre read action and the post write action of a service point are activated. Both actions are mapped to the same INTECRIO task.

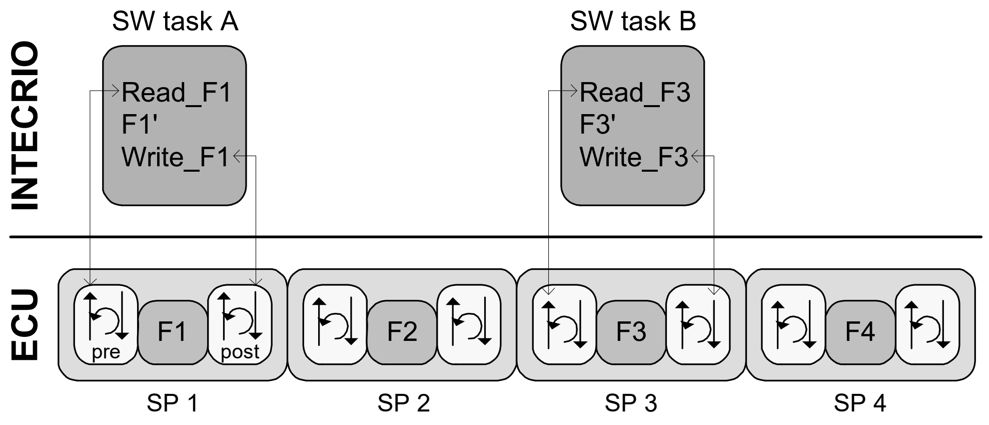


Fig. 8-8 Example: classical bypass

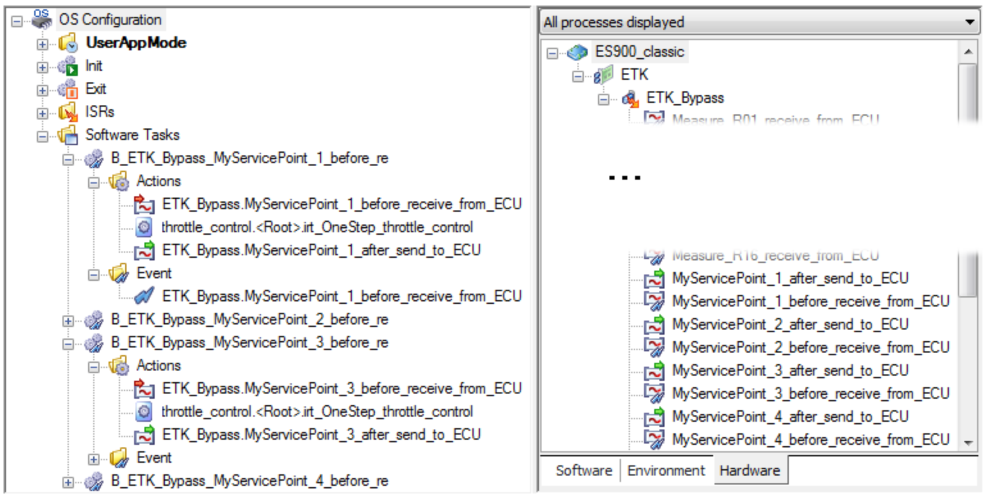
To achieve this kind of OS configuration, the following steps are required:

A Use the **Auto Mapping** feature of the OSC as a starting point.

  With that, actions from different service points are mapped to different software tasks, and appropriate events are assigned. Software processes are mapped to timer, init or exit tasks.

B In the OSC, move the software processes that replaces the ECU function of a certain service point to the INTECRIO software task that contains read and write action of that service point.

C Remove empty tasks from the OS Configuration (optional).



```
OS Configuration
  UserAppMode
  Init
  Exit
  ISRs
  Software Tasks
    B_ETK_Bypass_MyServicePoint_1_before_re
      Actions
        ETK_Bypass.MyServicePoint_1_before_receive_from_ECU
        throttle_control.<Root>.irt_OneStep_throttle_control
        ETK_Bypass.MyServicePoint_1_after_send_to_ECU
      Event
        ETK_Bypass.MyServicePoint_1_before_receive_from_ECU
    B_ETK_Bypass_MyServicePoint_2_before_re
    B_ETK_Bypass_MyServicePoint_3_before_re
      Actions
        ETK_Bypass.MyServicePoint_3_before_receive_from_ECU
        throttle_control.<Root>.irt_OneStep_throttle_control
        ETK_Bypass.MyServicePoint_3_after_send_to_ECU
      Event
    B_ETK_Bypass_MyServicePoint_4_before_re
```

```
All processes displayed
ES900_classic
  ETK
    ETK_Bypass
      Measure_R01_receive_from_ECU
...
      Measure_R16_receive_from_ECU
      MyServicePoint_1_after_send_to_ECU
      MyServicePoint_1_before_receive_from_ECU
      MyServicePoint_2_after_send_to_ECU
      MyServicePoint_2_before_receive_from_ECU
      MyServicePoint_3_after_send_to_ECU
      MyServicePoint_3_before_receive_from_ECU
      MyServicePoint_4_after_send_to_ECU
      MyServicePoint_4_before_receive_from_ECU
Software | Environment | Hardware
```

