ASCET V6.0

Getting Started

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Contents

1 Introduction

ASCET provides an innovative solution for the functional and software development of modern embedded software systems. ASCET supports every step of the development process with a new approach to modelling, code generation and simulation, thus making higher quality, shorter innovation cycles and cost reductions a reality.

This manual supports the reader in getting to know ASCET, and quickly achieving results. It provides a step-by-step introduction to the system, while at the same time making all information easily accessible for reference.

1.1 System Information

The ASCET product family consists of a number of products that provide interfaces to simulation processors, third-party software packages and for remote access to ASCET. The following products are available for the current version of ASCET:

- *ASCET-MD*—support for the development and simulation of models.
- *ASCET-RP*—support for experimental targets to allow hardware-in-the-loop simulation and rapid prototyping applications. A toolbox for running ETK Bypass experiments is also integrated. ASCET-RP provides the connection to INTECRIO.
- *ASCET-SE*—support for various microcontroller targets. Generation of optimized executable code, including operating system configuration and integration, for various microcontrollers and two real-time operating systems.

Various kinds of additional modules are optional:

- *ASCET-DIFF*—A comparison tool for ASCET models.
- *ASCET-SCM*—offers interfaces to configuration and version management tools.

Various additional customer-specific products can be integrated in ASCET. More detailed information is available upon request.

1.2 User Information

1.2.1 User Profile

This manual addresses qualified personnel working in the fields of automobile control unit development and calibration. Specialized knowledge in the areas of measurement and control unit technology is required.

ASCET users should be familiar with the Microsoft Windows 2000, Windows XP, or Windows Vista, operating system. All users should be able to execute menu commands, enable buttons, etc. Furthermore, the users should be familiar with the Windows file storage system, especially the connections between files and directories. The users have to know how to use the basic functions of the Windows File Manager and Program Manager or the Windows Explorer, respectively. Moreover, the users should be familiar with the "drag-and-drop" functionality.

Any user who is not familiar with the basic techniques found in Microsoft Windows should learn them before using ASCET. For more information on the Windows operating system, please refer to the manuals published by Microsoft Corporation.

Knowledge of a programming language, preferably ANSI C or Java, can be helpful for advanced users.

1.2.2 Documentation Structure

The ASCET "Getting Started" manual contains the following chapters:

- **"Introduction"** (this chapter)

  This chapter provides an outline of the possible applications of ASCET. Furthermore, it contains general information such as innovations in ASCET V6.0, user and system information.

- **"Embedded Automotive Control Software Development with ASCET"**

  This chapter provides an overview of the ASCET product family and the development process supported by it. This chapter should be read first by all users new to ASCET.

- **"ASCET and AUTOSAR"**

  This chapter describes the cooperation of ASCET and AUTOSAR.

- **"Tutorial"**

  The "Tutorial" mainly addresses users who are new to ASCET. It describes the use of ASCET using practice-oriented examples. The entire tutorial contents are subdivided into short individual components based on each other. Before you start working on the tutorial, you should have read chapter "Embedded Automotive Control Software Development with ASCET" on page 13.

Note

ETAS offers efficient training in the use of ASCET in order to provide an even more thorough knowledge of ASCET, especially if the user has to gain a comprehensive insight in the functionality of ASCET in a very short period of time.

- **"Glossary"**

  This chapter explains all technical terms used in the manual. The terms are listed in alphabetic order.

- **"Appendix A: Troubleshooting ASCET Problems"**

  This chapter contains information on troubleshooting, the directory structure, and the reference files required.

- **"Appendix B: Troubleshooting General Problems"**

  This chapter gives some information of what you can do when problems arise that are not specific to an individual ETAS software or hardware product.

- **"Appendix C: AUTOSAR"**

  This chapter contains further information on using the AUTOSAR capabilities of ASCET.

The installation procedure is described in a separate document.

In the ASCET online help, you can find further detailed information. Information on using the online help can be found in section 1.3.3 "Manual and Online Help" on page 12.

1.2.3 How to Use this Manual

Documentation Conventions

All actions to be performed by the user are presented in a a task-oriented format as illustrated in the following example. A *task* in this manual is a sequence of actions that have to be performed in order to achieve a certain goal. The title of a task description usually introduces the result of the actions, e.g. "To create a new component", or "To rename an element". Task descriptions often contain illustrations of the particular ASCET window or dialog box the task relates to.

To achieve a goal:

Any preliminary information...

- Step 1

  Explanations are given underneath an action.
- Step 2

  Any explanation for Step 2...
- Step 3

  Any explanation for Step 3...

Any concluding remarks...

Specific example:

To create a new file:

When creating a new file, no other file may be open.

- Choose **File** → **New**.

  The "Create file" dialog window opens.
- In the "File name" field, type the name of the new file.

  The file name must not exceed 8 characters.
- Click **OK**.

The new file will be created and saved under the name you specified. You can now work with the file.

Typographic Conventions

The following typographic conventions are used in this manual:

Select **File** → **Open**.	Menu commands are shown in **blue boldface**.
Click **OK**.	Buttons are shown in **blue boldface**.
Press <ENTER>.	Keyboard commands are shown in angled brackets and capitals.
The "Open File" dialog window opens.	Names of program windows, dialog boxes, fields, etc. are shown in quotation marks.

Select the file `setup.exe`.	Text in drop-down lists on the screen, program code, as well as path- and file names are shown in the `Courier` font.
A *distribution* is always a one-dimensional table of sample points.	General emphasis and new terms are set in *italics*.
The OSEK group (see http://www.osekvdx.org/) has developed certain standards.	Links to internet documents are set in blue, underlined font.

Important notes for the users are presented as follows:

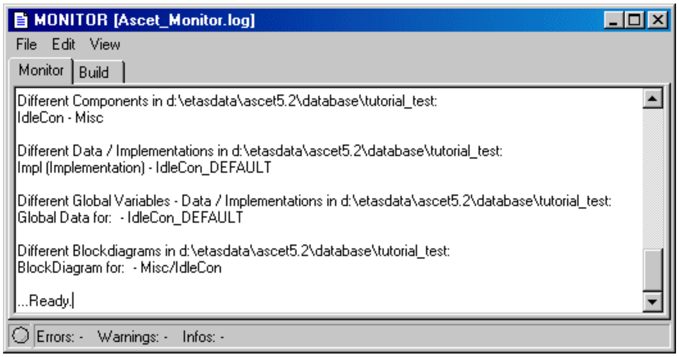
Note

Important note for users.

1.3 Supporting Functions

1.3.1 Monitor Window

The monitor window (see the ASCET online help) is used to log the working steps performed by ASCET. All actions, including errors and notifications, are logged. As soon as an event is logged, the monitor window is displayed in the foreground.



```
Different Components in d:\etasdata\ascet5.2\database\tutorial_test:
IdleCon - Misc

Different Data / Implementations in d:\etasdata\ascet5.2\database\tutorial_test:
Impl (Implementation) - IdleCon_DEFAULT

Different Global Variables - Data / Implementations in d:\etasdata\ascet5.2\database\tutorial_test:
Global Data for:  - IdleCon_DEFAULT

Different Blockdiagrams in d:\etasdata\ascet5.2\database\tutorial_test:
BlockDiagram for:  - Misc/IdleCon

...Ready.
```

```
Errors: -   Warnings: -   Infos: -
```

In addition to displaying information, the monitor window also provides the functionality of an editor.

- The display field in the "Monitor" tab of the monitor window can be freely edited. This way, your own notes and comments can be added to the ASCET messages.

- The ASCET messages can be saved as text files along with your comments.
- Other ASCET text files already stored can be loaded so that you can compare specific working steps.

1.3.2 Keyboard Assignment

You can display an overview of the keyboard commands currently used at any time by pressing <CTRL> + <F1>.

1.3.3 Manual and Online Help

If not specified otherwise during installation, the ASCET Getting Started manual and installation guide are available electronically. The volumes, named **`ASCET V6.0 Getting Started.pdf`** and **`ASCET V6.0 Installation.pdf`**, are stored in the `ETAS\ETASManuals` folder. Printed copies of the Getting Started volume can be ordered here:

http://www.etasgroup.com/order_manual/ascet

Using the index, full text search, and hypertext links, you can find references fast and conveniently.

The online help can be accessed via the <F1> key. It is stored in the `ETAS\ASCET6.0\Help` folder.

2 Embedded Automotive Control Software Development with ASCET

Embedded automotive software development is an interdisciplinary task requiring cooperation between the different vehicle domains (infotainment, chassis, body, powertrain) as well as between different companies, i.e. the vehicle manufacturer and the supplier. Furthermore, embedded automotive software is an integral part of a mechanical subsystem which means that it

- implements control algorithms which read data from sensors, and calculate control values which are sent to an actuator.
- runs typically in so-called electronic control units (ECUs for short), employing one or more microcontrollers and additional electrics and electronics.
- will normally not be changed during the lifetime of a vehicle.
- has to obey all requirements with respect to safety and reliability of the mechanical subsystems.