Fig. 8-9 OS configuration for a classical ECU function bypass

8.6.3.3 Bypass of an Entire ECU Functionality

One INTECRIO task may contain pre and post write actions from different service points and ECU tasks. This can be used to bypass the entire ECU functionality (consisting of several processes in different ECU tasks), which minimizes the number of interrupts and thus latency. Read signals are not updated while the task runs on the rapid prototyping target. Partial results are sent to the ECU as fast as possible to ensure the currency of the values of other functions.

In the example shown in Fig. 8-10, service points SP 1 and SP 2 belong to a high-priority ECU task A. Service point SP 3 belongs to a medium-priority ECU task B. Service point SP n belongs to a low-priority ECU task C. The read action of SP 1 and the write actions of all service points are assigned to the same INTECRIO software task.

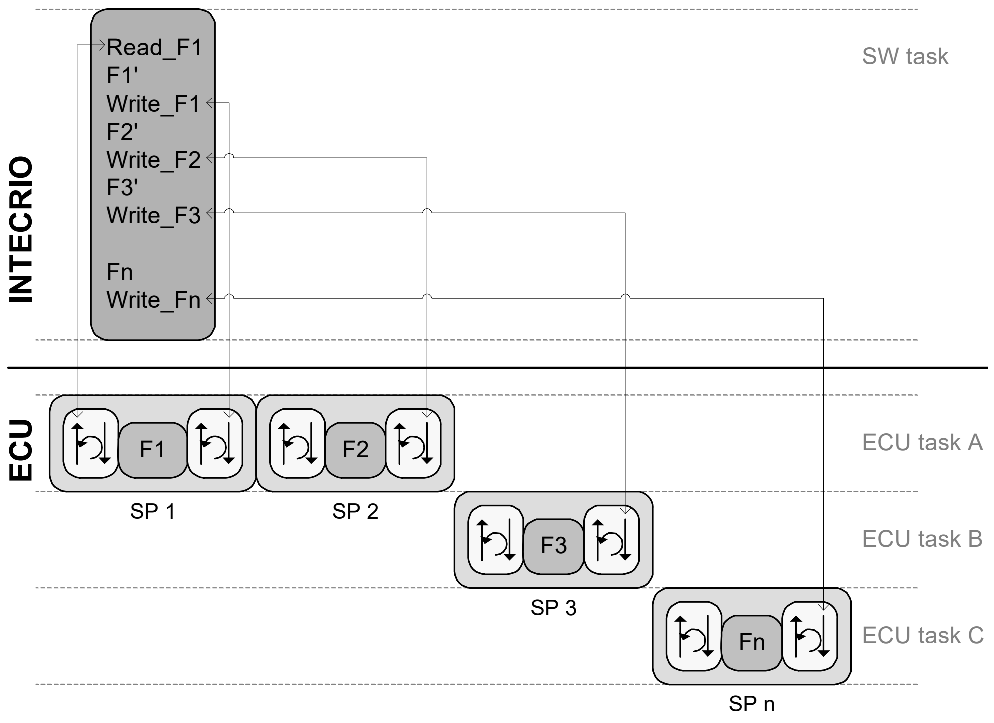


Fig. 8-10 Example: Bypass of an entire ECU functionality

To achieve this kind of OS configuration, the following steps are required:

A Use the **Auto Mapping** feature of the OSC as a starting point.

With that, actions from different service points are mapped to different software tasks, and appropriate events are assigned. Software processes are mapped to timer, init or exit tasks.

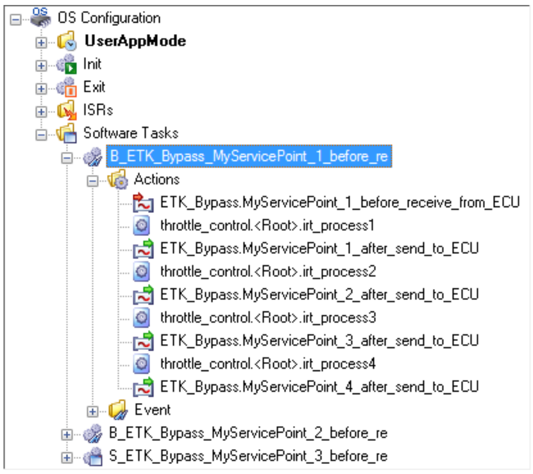
B In the OSC, move the write actions (i.e. send signal groups) from the fastest timer task, where they were mapped automatically, to the INTECRIO software task that contains the read action of SP 1.