As a result, creating a common understanding of the functionality which has to be implemented in software is the basis for a seamless integration and non-functional optimizations, e.g. resource consumption. The latter point becomes apparent if one keeps in mind that ECUs are produced in large quantity. Small cost reduction of a single ECU may hence result in significant savings of the series' overall cost. For example, saving of memory resulting in a cheaper derivate of a microcontroller will lessen the overall cost even though the cost for a single ECU changes only marginally.

A graphical model of the function frequently serves as the basis for the common understanding described above. On the one hand, the graphical model is more abstract then embedded C code, while on the other it is formal, i.e. unambiguous without leeway for interpretations compared to a non-formal textual specification. It can be executed on a computer in a simulation. It can be experienced in a vehicle at an early point in time by means of rapid prototyping. For short, a graphical model of a function serves as digital specification.

Using automatic code generation, graphical functional models can be transformed to embedded automotive software. To accomplish this, functional models must be enhanced by adding dedicated design information that includes non-functional product properties like safety and resource consumption measures.

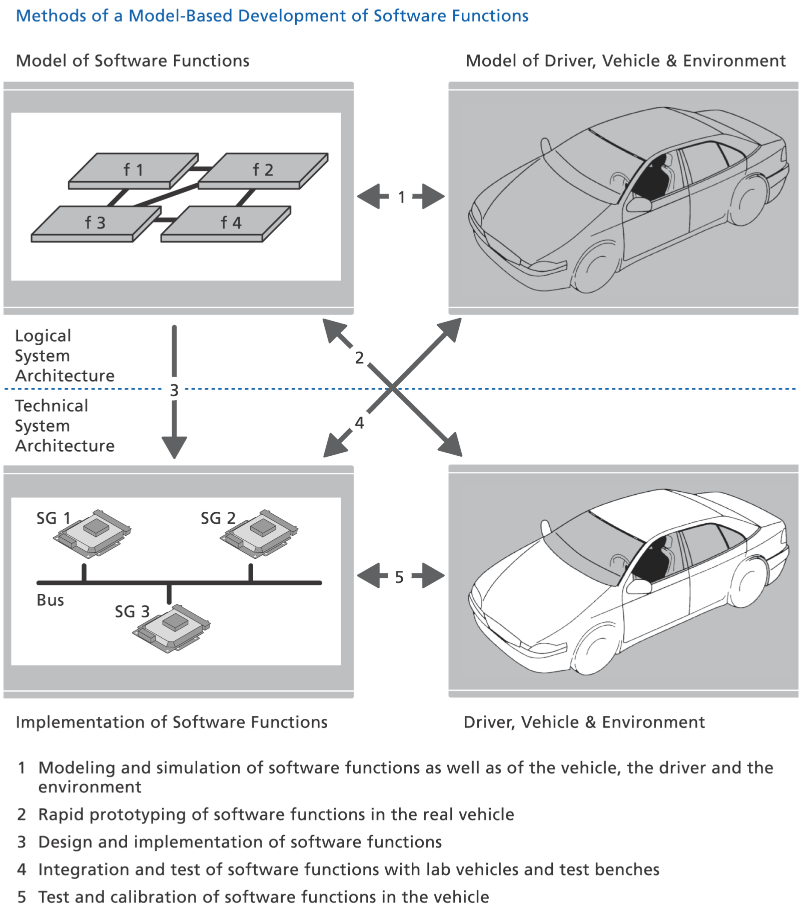
The operating environment of ECUs can be simulated by means of hardware-in-the-loop test systems (HiL for short) which facilitate early testing of ECUs in the laboratory. HiL-testing of ECUs offers a greater flexibility in generating test-cases than in-vehicle tests typically provide.

The calibration of embedded automotive software often can be finalized only at some point toward the end of the development process. In many cases, this procedure is carried out in the vehicle with all systems (i.e. mechanical systems embedding automotive software of all domains) running, and requires support of dedicated tools and methods, which have also to be considered during the generation of the software.

Chapter 2.1 describes in detail the stages of model-based design and explains the abstraction mechanisms employed in ASCET to create a graphical model of a function. Chapter 2.2 shows how ASCET models can be used in an ECU production development environment while chapter 2.3 summarizes the major topics.

2.1 Model-Based Design

The development of embedded automotive control software is characterized by several development steps which can be summarized by using the V-model. One starts with the analysis and design of the logical system architecture, i.e. defines the control functions, proceeds with defining the technical architecture, which is a set of networked ECUs, and then proceeds with software implementation on an ECU. The software components will be integrated and tested, then the ECU is integrated in the vehicle network and, last but not least, the system running the implemented functions is fine-tuned by means of calibration. However, this is not a top-down process, but requires early feedback by means of simulation and rapid-prototyping.



Methods of a Model-Based Development of Software Functions
Model of Software Functions
Model of Driver, Vehicle & Environment
f 1
f 2
f 3
f 4
1
Logical System Architecture
Technical System Architecture
2
3
4
SG 1
SG 2
SG 3
Bus
5
Implementation of Software Functions
Driver, Vehicle & Environment
1 Modeling and simulation of software functions as well as of the vehicle, the driver and the environment
2 Rapid prototyping of software functions in the real vehicle
3 Design and implementation of software functions
4 Integration and test of software functions with lab vehicles and test benches
5 Test and calibration of software functions in the vehicle

Fig. 2-1 Model-Based Development of a Software Function

2.1.1 Control Algorithm Development

At first, control algorithms are developed. This is mainly a control-engineering task. It starts by the dynamic analysis of the system to be controlled, i.e. the plant. A plant-model is a model of the vehicle (including the sensors and actuators), its environment (e.g. the road conditions), and the driver. Typically, only subsystems of the vehicle are considered in special scenarios like the engine with the powertrain and the driver, or the chassis with the road-conditions. These models can be either analytical, such as an analytically solved differential equation, or a simulation model, i.e. a differential equation to be solved numerically. In practice, a plant-model is often a mixture of both.

Then, according to some quality criteria, the control law is applied. Control laws compensate the dynamics of a plant. There are a lot of rules to find good control laws. Automotive control algorithms very often combine closed-loop control laws with open-loop control strategies. The latter are often automatons or switching constructs. This means that control algorithms are hybrid systems from a system-theory point of view. Typically, the control law consists of set-point generating function with controlling and monitoring functions, all realized by software (see section "Software Realization of Control Algorithms"). The first step is to design a control algorithm for a vehicle subsystem which is represented as a simulation model. Both the control algorithm and the plant model are running on a computer. The plant is typically realized as a quasi-continuous-time model while the control algorithm is modelled in discrete-time. The value range of both models is continuous, i.e. the state variables and parameters of the control algorithm and the plant are realized as floating point variables in the simulation code. This model is depicted in the upper part of Fig. 2-1 on page 15. The logical system architecture represents the control algorithm which is coupled to a model of the driver, the vehicle & the environment. The arrow labelled 1 represents the control algorithm design step. Control algorithm modeling is based on the use of shared signals. This means that one component shares the signal in a provide role while other components share the signal in a require role.

Software Realization of Control Algorithms

Control algorithms are hybrid systems, i.e. a mixture of open- and closed-loop systems where the open-loop parts are quite often non-linear, discrete systems, for example finite-state-machines. If the control algorithms run on a microcontroller, they have to be transformed in a sequential programming language, e.g. C. The easiest way for a realization of the control algorithm is to construct a main-loop, which is triggered by an interrupt, and to call several subroutines, which contain the sequential program. Data exchange between the subroutines is performed by global variables. Triggering the main-loop by interrupts realizes a reoccurring execution of the sequential-program. If the interrupt is a timing interrupt, the main-loop realizes a sampled system.

This kind of straight-forward realization of control algorithms in software runs into its limits if multi-rate systems are considered, i.e. systems having different sample-rates, which are realized by several tasks instead of one main-loop. These multi-tasking systems require a proper exchange of signal data between the tasks. Furthermore, it is quite difficult on C code level to distinguish between state variables, parameters, input and output signals. Realization of control algorithms in ASCET closes the gap between the control-engineering view and the implementation view of the control algorithm. Instead of simply using variables and subroutines, it provides the control algorithm modelling constructs:

- Modules
- Classes
- Projects

Combinations of these constructs allow the construction and execution of complex control algorithms on several targets. Targets are a PC, a rapid-prototyping system or a microcontroller. Execution is performed by first transforming the ASCET model to C code and afterwards transform the C code to executable code on the respective target. All modelling constructs are maintained in a database.

Modules

Modules provide means for sequential statements, for (state) variables, parameters, input- and output signals. Sequential statements are realized in a block diagram editor (BDE) by variables with sequence calls. These sequence calls assign the result of an expression to the variable. An alternative to the BDE in ASCET to realize statements is the ESDL programming language. Sequential statements can be grouped to processes. Processes represent subroutines.

Input-signals are modelled as so-called receive messages. Expressions can read from receive messages and use the actual value of that message for further calculations. Output signals are modelled as so-called send messages. The result of an expression can be assigned (written) to a send message. In the block diagram editor, the assignment to a message is realized by a sequence call similar to variables.

Parameters have an own representation. Their value can only be read from an expression, but assignments are not allowed.

To summarize, a module consists of send and receive message for data exchange with other modules. It has several processes which cluster sequential statements. Besides messages, a module contains variables and parameters. Receive-message reading can be shared by the processes of the modules, while message-writing requires disjoint access by the processes. There might be messages which are only exchanged between processes within a module. These dedicated messages are called send-receive message.

Classes

If a process is running, it might want to store data to process internal variables, e.g. the state of a control algorithm. From a computer science point of view, internal variables are typed. Clustering types results in compound types. Furthermore, statements can be defined on the elements of a compound type. These operations can themselves be clustered in sub-functions, or methods. In particular, methods can have arguments which decouple the access to the data elements of a compound type from the actual data manipulation. A compound type with methods is called a class. Since a class is a type, it can be instantiated like the definition of a variable. In ASCET, variables and instances of classes can be defined in classes or modules.

If a class is defined as instance in the scope of another, i.e. outer class, the methods of the instantiated class can be called by the methods of the outer class. If an "instantiated method" realizes a calculation, e.g. a filtering algorithm, its results can be used in the calculations of the calling methods. Using this mechanism, one can represent control algorithms as a typed object hierarchy. Calling a method of the top-level class, i.e. the outermost class which is not instantiated in another class, will result in the deliverable of the output value(s) of a method. For the calculation of the result, methods of embedded instances will be called sequentially and yield their results which will be used by other calculations. From this point of view, the execution of a top-level method is equal to the sequential execution of an object-oriented program.

Parameters

From a computer scientist point of view, parameters are a special kind of internal variables because they can only be read while writing is forbidden. From the control-engineering point of view, parameters are used to trim the control algorithm to a dedicated vehicle. Parameters are set before the start of the control algorithm execution and remain fixed[1] during the run-time of the control algorithm. Because parameters are special kind of variables, they can be grouped in a similar way as variables.

Classes might contain parameters (they can be seen as elements of a compound type). Since classes can be instantiated several times, these parameters will exist several times, too. However, as a rule, parameters are not initialized by dedicated methods (e.g. constructors) in a start-up phase, but typically exist in read-only memory. This means, that an initial set of values has to be provided before run-time, e.g. at design time. This set of values is called data-set. If the allocation of parameter values to instances of behavioral classes is done at design time, a data-set has to be associated to a particular instance. In

[1]. Adaptive parameters are not considered here.

ASCET, at design time of the class, the data-sets for tentative instances have to be defined, too, while the association to a particular instance is done when the instance is created.

Employing Classes in Modules

As written above, the sequential execution of a control algorithm starts with calling the method of a top-level class. This method call is initiated by the execution of a process. The arguments of a method are typically fed by the receive messages of the process, while the return value of the method will be fed to a send-message (Of course, these methods might also be fed by internal variables of a module).

From a real-time perspective, the process calling a method of a top-level class generates a sequential call-stack of methods which belong to encapsulated instances. Even the methods of leave instances are executed in the context of the task the process is mapped to. Making the call-stack of methods deep might compromise reactivity to events. Therefore, when designing classes and employing them into real-time components, one has to find an appropriate balance between object-oriented reusability and reactiveness in a task-schedule.

Continuous Time Blocks for Plant Modelling

ASCET provides dedicated blocks for the modelling of continuous time systems. These continuous-time blocks (CT blocks) have two flavors:

- Structure blocks which group elementary blocks, and
- Basic blocks which describe the dynamics of elementary systems

Basic blocks assume a non-linear system in normal form of

$$\dot{x} = f(x,u)$$
$$y = g(x,u)$$

and specify the dynamic behavior in an object oriented manner. There is an initialization and termination method, input, update and derivative methods to realize f as well as direct and non-direct output methods to realize g. Furthermore, there is a state-event detection method as well as an event method describing what to do in case of a state-event. Last but not least there is a method to resolve dependent parameters. The expressions can either be expressed by using the ESDL or C syntax.

An ECU composition is a set of communicating modules and an operating system. The operating system configuration defines the tasks and their schedule, while the operating system itself realizes the tasks as well as the messages. The task-schedule contains the assignment of processes to tasks. To perform closed-loop simulations on a PC, CT blocks (cf. section "Continuous Time Blocks for Plant Modelling" on page 19) are attached to the real-time components of the control algorithm. Binding between the messages of the real-time components and the CT blocks has to be done explicitly, i.e. by connecting ports graphically and not by name-matching. The methods of a CT block are called from the numerical integration algorithms. The integration algorithms will be executed as separate task in the resulting operating system configuration.

After mapping the processes to tasks and creating the appropriate CT block tasks, the OS configuration will be translated to executable code. In case of a closed-loop simulation on a PC, a simulation environment with appropriate event queues and numerical solvers will be generated. The simulation environment is no real-time execution environment.

2.1.2 Rapid Prototyping

Unfortunately, the employed plant models are typically not detailed enough to serve as a unique reference throughout the design process. Therefore, the control algorithm has to be checked in a real vehicle. This is the first time the control algorithm will run in real-time. The execution entry points of the software components are mapped to operating system tasks while dedicated software components for hardware access have to be created and connected with the software components of the control algorithm. This step is shown in Fig. 2-1 on page 15 in linking the logical system architecture to the real vehicle which is driven by a driver in a real environment, represented by the arrow labelled 2. There are many ways to realize this step. First of all, one can use a dedicated rapid prototyping system with dedicated I/O boards to interface with the vehicle. The rapid prototyping systems (RP system) consist of a powerful processor board and I/O boards. The boards are connected via an internal bus-system, e.g. VME. Compared to a production ECU, these processor boards are in general more powerful; they have floating point arithmetic units, and provide more ROM and RAM. Interfacing with sensors and actuators via bus-connected boards provides flexibility in different use cases. For short, priority is on rapid prototyping of control algorithms and not on production cost of ECUs.

The interfacing needs of the rapid prototyping systems often result in dedicated electrics on the boards. This limits flexibility, and an alternative is therefore to interface to sensors and actuators using a conventional ECU with its microcontroller peripherals and ECU electronics. A positive side-effect is that the software components of the I/O-hardware abstraction layer can be reused for series production later on. Fig. 2-2 shows that the control and monitoring functions run on a bypass system, which is connected via sensors and actuators to the vehicle.

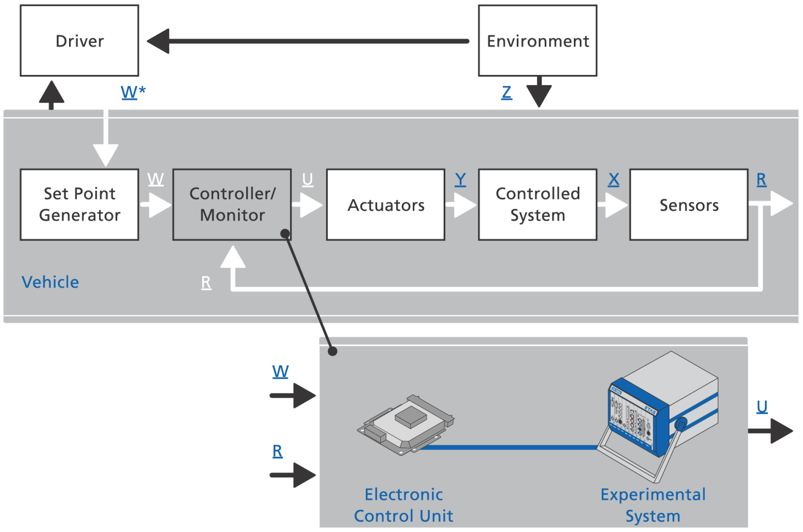


Fig. 2-2 A typical rapid prototyping system

For rapid prototyping in bypass configuration, as shown in Fig. 2-2, the ECU's microcontroller-peripherals are used to drive the sensors and actuators. This means that the control algorithm still runs in the rapid prototyping hardware whereas the I/O-drivers are running on the production ECU. The signals W, R, and U are digital values representing the set-point, the sampled reaction of the plant and the digital actuator signal. The actuator signal is transformed to an electrical or mechanical signal Y driving the vehicle in the state prescribed the driver's wish W*. W is the corresponding sampled digital signal. The actual state of the vehicle in terms of mechanical or electrical signals X is sampled and fed to the control algorithm as digital signal R. Furthermore, there are noise signals Z like the road conditions which are not directly taken into account by the control algorithm as measured input signal, but also influence the behavior of the vehicle. Provided no other vehicle signals are used directly, the RP system uses only a dedicated communication board in addition to the processor board. The sensor values R, the set-point values W, and actuator values U are transmitted over the high-speed link. In most cases, the ECU hardware is modified with dedicated facilities to accommodate the high-speed communication link.