You may use the "Hardware" tab of the OSC to search for a particular signal group, and the **Search** context menu of the group to locate it in the OS configuration tree view.

C Move the software processes to the same INTECRIO software task as the write actions.

You may use the "Software" tab of the OSC to search for a particular process, and the **Search** context menu of the process to locate it in the OS configuration tree view.

D Remove empty tasks from the OS Configuration (optional).



```
OS Configuration
  UserAppMode
  Init
  Exit
  ISRs
  Software Tasks
    B_ETK_Bypass_MyServicePoint_1_before_re
      Actions
        ETK_Bypass.MyServicePoint_1_before_receive_from_ECU
        throttle_control.<Root>.irt_process1
        ETK_Bypass.MyServicePoint_1_after_send_to_ECU
        throttle_control.<Root>.irt_process2
        ETK_Bypass.MyServicePoint_2_after_send_to_ECU
        throttle_control.<Root>.irt_process3
        ETK_Bypass.MyServicePoint_3_after_send_to_ECU
        throttle_control.<Root>.irt_process4
        ETK_Bypass.MyServicePoint_4_after_send_to_ECU
      Event
    B_ETK_Bypass_MyServicePoint_2_before_re
    S_ETK_Bypass_MyServicePoint_3_before_re
```

Fig. 8-11 OS configuration for the bypass of an entire ECU functionality

8.6.3.4 Read and Write Actions of the Same Service Point in Different Rasters

The read action and the write action of the same service point can be configured independently, they can be assigned to different tasks with different events or periodicities.

Fig. 8-12 shows two examples. On the left (A), a higher-priority model task is assigned a higher ETK raster priority for the write action. On the right (B), a lower priority model task is assigned a lower ETK raster priority for the write action.

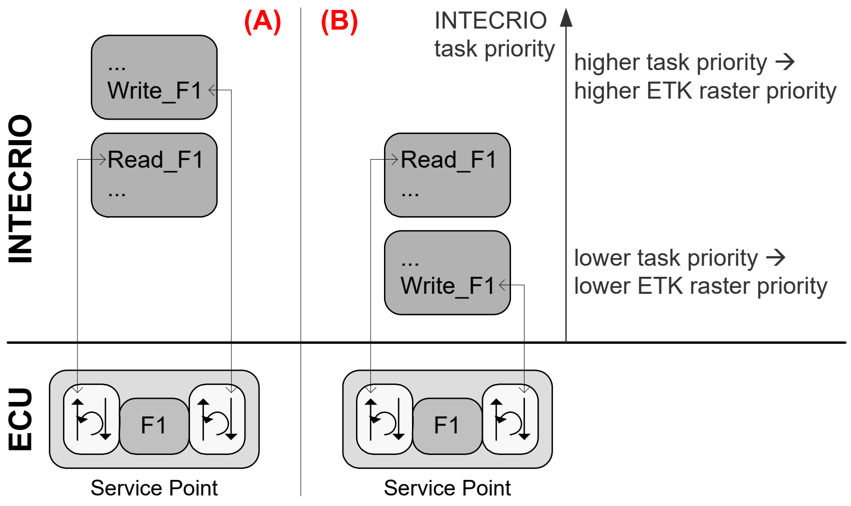

(A)
(B)
INTECRIO task priority
higher task priority → higher ETK raster priority
lower task priority → lower ETK raster priority
INTECRIO
... Write_F1
Read_F1 ...
ECU
F1
Service Point

Fig. 8-12 Examples: Read and Write actions in different rasters

To achieve this kind of OS configuration, the following steps are required:

A For a given service point, activate one read action and a write action after the read action.

B Manual configuration:

- Create a software task with appropriate priority, assign the read action to the `Actions` folder and the event of the read action to the `Events` folder of this task.

- Create another task (e.g., a timer task) with appropriate priority and assign the write action to the `Actions` folder of this task.