From the software development point of view, structured interfaces of the software running on the production ECU as well as in the control algorithm development improves the efficiency of rapid prototyping considerably.

Realtime-I/O Module

For rapid prototyping experiments, dedicated hardware will be used. Besides a high-performance microprocessor, there are means available for communication and I/O. For example, in the ETAS ES1000 family the above mentioned means are available as VME boards and communication is done via a VME bus.

From a certain point of view, a rapid prototyping system represents a reconfigurable embedded system. In particular, the communication and I/O hardware facilities need basic software modules as glue between the hardware and the control algorithm. These basic software modules are configurable. In ASCET, all basic software modules for the communication and I/O are represented in one ASCET module, the so-called realtime-I/O module. For example, there will be a process reading signals from the CAN buffer and providing the signals as send-message. This process will be scheduled in an operating system task. The signal name as well as the CAN-frame ID can be configured in an editor before.

If a control algorithm shall be tested on an ETAS rapid prototyping system, the realtime-I/O module has to be generated from the configuration parameters. It is represented as generic ASCET C module and has to be attached to the other real-time components, i.e. ASCET modules, to form a running rapid prototyping control algorithm.

Projects for Rapid Prototyping

A project for rapid prototyping does not contain a plant-model represented by continuous time blocks. Instead, it contains a real-time I/O module. This real-time I/O module is configured for the rapid prototyping project. On the model level, the module communicates with the control algorithm modules via messages. Depending on the configuration of the real-time I/O module, there are several processes to be hooked to an operating system task.

2.1.3 Implementation and ECU Integration of Control Algorithms

After the rapid-prototyping step, the control algorithm is valid for use in the vehicle. The code which was generated for rapid prototyping systems relied on the special features of the processing board, such as RAM resources and the floating point unit. To make the control algorithm executable under limited memory and computational resources, the model of the control algorithm has to be re-engineered. For example, computation formulas are transformed from floating point to fixed point control algorithms, and efficiency, scalability, modularity and other concerns are addressed. The adapted design can be automatically transformed to production code in a code generation step.

A physical plant, e.g. a vehicle, deals with physical quantities, like vehicle-speed and acceleration, coolant temperature, yaw-rate, battery voltage a.s.o. In simulation models, these physical quantities are realized by variables of type float, either in 64 or 32 bit guise. The simulation models represent a closed-loop control system, and means that both the vehicle model as well as the model of the control algorithm are represented in floating point. However, floating point units are expensive and their use in automotive micro-controllers is not common. This means, implementation of a control algorithm on an automotive micro-controller involves a floating-point to fixed point conversion.

Example: The coolant temperature might range from -50° Celsius to 150° Celsius. Fitting these values to an 16-bit integer straight forward would be quite inefficient. Only 0.3% of the available bits would be used as shown in Fig. 2-3(a), and the resolution of the temperature would only be 1° Celsius per Bit, resulting in a measured temperature of 83.4° Celcius, which is represented as 80° Celsius in the control software.

This can be changed by multiplying every temperature value by 217.78 thus having a resolution of approximately 0.0046° Celsius per Bit, as shown in Fig. 2-3(b). Unfortunately, this adaptation will end up in a floating-point multiplication itself and is not therefore not desirable.

An alternative would be to limit the resolution to 0.0078125° Celsius per bit. Now the multiplication operation can be expressed by a 7bit left-shift operation. Applying this operation to the temperature range yields bit-patterns from -6400 to 19200, thus using a 16 bit integer variable by 39%. This scaling is shown in Fig. 2-3(c).

An even better utilization can be achieved by using an unsigned 16-bit integer value and a resolution of 0.00390625° Celsius per bit with an offset. This offset is set to -12800. The temperature range can now be used from -12800 to

38400, thus using a range from 51200 values and hence provides a utilization of more than 78%, as shown in Fig. 2-3(d). However, the offset requires an additional subtraction.

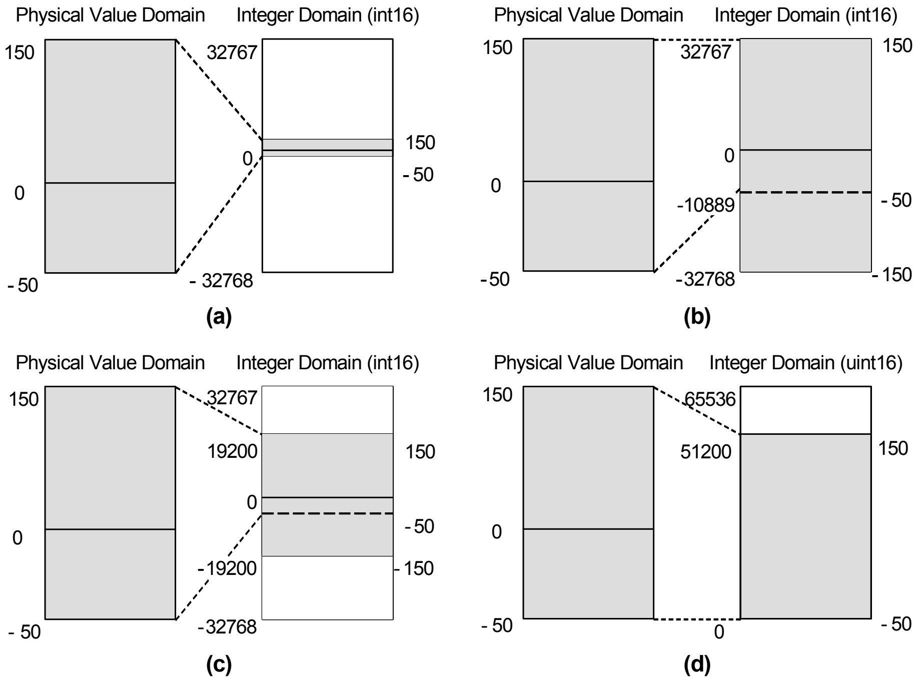


Fig. 2-3 Unscaled Mapping (a), Aribtrary Mapping (b), 2^7 Scaling (c), 2^8 Scaling with Offset (d)

The relationship can be expressed by the linear relationship:

```
Impl_value = f_impl(phys_value) =
phys_value*256+12800
```

or, more generally, by

```
impl=scal * phys_value + x
```

where `scal` is the scaling factor and `x` the offset. The resolution is the reciprocal scaling factor, which means that the physical value is represented by an implementation value of

```
phys_value = impl_value / scal - ofs
```

Associating an implementation formula to every variable has a heavy impact on the statements, i.e. expressions and assignments, of methods or processes. Even the simple assignment of two variables representing physical values

```
a = b
```

is not a trivial operation if the implementations, i.e. the associated implementation formulae, are different. Let `a` and `b` be implemented by the following implementation formulae as unsigned 8 bit variables (range from 0 to 255):

```
a = 2 * a_impl, b = 3 * b_impl
```

meaning that the physical value of `a` has a resolution of 2 while the physical value of `b` has a resolution of 3. Representing the assignment `a=b` in implementation terms yields:

```
2* a_impl = 3* b_impl
```

This is followed by a simple substitution:

```
a_impl = (3 / 2)* b_impl
```

Compared to the original statement `a=b`, we have now an adapted statement `a_impl = (3/2) * b_impl`. With respect to implementation formulae[1], the adaptations are merely arithmetic operations with constants. However, care must be taken with the series of adaptive operations in order to consider the requirement for maximum precision. If one, as shown above, first performs the division, the various conversion equations would be ineffective due to the integer computation, and the results would be about 50% incorrect. A better way to express the adapted statement would be:

```
a_impl = 3 * b_impl / 2
```

As a result, statements of physical variables adapted by implementation operations often take into account more than just a simple operation.

The question of overflow must be taken into account. This means that if one first multiplies by 3, there is an overflow as soon as `b_impl` becomes greater than 255 / 3 = 85. Similarly, one must always be careful of underflows and rounding errors. If one first divides by 2, this is equivalent to a right shift operation, i.e. the last bit is dropped. No distinction can then be made whether `b_impl` has the value 1 or 0. In both cases, the result for `a_impl` and thus also for `a` is the value 0. In fact, the assignment `a = b` only makes sense if the physical ranges are identical (here max. 0 to 510). `b_impl` can therefore assume the maximum value 510 / 3 = 170. An overflow can occur here and must be avoided at all cost. One might think of making a case distinction in the

[1]. At least the formulae ASCET supports

code generation, i.e. first multiply for values from `b_impl` to 170 and first divide for values from `b_impl` greater than 170. But this leads to a requirement for more code. So here, one must accept a negligible error in precision of max. 1.5. within the entire value range. It is clear that the situation itself can become more difficult with regular arithmetic operations with few operands, not to mention complex links and expressions.

C Code Classes and Modules

For the migration of legacy code or for micro-controller peripheral access, one might define classes with the internal behavior of the method specified in C code as well as modules with the internal behavior of processes specified in C. Both C code classes and C code modules already represent implemented code. This code will be integrated verbatim into the executable for the target. Therefore, C code classes and modules are target-dependent. If one changes the target of a project, one has to provide the C code for the actual target too.

Projects for Embedded Microcontrollers

As written above, C code classes and modules can be used to access the peripherals of a microcontroller. The ASCET project editors allow to fully configurate and generate an operating system. Together with the modules representing the control algorithms, projects for embedded microcontrollers can be used as integration platform. In this case, the code generator will examine the OS schedule and the message communication between the modules and generate the tasks, the messages and the access-code[1] of processes to messages. The resulting C code for the project and all its contained modules can be transformed to a `*.hex` file and flashed onto the microcontroller. Needless to say that an ASAP2 file will be generated too containing all variables to be measured as well as all parameters to be calibrated.

However, there are many cases where a build environment and dedicated basic software modules are used for a series production ECU. In this case, typically only the application software, i.e. the control algorithm, is modelled in ASCET[2]. The messages are generated—including the access code of processes—as well as so-called task bodies, i.e. a sequence of processes as specified in the OS editor. This task body can then be copied to an appropriate OS configuration editor (external to ASCET).

1. Typically realized as macro

2. This use-case is often called *additional programmer*

2.1.4 Reuse of the Control Algorithm in Different Kinds of Projects

As written above, all ASCET modelling elements are maintained in a data-base. Furthermore, projects for different targets differ in the number and kind of modules for the same control algorithm.

- Project for closed-loop simulation: This project references the modules for the control algorithm as well as CT blocks.
- Project for rapid prototyping: This project references the modules for the control algorithm (which are the same modules as for the closed-loop simulation) and the realtime-I/O module. The configuration data for the realtime-I/O module is kept at the project
- Project for embedded microcontroller: This project references the modules for the control algorithm as well as the (C code) modules for the peripheral access. If one wants to obtain fixed-point code, one has to attach implementation formulae to modules, classes and projects. Before generating code, one has to the select the appropriate implementation for the project.

ASCET projects can be executed on different execution targets, which might be a PC, a rapid prototyping system, or a production ECU[1]. To run experiments, ASCET provides an integrated experiment environment (or EE for short) if the project runs on a PC or rapid-prototyping system. For ECU experiments, an EE is integrated in the measurement and calibration system INCA[2] because ECU experiments are to some extent similar to the fine-tuning[3] of a control algorithm in the vehicle.

From a software perspective, there are four kinds of experiments:

1. Physical Experiment
2. Quantized Experiment
3. Implementation Experiment
4. Object-Based Controller Implementation Experiment

Only the *physical experiment* does not need any implementation information. The *quantized experiment* needs the quantization, the implementation and object based implementation experiments need additionally the limits and, more important, an integer base type. ASCET control algorithm models are

1. or an evaluation board
2. If the ASCET project consists of CT blocks only and the project runs on a PC or rapid prototyping hardware, the EE is integrated into LABCAR operator.
3. Because of the limited ECU resources for experimenting, dedicated means are necessary which are not in the scope of this paper.

composed of statements whose generated code looks differently depending on the type of the target and the selected experiment. In physical experiments, the physical statements will be resolved to real64 variables with no quantization effects. The quantized experiment uses also real64 variables as basis, but coerces the physical statements in a way that quantization effects will become visible. The *implementation experiment* uses the full implementation information and is based on integer types. This means that the types of the variables in the generated code are the chosen base-types of the implementation and the operators in the physical statements have been transformed to implementation statements.

The *object-based controller implementation experiment* uses the types and implementation statements of the implementation experiment, but the structure of the modules and classes is resolved in a different way. For example, it is possible for every variable in ASCET not only to attach base types, limits and implementation formulae, but also memory classes. The memory classes reflect the memory layout of the employed microcontroller. However, as written above, the object-based controller implementation experiment can only be chosen for production ECUs, and online experimentation can only performed by INCA or any other measurement & calibration tool.

When working with a PC or rapid-prototyping target, and all the implementation information w.r.t. base-type, limit, offset and quantization has been attached to all elements, one can study the effects of implementation formulae or integer base types with respect to the physical environment by just switching the experiment type.

2.1.5 Testing the Technical System Architecture in the Lab

The result of the implementation and integration phase is the technical system architecture, i.e. networked ECUs. These ECUs are tested against plant-models in real-time. The plant-models themselves are augmented by models of the sensors and actuators and dedicated boards being able to simulate the electrical signals as they are expected by the ECU electronics. These kind of systems are called Hardware-in-the-Loop systems (or HiL for short) and consist of processing and I/O boards. The plant model is initialized with different values simulating typical driving manoeuvres. Then, the driving manoeuvre is simulated on the HiL and providing ECU sensor data as output and accepting ECU actuator data as input. This way it can be checked whether the ECU integration was successful. HiL testing is represented by the arrow labelled 4 in Fig. 2-1 on page 15.

2.1.6 Testing and Honing of the Technical System Architecture in the Vehicle

As written above, there are many use cases where plant models are not detailed enough to represent the vehicle's dynamics. Though a lot of calibration activities can nowadays be done by means of HiL-systems, final honing of a vehicle's control algorithm still needs to be done with the production software in a production ECU in a real vehicle. This requires that the technical system architecture is built into a vehicle and tests are done on a proving ground. This kind of fine-tuning only concerns the parameter setting of the control algorithm.

2.2 Using ASCET in a Production Environment

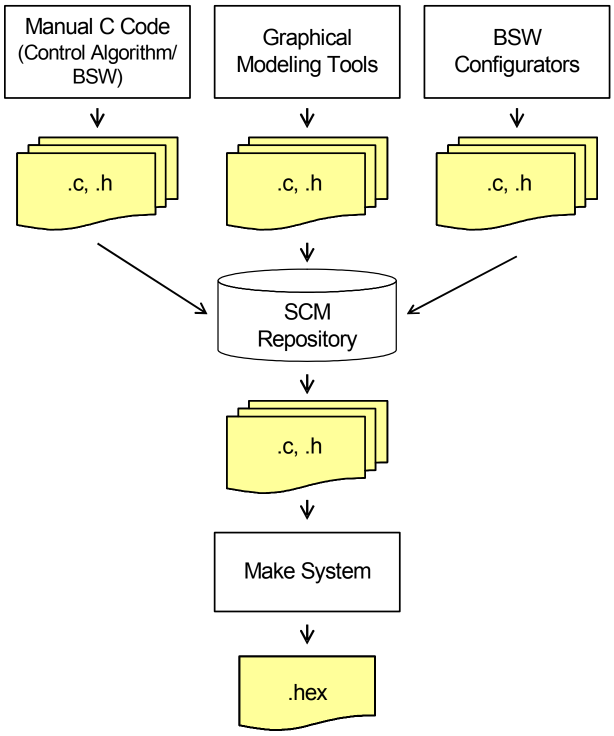


Fig. 2-4 Advanced Software Production Environment

In a manual coding environment, there are typically several software developers providing the C code for the control algorithm as well as for the basic software modules, including the operating system. Then there is an ECU integrator collecting all necessary source code files and starting the so-called make toolchain, which starts the compiler and linker. The C code is transferred between the software developers by using the file-system on the one hand and a source-code management (SCM) system[1] on the other. The latter is a database holding different versions of the source code files but also allowing the creation and maintenance of configurations. The latter are used as a baseline to generate/integrate ECU software. To see differences between two versions of a C code file, difference browsers highlighting the changes in the program text are used. In the last decade, intensive use of SCM systems and difference browsing contributed considerably to the enhanced quality of embedded automotive software.

In advanced software production environments, some of the C files for control algorithms are generated from control algorithm models, e.g. an implemented ASCET model, while a lot of C files for basic-software modules, e.g. OS and COM stack, are generated by so-called configurators. Leaving the ASAM-MCD-2MC file generation aside, such an advanced production environment is shown in Fig. 2-4 on page 29. It shows the C code-generating entities, the SCM database as well as the make system. Looking deeper in such an advanced production environment, and focussing on the model-based generation of C code for control algorithms with ASCET, one will realize that the models, which are the basis for the source code, will evolve in the course of the control algorithm development, e.g. incorporating the results of rapid prototyping. Hence, the models have to be maintained in the SCM database too.