Or

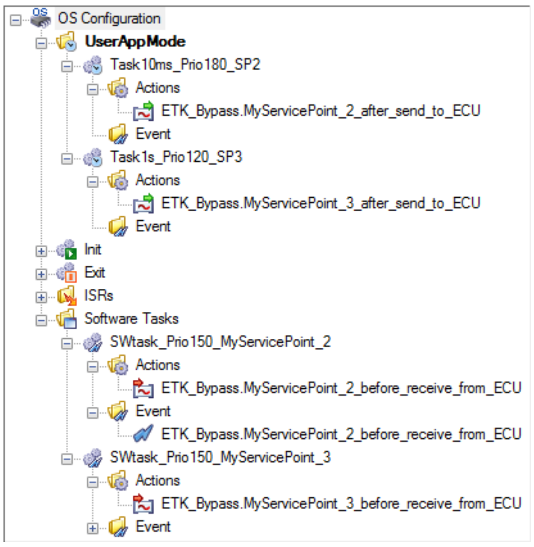
C Use the **Auto Mapping** feature of the OSC as a starting point:

- Perform **Auto Mapping**.

  Auto Mapping maps both actions of the service point to the same software task.
- Move the write action to the INTECRIO task you want to use.

D Map the software processes to appropriate tasks.

E Remove empty tasks from the OS Configuration (optional).



```
OS Configuration
  UserAppMode
    Task10ms_Prio180_SP2
      Actions
        ETK_Bypass.MyServicePoint_2_after_send_to_ECU
      Event
    Task1s_Prio120_SP3
      Actions
        ETK_Bypass.MyServicePoint_3_after_send_to_ECU
      Event
  Init
  Exit
  ISRs
  Software Tasks
    SWtask_Prio150_MyServicePoint_2
      Actions
        ETK_Bypass.MyServicePoint_2_before_receive_from_ECU
      Event
        ETK_Bypass.MyServicePoint_2_before_receive_from_ECU
    SWtask_Prio150_MyServicePoint_3
      Actions
        ETK_Bypass.MyServicePoint_3_before_receive_from_ECU
      Event
```

Fig. 8-13 OS configuration (incomplete) for a bypass with read and write actions of a service point in different tasks

8.6.3.5 ECU-Synchronous Write-Back

The idea of ECU-synchronous write-back is to calculate results at the earliest possible stage on the rapid prototyping system (E-target) so it can be retrieved by the ECU at the right point-in-time.

Fig. 8-14 illustrates how service points can be used for ECU-synchronous write-back. Following the pre-action Read_F1 of service point SP 1, the result, F3', is available in the rapid prototyping system, but not in the ECU. At the right point in time, service point SP 3 fetches F3' and writes the result to the ECU as F3. Note that the (Read_F3) action is a "dummy" action that merely serves to release the ETK channel, and that no signal has to be selected for that dummy signal group.

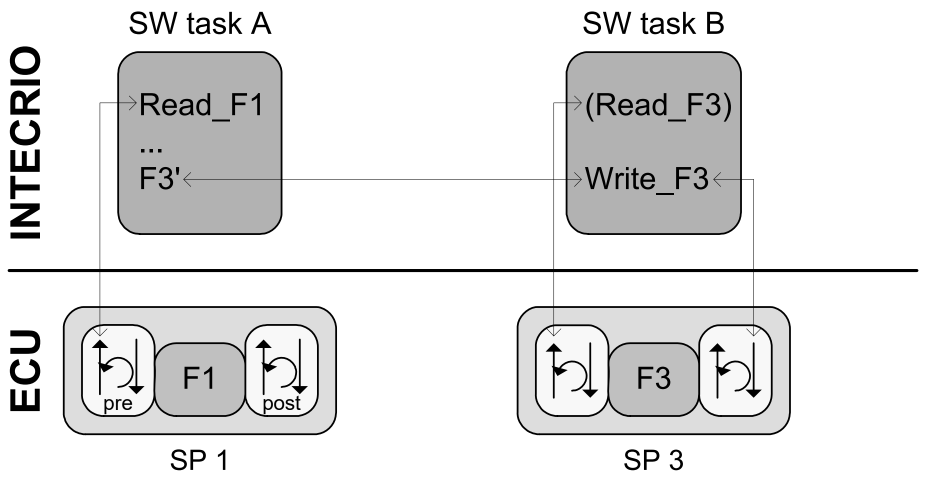


Fig. 8-14 Example: ECU-synchronous write-back

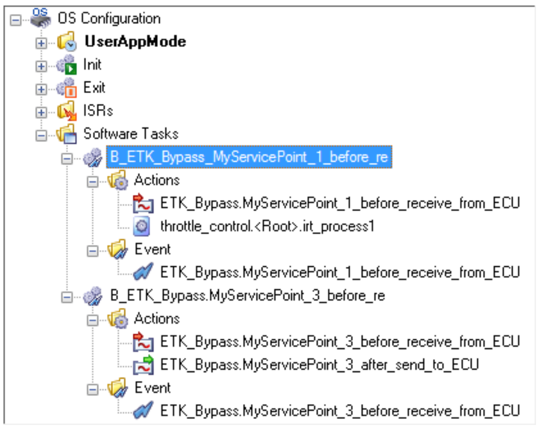
To achieve this kind of OS configuration, the following steps are required:

A Use the **Auto Mapping** feature of the OSC as a starting point.