ASCET components are stored in a local database. The local database holds exact one version of the model. The ASCET-SCM interface establishes a link from the local database to the SCM repository and enables the model exchange. This model exchange is shown in part (a) of Fig. 2-5 on page 31. Since, in source-code development, difference-browsing between different versions is indispensable, a similar feature is highly desirable in model-based development, too. The ASCET-SCM interface can be enhanced by the so-called Model-Diff-Browser, thus highlighting, e.g., an additional message in the block diagram editor of a module.

2.2.1 Model Conversion

As written above, the development of embedded real-time software is driven both by control engineers and computer scientists. Sometimes, there are development processes which start control software development either from a totally behavioral driven point of view or a totally structural driven point of view, and sometimes even from both views independently of each other.

[1]. Typical SCM systems are CVS and SubVersion

While ASCET (and AUTOSAR) integrates both approaches with its orthogonal approach, one might want to take over models stemming from a pure behavioral or structural approach.

In the behavioral domain, MATLAB®/Simulink® is a quite popular approach to model closed-loop control algorithms without bothering, at least for PC simulation, with too many structuring details. After having performed the PC simulation, the control algorithm parts might be taken over to an ASCET module or class as block diagram specification, while the plant parts might be represented as ASCET CT blocks.

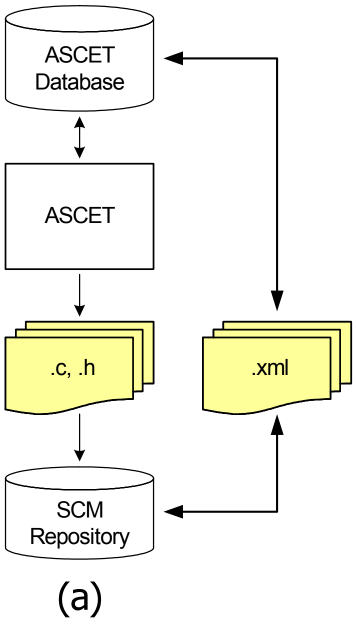


Fig. 2-5 ASCET-SCM interface with (b) and without (a) Diff-Browsing facility

In the structural domain, UML has a certain popularity in both its 1.4 or 2.0 guises. Besides very simple class and object diagrams, interaction and collaboration diagrams are used to display complex interactions, e.g. in vehicle access systems or diagnostics. Sometimes, the classes, objects and their interaction shall be refined in ASCET models so that the natural equivalent in ASCET of UML, i.e. classes and objects, reflect the object interaction by means of sequence calls. Embedding the objects in ASCET real-time objects not only add the real-time perspective to the UML models, but also allow model execution.

The model-to-model converter (or M2M for short), a tool provided by the ETAS partner Aquintos, allows these kind of structural and behavioral transformations. It is available for UML 1.4 products and MATLAB/Simulink.

2.3 Summary

Model-based design and implementation of control algorithms is supported by ASCET for several development stages. The employed abstraction means allow to use the physical control algorithm model as backbone for all subsequent implementation annotations throughout the course of development. In particular, no blocks need to be replaced when changing the target. Employing the SCM interface with difference browsing, ASCET can be seamlessly integrated in an ECU production development environment.

3 ASCET and AUTOSAR

This chapter describes the cooperation of ASCET and AUTOSAR. Chapter 3.1 overviews the purpose of AUTOSAR, chapter 3.2 describes the AUTOSAR runtime environment (RTE), chapter 3.3 lists the AUTOSAR elements supported by ASCET.

This chapter contains no detailled introduction to AUTOSAR; see chapter 8 "Appendix C: AUTOSAR" on page 161 for more details. The AUTOSAR documents can be found at the AUTOSAR website: http://www.autosar.org/

3.1 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.

3.1.1 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.

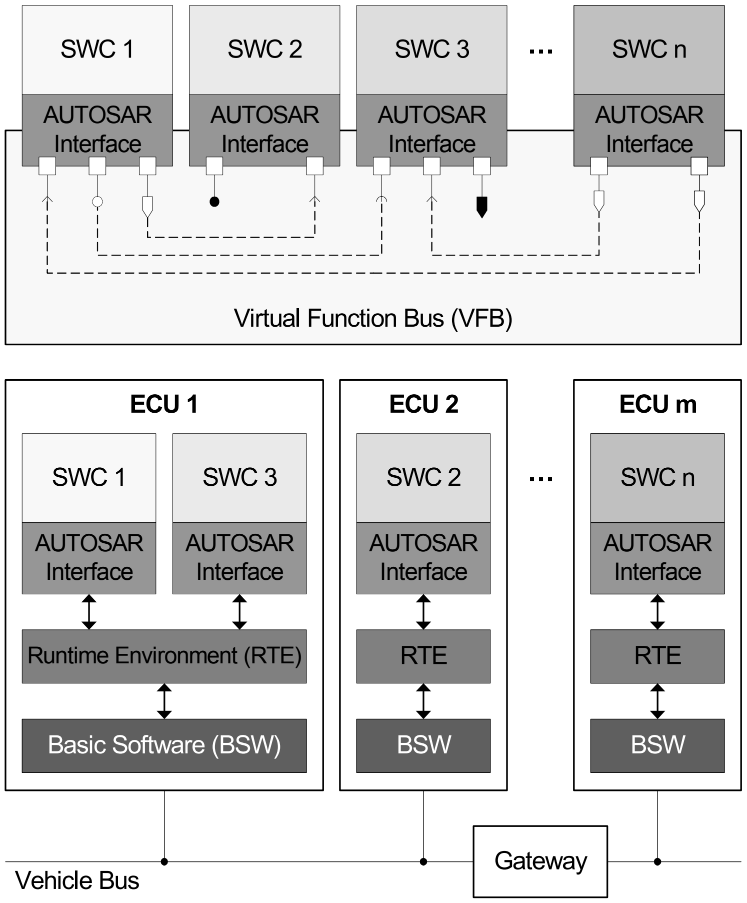


Fig. 3-1 AUTOSAR software component (SWC) communications are represented by a virtual function bus (VFB) implemented through the use of the runtime environment (RTE) and basic software (BSW).

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 has been supplying the auto industry with automotive operating systems for more than a decade: ERCOS^{EK} and now RTA-OSEK. The *RTA-RTE* AUTOSAR Runtime Environment and *RTA-OS* AUTOSAR Operating System (probably available in the third quarter of 2008) will extend the RTA product portfolio with support for the key AUTOSAR software modules. RTA-OSEK currently supports AUTOSAR OS Scalability Class 1.

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

3.1.2 Creating AUTOSAR Software Components

In addition to an AUTOSAR authoring tool, which provides initial descriptions of the system architecture and AUTOSAR interfaces, ASCET allows defining and implementing the behavior of AUTOSAR-compliant vehicle functions.

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.

ASCET V6.0 supports AUTOSAR SWC descriptions and the generation of AUTOSAR-compliant SWC production code according to AUTOSAR V2.1.

3.2 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:

1. be implemented without reference to an ECU (the VFB model); and
2. 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

- 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 realisation 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.

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.

3.3 AUTOSAR Elements in ASCET

The following AUTOSAR elements are supported in ASCET:

3.3.1 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, how the SWC behaves, 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 delcare one uniquely named variable of that type (one or more SWC instance).

3.3.2 Ports and Interfaces

In the VFB model, software components interact trough ports which are typed by interfaces. The *interface* controlls 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.

ASCET V6.0 supports one interface type:

- sender-receiver (signal passing)

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

If a system is built from SWC instances, the Rports and Pports of the instances are connected. One sender must be connected with one receiver.

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.

Sender-receiver communication can be "`1:n`" (one sender, several receivers) or "`n:1`" (several senders, one receiver). In the second case, no synchronization is imposed on the senders.

3.3.3 Runnable Entities and Tasks

A *runnable entity* is a piece of code in an SWC that is triggered by the RTE (cf. chapter 3.2) at runtime. It corresponds largely to the processes known in ASCET.

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. ASCET supports runnable entities of category 1.

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

3.3.4 Runtime Environment

The runtime environment is described in chapter 3.2.

4 Tutorial

The tutorial mainly addresses users who are new to ASCET. It describes the use of ASCET using practice-oriented examples. The entire tutorial contents are subdivided into short individual components based on each other. Before you start working on the tutorial, you should have read chapter "Embedded Automotive Control Software Development with ASCET" on page 13.

4.1 A Simple Block Diagram

In ASCET you use components, such as classes and modules, as the main building blocks of your applications. You can either use predefined components, which come with ASCET or have been developed earlier, or create your own, which is what you will be doing in this tutorial.

In ASCET components are usually specified graphically. Once all the components have been specified, they are assembled into a project, which forms the basis of an ASCET software system. A software system consists of C code that has been generated from the graphical model description, and which can be run on a microcontroller or experimental target computer.

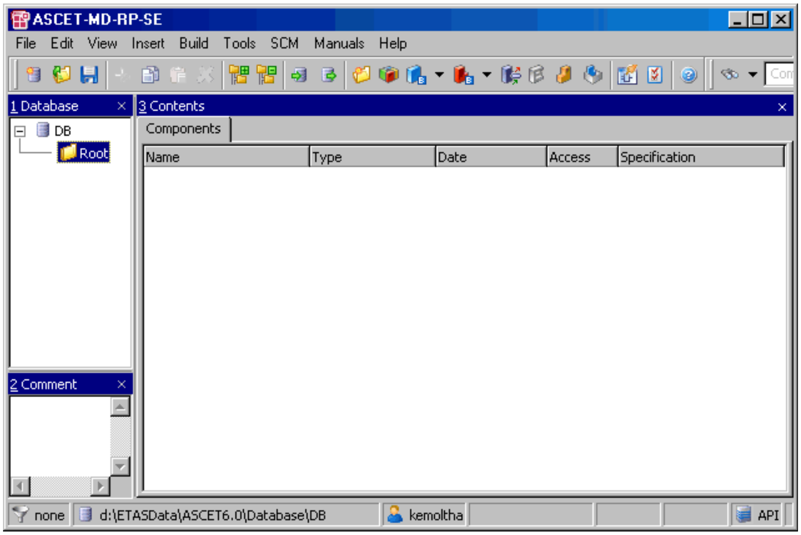
4.1.1 Preparatory steps

Before you can start, you have to open a database to work in. All the components of this tutorial will be stored in this database, so you will only have to do this once.

All components and projects for this tutorial can be found in the folder called `ETAS_Tutorial_Solutions` in the database `tutorial`. It is therefore not necessary to specify all the components described here yourself .

It is, however, advisable to specify at least the components of lessons one, three and four, to get some practice using ASCET.

At the start of ASCET, the Component Manager opens, loading the database that was last opened.



It is recommended that you create a new database for the tutorial to keep the data transparent.

To create a new database:

- In the Component Manager, select **File** → **New Database**

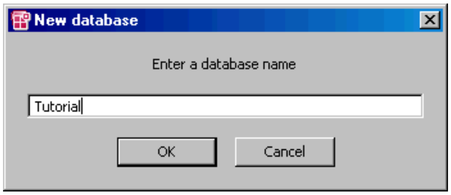
or

- click on the **New** button

or

- press <CTRL> + <N>.

  The "New database" window opens.



- Enter the name `Tutorial`.
- Click on **OK**.

  The new database, containing only the database name and the `Root` folder, opens.

To open a database:

When the `Tutorial` database already exists, proceed as follows:

- In the Component Manager, select **File** → **Open Database**

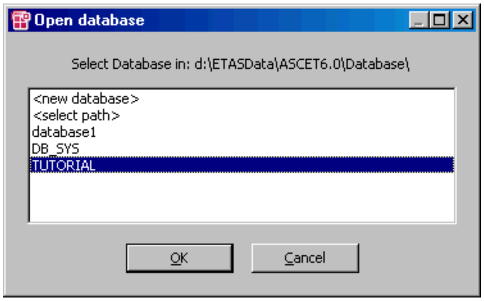
or

- click on the **Open** button

or

- press <CTRL> + <O>.

  The "Open Database" dialog box is displayed. It contains a list of the databases in the current database path.



Select Database in: d:\ETASData\ASCET6.0\Database\

```
<new database>
<select path>
database1
DB_SYS
TUTORIAL
```

- If the `Tutorial` database is on the list, select it and click on **OK**.

  The Component Manager displays the contents of the `Tutorial` database.

- If the `Tutorial` database is stored somewhere else, use the `<select path>` option to specify the database and click on **OK**.
- In the "Select database path" window, select the database and click on **OK**.

The first step in creating your own components is to create a new top level folder named `Tutorial` and a subfolder named `LessonN` for each lesson.

To create a new folder:

- In the "1 Database" field, select the database name.
- Select the menu item **Insert** → **Folder**

or

- click on the **Insert Folder** button

or

- press <INSERT>.

  A new top-level folder named `Root` appears in the "1 Database" pane.
- Change the name of the top-level folder to `Tutorial`. You can type over the highlighted name and then press <ENTER>.
- Select the folder `Tutorial`.
- Select **Insert** → **Folder** once again.

  A new folder named `Folder` is created in the "1 Database" pane.
- Change the name of the new folder to `Lesson1`.

All the components you create in this tutorial will be stored in a `LessonN` folder. You should create a new folder for every lesson. Every database has at least one top-level folder which can have any number of subfolders.

Note

All folder and item names and the names of variables and methods they contain must comply with the ANSI C standard.

You can proceed by creating your first component in the `Lesson1` folder.

To create a component:

- In the "1 Database" pane, click on the folder `Lesson1`.

- Select **Insert** → **Class** → **Block Diagram**.

  A new component named `Class_Block-diagram` appears in the "1 Database" pane under the `Lesson1` folder. This component is of type *class*, which is frequently used in ASCET.

- Change the component name to `Addition`.

4.1.2 Specifying a Class

After you have created a new component in the `Tutorial/Lesson1` folder you can specify its functionality. First define the interface for the component, i.e. its methods, arguments and return values. Then draw a block diagram that specifies what the component does.

To specify the functionality of a component:

- In the "1 Database" pane, select the component `Addition`.
- To open the component, select **Edit** → **Open Component**

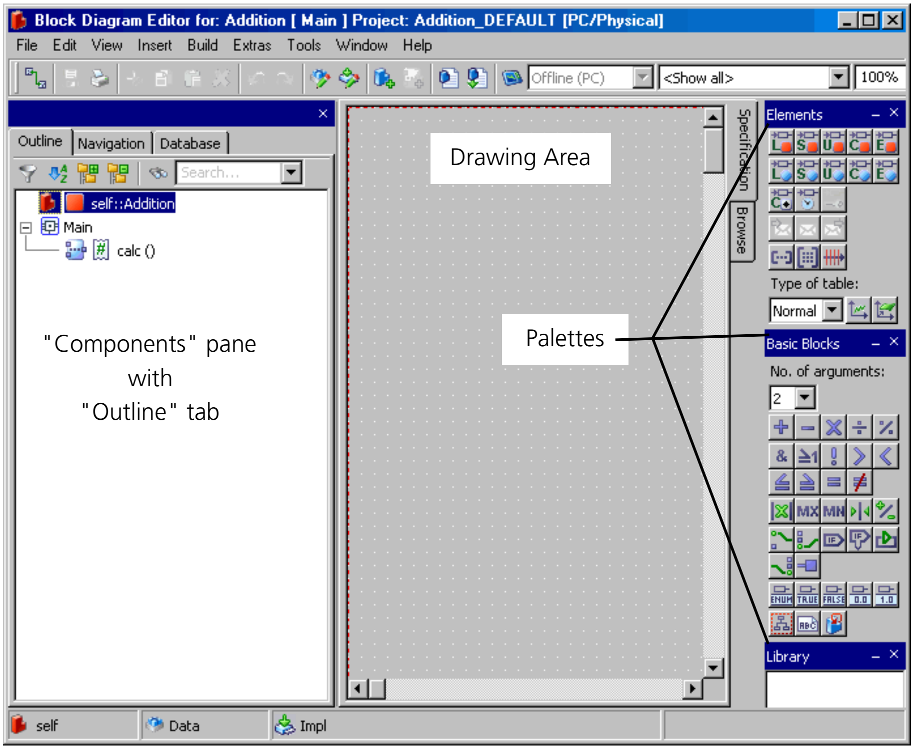
or

- double-click on the component

or

- press <RETURN>.

  The block diagram editor opens. This is the main window for specifying component functionality.



- In the "Outline" tab, select the method `calc`. This method is created by default.
- Select **Edit** → **Rename**

or

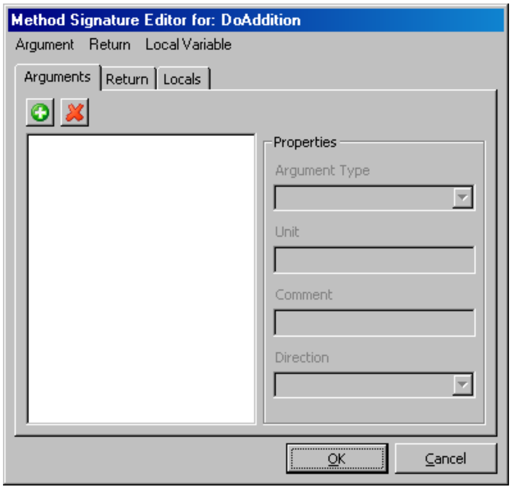
- press <F2>.

  The name of the method `calc` is highlighted.
- Change the name of the method to `doAddition`.
- Select **Edit** → **Properties**

or

- double-click on the method name.

  The signature editor for the method opens.



Every class needs at least one method. Methods in ASCET are similar to methods in object-oriented programming, or functions in procedural programming languages. A method can have several arguments and one return value (these are all optional). Arguments are used to transmit data to a component. Return values are used to return results of calculations within the component to the "outside".