With that, actions from different service points are mapped to different software tasks, and appropriate events are assigned. Software processes are mapped to timer, init or exit tasks.

B In the OSC, move the F3' software process to the INTECRIO software task assigned to the read action of SP 1.

C Remove empty tasks from the OS Configuration (optional).



```
OS Configuration
  UserAppMode
  Init
  Exit
  ISRs
  Software Tasks
    B_ETK_Bypass_MyServicePoint_1_before_re
      Actions
        ETK_Bypass.MyServicePoint_1_before_receive_from_ECU
        throttle_control.<Root>.irt_process1
      Event
        ETK_Bypass.MyServicePoint_1_before_receive_from_ECU
    B_ETK_Bypass.MyServicePoint_3_before_re
      Actions
        ETK_Bypass.MyServicePoint_3_before_receive_from_ECU
        ETK_Bypass.MyServicePoint_3_after_send_to_ECU
      Event
        ETK_Bypass.MyServicePoint_3_before_receive_from_ECU
```

Fig. 8-15 OS configuration (incomplete) for a bypass with read and write actions of a service point in different tasks

For SBB V3 and higher, the results of OS mapping and trigger assignment in the build process are reported in an XML log file. The file is stored in the workspace log directory, it is named `<system name>_ETKSBBV3_TriggerInfo.xml`.

This file lists, for each service-point action used in the system project, the name (`TASKNAME`) and priority (`TASKPRIO`) of the task where the signal group is executed, as well as number (`TRGNUMBER`) and priority (`RASTERPRIO`) of the ETK trigger with which the signal group data will be transferred.

Example:

```
<TriggerInfo
 SIGNALGROUPNAME=
   "ETK_Bypass.MySP_1.MySP_1_before_receive_from_ECU"
 RASTERPRIO="8"
 TASKNAME="M_ETK_Bypass_MySP_1_before_re"
 TASKPRIO="195"
 TRGNUMBER="28"
 TRGFLAGADDR="a303efb8"
 RAID="1"/>
```

This information is useful if the bypass system must be debugged.

8.6.4 Summary

The implementation and integration of the ECU drivers must take care of the following:

- As the service-based bypass only overwrites ECU values with bypass values without preventing the ECU from writing these values, there is a possibility of data inconsistency which can lead to unpredicted behavior of the ECU.
- INTECRIO provides a configuration variable to set the maximal number of tolerated lost cycles, e.g. how many ECU calculation cycles without receiving bypass values are tolerated before this is regarded as an error. But it is up to the provider of the ECU software to make sure missing bypass output values are detected.
- INTECRIO provides a configuration variable to set a specific error behavior (if also supported by the ECU implementation). But it is up to the provider of the ECU software to make sure bypass failures or bypass deactivation can be detected by the ECU software! The configuration setting in the INTECRIO GUI can then be used to choose between different provided error behaviors in the ECU.
- INTECRIO allows disabling the bypassed ECU process. In this case, no ECU values can be used as fallback values for bypass failures! It is up to the provider of the ECU software to make sure sensible data is written to the variables if both the ECU process and the bypass is disabled.

9 Contact Information

Technical Support

For details of your local sales office as well as your local technical support team and product hotlines, take a look at the ETAS website:

www.etas.com/hotlines

ETAS Headquarters

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70469 Stuttgart		Fax:	+49 711 3423-2106
Germany		Internet:	www.etas.com

10 Glossary

This glossary contains explanations of the technical terms and abbreviations used in the INTECRIO documentation. While many terms are also used in a more general sense, this glossary specifically addresses the meaning of those terms as they are applied to INTECRIO. The terms are listed in alphabetical order.

10.1 Abbreviations

API

Programming interface for the application developer (**A**pplication **P**rogramming **I**nterface).

ASAM-MCD

Working Group for Standardizing Automation and Measuring Systems, including the Working Groups Measuring, Calibrating, and Diagnostics (German: **A**rbeitskreis zur **S**tandardisierung von **A**utomations- und **M**esssystemen, mit den Arbeitsgruppen **M**essen, **C**alibrieren und **D**iagnose)

ASAM-MCD-2MC

A file format used to describe the calibration variables and measured signals contained in the control unit software, and additional specific information designed to parameterize the experiment interface. ASAM-MCD-2MC is used to import the information required for this into an experiment (A2L file).

INTECRIO V5.0 supports the ETK AML versions 1.1 (only hook-based bypass) or 1.2 – 1.7 (hook-based and service-based bypass), XETK AML versions up to 2.5, ASAP1B_Bypass AML V1.0 and higher, and SBB AML versions 2.0, 3.0 and 3.1.

For further information, refer to https://www.asam.net.

ASCET

ETAS product family for the development of electronic control unit software. ASCET models can be imported in INTECRIO.

ASCET-MD

ASCET **M**odeling & **D**esign – the behavioral modeling tool of the ASCET product family.

ASCET-RP

ASCET **R**apid **P**rototyping – the rapid prototyping tool of the ASCET product family.

AUTOSAR

Automotive **O**pen **S**ystem **Ar**chitecture; see https://www.autosar.org/

BMT

Behavioral **M**odeling **T**ool. The BMT can be used to edit, simulate and animate the behavior of models and generate the function code.

BR_XETK

Emulator test probe (ETK) with Automotive Ethernet interface.

Requires an ES800 hardware system with ES882/ES886.

BSW

Basic **s**oft**w**are; provides communications, I/O, and other functionality that all software components are likely to require.

CAN

Controller **A**rea **N**etwork; a robust vehicle bus standard designed to allow microcontrollers and devices to communicate with each others' applications without a host computer.

CANdb

CAN data**b**ase; CAN description file created with the CANdb data management program made by the company Vector Informatik.

INTECRIO V5.0 supports the CANdb versions V2.3 and higher.

CPU

Central **P**rocessing **U**nit. In the context of INTECRIO, this refers to a single microcontroller.

Distab

Data exchange method, used in ETK bypass experiments for data exchange between experimental target and ECU.

INTECRIO V5.0 supports hook-based bypass with Distab 12 and higher (XETK AML: Distab 13), as well as service-based bypass with Distab 13.

In combination with ES830 or ES910.3, INTECRIO V5.0 supports also bypass with Distab 17.

ECU

Electronic **C**ontrol **U**nit; a small embedded computer system that consists of a CPU and the associated periphery, where everything is usually located in the same housing.

ETK

emulator test probe (German: **E**mulator-**T**ast**k**opf)

FETK

emulator test probe (ETK) for the ETAS ES89x ECU and Bus Interface Modules

FIBEX

Field **B**us **Ex**change – an exchange format based on an XML schema which is used for descriptions of the complete in-vehicle communication network. FIBEX is defined for various network types (CAN, LIN, MOST, FlexRay) and contains information about bus architecture, signals, properties of network nodes, etc.

The FIBEX file format is standardized by ASAM (Association for Standardization of Automation and Measuring Systems).

INTECRIO V5.0 supports the FIBEX baseline versions FIBEX V2.0.x and V3.1.0; the latter with some restrictions (see the online help for details).

For further information, refer to https://www.asam.net.

FIFO

First **i**n, **f**irst **o**ut

HBB

hook-**b**ased **b**ypass

HC

Hardware **C**onfigurator

IER

INTECRIO **E**mbedded Coder **R**eal-Time Target (Embedded Coder real-time target for importing Simulink models in INTECRIO)

INCA

ETAS measuring, calibration and diagnostics system (**In**tegrated **C**alibration and **A**cquisition Systems)

For cooperation with INTECRIO V5.0.4, you need INCA V7.2.17 or higher.

INCA-EIP

INCA add-on; allows access to the rapid prototyping (ES910, ES830) and virtual prototyping (VP-PC) targets for INCA.

For cooperation with INTECRIO V5.0.4, you need INCA-EIP V7.2.17 or higher.

INTECRIO-RP

INTECRIO **R**apid **P**rototyping package – provides connectivity to the rapid prototyping targets.

INTECRIO-VP

INTECRIO **V**irtual **P**rototyping package – provides connectivity to the virtual prototyping targets.

IRT

INTECRIO **R**eal-Time **T**arget (Simulink Coder real-time target for importing Simulink models in INTECRIO)

LDF

LIN **d**escription **f**ile – a configuration file for a LIN controller.

INTECRIO V5.0.4 supports the LDF versions 1.3, 2.0, 2.1, and 2.2.

LIN

Local **I**nterconnect **N**etwork; a serial network protocol used for communication between components in vehicles.

LIN is used where the bandwidth and versatility of CAN are not needed. Typical application examples are the networking within the door or the seat of a motor vehicle.

LSB and lsb

Least **S**ignificant **B**yte (capital letters) or **b**it (small letters)

MDA

Measure **D**ata **A**nalyzer program; an offline instrument by ETAS for displaying and analyzing saved measurement data.

MSB and msb

Most **S**ignificant **B**yte (capital letters) or **b**it (small letters)

OIL

OSEK **I**mplementation **L**anguage – as describing language for electronic control unit networks, it is an indirect part of the OSEK operating system. OIL is used to describe static information of the electronic control unit network, such as communication connections and electronic control unit properties.

OS

Operating **S**ystem

OSC

OS configurator (**O**perating **S**ystem **C**onfigurator)

OSEK

Working group for Open Systems for Electronics in Motor Vehicles (German: **O**ffene **S**ysteme für die **E**lektronik im Kraftfahrzeug)

PDU

Protocol **d**ata **u**nit; a data unit that contains payload and control information which is passed between the layers in a protocol stack.

In INTECRIO V5.0, a FlexRay PDU corresponds to a signal group.

RE

Runnable **e**ntity; a a piece of code in an SWC that is triggered by the RTE at runtime. It corresponds largely to the processes known in INTECRIO.

RP

Rapid **p**rototyping; see also page 166

RTA-OSEK

ETAS real-time operating system; implements the AUTOSAR-OS V1.0 (SC-1) and OSEK/VDX OS V2.2.3 standards and is fully MISRA compliant.

RTA-OS

ETAS real-time operating system; implements the AUTOSAR R3.0 OS and OSEK/VDX OS V2.2.3 standards and is fully MISRA compliant.

RTA-RTE

AUTOSAR runtime environment by ETAS

RTE

AUTOSAR runtime environment; provides the interface between software components, basic software, and operating systems.

RTIO

Real-**T**ime **I**nput-**O**utput

SBB

Service-**b**ased **b**ypass

SBC

Electrohydraulic brake system (**S**ensotronic **B**rake **C**ontrol)

SCOOP

Source **Co**de, **O**bjects, and **P**hysics

SCOOP-IX

SCOOP **I**nterface E**x**change language.

INTECRIO V5.0 supports SCOOP-IX versions V1.0, V1.1, V1.2, V1.4, and V1.5.

SP

Service **p**oint; see also Page 167

SWC

Atomic AUTOSAR software component; the smallest non-dividable software unit in AUTOSAR.

UDP

User **D**atagram **P**rotocol

UML

Unified **M**odeling **L**anguage

VFB

Virtual **f**unction **b**us in AUTOSAR

VP

Virtual **p**rototyping; see also page 167

XCP

Universal measurement and **c**alibration **p**rotocol; the **x** generalizes the various transportation layers that can be used. The long name is ASAM MCD-1 XCP.

INTECRIO V5.0 supports XCP version V1.0 and all subsequent versions which are compatible with V1.0. In addition, the `XCPplus` keyword from V1.1 and higher is supported.

XETK

emulator test probe (ETK) with Ethernet interface

XML

E**x**tensible **M**arkup **L**anguage

10.2 Terms

Actuator

Executing hardware unit. It forms the physical interface between electronic signal processing and mechanics.

Application mode

An application mode is part of the operating system; it describes different possible states of a system, such as the application mode EEPROM programming mode, starting or normal operation.

AUTOSAR software component

see SWC

Basic software

see BSW

Bypass experiment

In a bypass experiment, parts of an electronic control unit program are executed on the experimental target (ES900, ES800). This requires a special hook in the code.

INTECRIO V5.0 supports several types of bypass experiments: XCP bypass on CAN or UDP, as well as hook-based and service-based ETK/XETK/FETK bypass.

Connection, dynamic

Connection between signal source and sink that can be changed at runtime without a new build process.

Connection, static

Connection between signal source and sink that cannot be changed at runtime.

Crossbar

Manages and controls the connections between modules, functions and hardware in a non-AUTOSAR environment.

Embedded Coder®

An add-on for the Simulink® Coder™; extends the capabilities provided by the Simulink Coder to support specification, integration, deployment, and testing of production applications on embedded targets.

Environment system

Environment systems are used to model the plant model for virtual prototyping. They are built out of modules and functions, the same way as software systems.

Event

An event is an (external) trigger that initiates an action of the operating system, such as a task.

Event interface

see Process

FlexRay

FlexRay is a scalable and fault tolerant communication system for high-speed and deterministic data exchange. FlexRay's time-division multiplexing facilitates the design of modular or safety-related distributed systems. Its high bandwidth of 10 MBaud on two channels helps to cope with the high network load caused by the increasing amount of innovative electronic systems in modern vehicles.

The communication system's specifications are released by the FlexRay consortium which is widely supported by vehicle manufacturers and suppliers worldwide.

Fullpass experiment

In a fullpass experiment, the complete electronic control unit program is executed on the experimental target.

Function

A grouping object for software systems that does not feature its own functionality. Modules or functions are assembled and connected in a function; they are thus clearly arranged and can be easily reused.

Graphical framework

The window that displays after the start of INTECRIO. The different INTECRIO components are integrated in the graphical framework.

Hardware system

A hardware system contains the complete description of a hardware topology, consisting of the descriptions of the associated ECUs (experimental targets) as well as the descriptions of the interfaces (bus systems) between the devices.

Implementation

An implementation describes the conversion of the physical task definition (of the model) into executable fixed-point code. An implementation consists of a (linear) conversion formula and a limiting interval for the model values.

Integration

The convergence of model code, which may have been developed by different partners or with different tools, to control algorithm, the configuration of this algorithm for the hardware on which it is supposed to run, and finally the creation of an executable file.

INTECRIO

INTECRIO is a tool that combines, i.e. integrates, the parts of the control algorithm created with different behavioral modeling tools that allows for creating and configuring a hardware system and the connection of this hardware system with the control algorithm.

legacy AUTOSAR module

AUTOSAR module imported with INTECRIO V5.0.0 or older.

MATLAB®

High-performance language for technical calculations; contains mathematical calculations, visualization and programming in one environment.

MATLAB® Coder™

Code generator for MATLAB code.

Module

A module in INTECRIO contains the generic description of a functionality for an electronic control unit. For example, it corresponds to an ASCET project or a Simulink model.

OS configurator and OSC

The task of the operating system configuration is carried out within INTECRIO the OS configurator and the OSC editor. The OSC is part of the OS configurator, an easy to handle editor for the operating system configuration that provides the user with a quick overview of the system and allows for editing the configuration in an application-oriented display.

Process

A process is a simultaneously executable functionality that is activated by the operating system. Processes are specified in modules and do not feature any arguments/inputs or result values/outputs.

Processor

see CPU

Project Configurator

The project configurator is part of the integration platform of INTECRIO. It is used to specify software systems and system projects.

Project Integrator

The project integrator combines all the components of the system (modules and functions, hardware interfacing, OS configuration, etc.) into an executable file.

Prototype

Completely executable file for an experimental target system. Such a prototype shows the software functions in practical use – entirely with different goal directions and in a different appropriation.

Rapid prototyping

The execution of a software on an experimental target, i.e. a computer with an interface to the vehicle.

RTA-Trace

Discontinued software tracing tool that can monitor system behavior over a versatile interface to the ECU. Existing installations can still be used.

Runnable entity

see RE

Runtime environment

see RTE

Sensor

Sensors convert a physical or chemical (usually nonelectrical) quantity into an electrical quantity.

Service point

A service point is an encapsulation of a process in the ECU software. It provides data transfer actions to and from the target system; these actions can be enabled and configured by the user.

Service point cluster

A group of service points that are executed in the ECU with the same priority (service points located in the same ECU task).

Service point cluster group

A group of service point clusters. The group contains all service points of all tasks that can potentially be invoked at the same time in the ECU.

Simulink®

Tool for modeling, simulation and analysis of dynamic systems. The models can be imported in INTECRIO.

Simulink® Coder™

Code generator for Simulink and Stateflow models. Requires the MATLAB® Coder™.

Stateflow®

Tool for modeling and simulation of complex event-controlled systems. It is seamlessly integrated in MATLAB and Simulink.

Software system

A software system contains the generic parts of the ECU description: modules, functions and connections.

System project

A system project combines a hardware system, a software system, an environment system (if applicable), the mapping of the signals and the configuration of the operating system in a common project and allows for the generation of executable code.

Task

A task is an ordered collection of processes that can be activated by the operating system. Attributes of a task are its application modes, activation trigger, priority and modes of its scheduling. Upon activation, the processes of the task are executed in the specified order.

Validation

Process for the evaluation of a system or a component with the purpose of determining whether the application purpose or the user expectations are met. Therefore, the validation is the check whether the specification meets the user requirements, whether the user acceptance is reached by a function after all.

Verification

Process for evaluating a system or a component with the purpose of determining whether the results of a given development phase correspond to the specifications for this phase. Therefore, software verification is the check whether an implementation of the specification specified for the respective development step is sufficient.

Virtual prototyping

Function developers create virtual prototypes of electronic vehicle functions and test them on the PC.

Workspace

The workspace combines all the data generated while working with INTECRIO. From the WS browser, i.e. the tree view of the workspace, you can call up all the components of INTECRIO.

X-Pass experiment

Mixture of bypass and fullpass experiment. The experimental target (ES900, ES800) utilizes the ECU with bypass hooks as interface to the outside world.

Figures

Tables

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