To specify the method signature, you can add two arguments of type `continuous` and a return value using the signature editor.

To specify the method signature:

- In the signature editor, select **Argument** → **Add**.

  A new argument called `arg` appears in the "Arguments" pane.
- Change the name of the argument to `input1`.
- Add another argument called `input2`.

  By default the data type of the arguments is set to *continuous* (or *cont* for short), which is what you need in the example.

- Activate the "Return" tab of the signature editor.
- Activate the **Return Value** option.

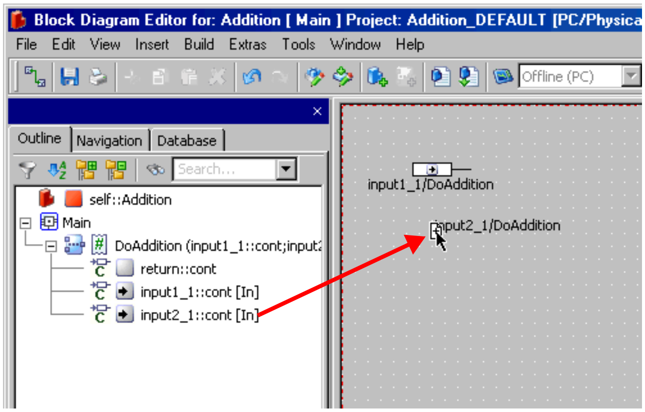
  The type of the return value is also set to *cont* by default.
- Click on **OK** to close the signature editor.

The names of the arguments and the return value for the method `doAddition` appear below the method in the "Outline" tab on the left of the Block Diagram Editor. Now you can specify the functionality of the component by drawing a block diagram.

To specify the functionality of the component `Addition`:

- Drag the first argument from the "Outline" tab and drop it onto the drawing area of the block diagram editor.

  The symbol for the argument appears in the drawing area.


Block Diagram Editor for: Addition [Main] Project: Addition_DEFAULT [PC/Physica
File Edit View Insert Build Extras Tools Window Help
Offline (PC)
Outline
Navigation
Database
Search...
self::Addition
Main
DoAddition (input1_1::cont;input2
return::cont
input1_1::cont [In]
input2_1::cont [In]
input1_1/DoAddition
input2_1/DoAddition

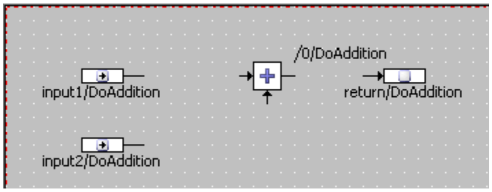
- Now add the other argument and the return value using the same drag-and-drop process.
- Click on the **Addition** button in the "Basic Blocks" palette.

  The mouse is loaded with an addition operator.

- Click inside the drawing area, between the symbols for the argument and for the return value.

  An addition symbol is displayed. By default it has two input pins (indicated by arrows) and one output pin. The output pin is located on the right.

You can now arrange the elements and the operator by dragging them to their places on the drawing area. Next, you need to connect the elements to specify the flow of information.



To connect the diagram elements:

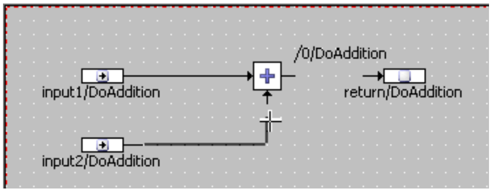
- Click on the **Connect** button in the "General" toolbar.
- Alternatively, you can right-click in the drawing area (but not on an element).

  The cursor changes to a crosshair when it is inside the drawing area.
- Click on the output pin of the first argument symbol to begin a connection.

  Now, as you move the mouse cursor, a line is drawn after it. Every time you click inside the drawing area, the line remains fixed up to that point. That way you can determine the path of the connection line

- Click on the left input of the addition symbol.

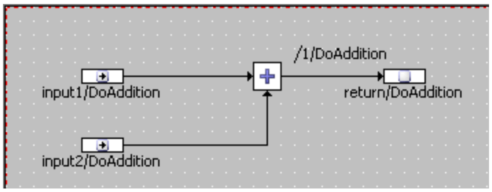
  The argument symbol is now connected to the input of the addition symbol.



- Connect the second argument symbol with the other input of the addition symbol.
- Connect the return value symbol with the output of the addition symbol.

  The connection between the addition operator and the return value is displayed as a green line to indicate that the sequencing for this operation needs to be determined.
- Select **Tools** → **Sequence Calls** → **Sequencing** → **Ignore Current** to determine the addition sequence automatically.

  The connection between the addition operator and the return value is displayed as a black line.

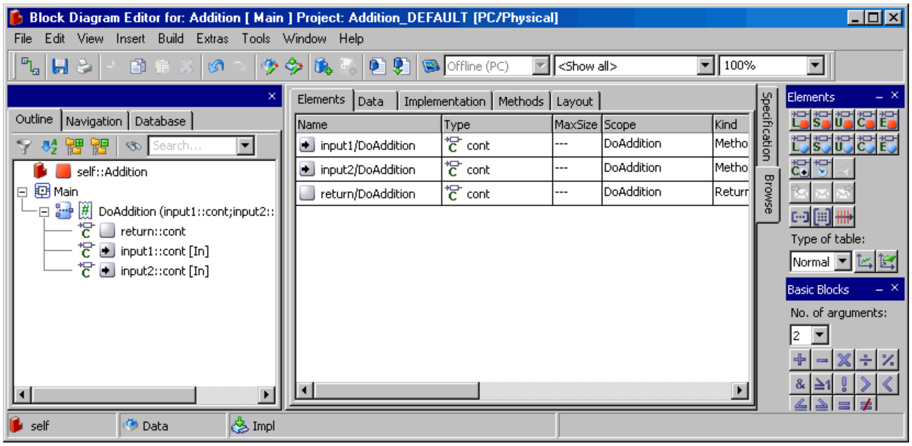


Component specification is now complete. The last step in editing your component is to specify its layout, i.e., the way it is displayed when used within other components.

To edit the layout of a component:

There are two ways to edit a layout:

- Use the **Browse** tab to go to the "Browse" view.



Block Diagram Editor for: Addition [Main] Project: Addition_DEFAULT [PC/Physical]

Offline (PC)
<Show all>
100%

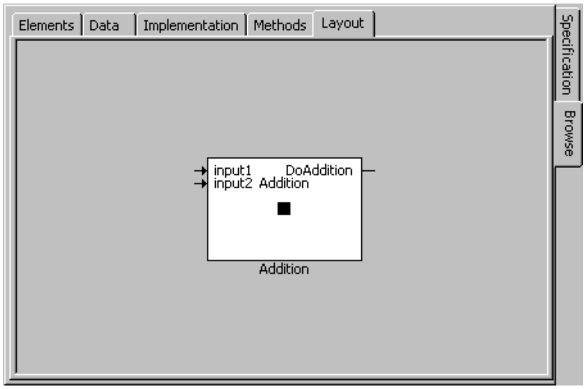
self::Addition
Main
DoAddition (input1::cont;input2::
return::cont
input1::cont [In]
input2::cont [In]

Name	Type	MaxSize	Scope	Kind
input1/DoAddition	cont	---	DoAddition	Metho
input2/DoAddition	cont	---	DoAddition	Metho
return/DoAddition	cont	---	DoAddition	Returr

Type of table: Normal

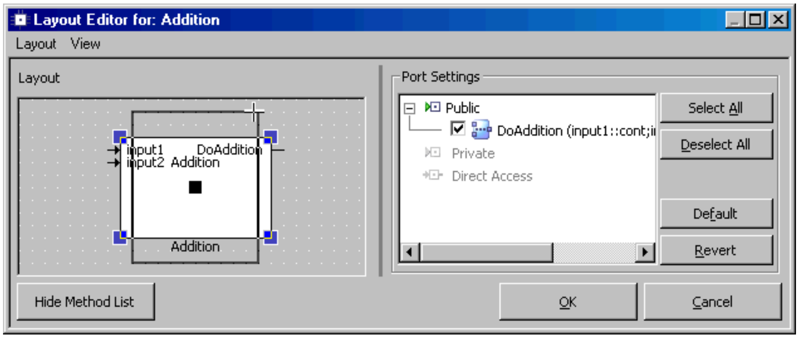
No. of arguments: 2

- Double-click in the "Layout" tab to open the Layout Editor.



- Alternatively, select **Edit** → **Component** → **Layout**.

  The Layout Editor opens.



- Resize the block by clicking on it and then dragging the handles to the size you want.
- Drag the pins of the arguments and the return value to create a symmetrical design.
- Click on **OK**.

Now that you have finished your component, the last step in this lesson is to save the component in the database.

To save the component `Addition`:

- Select **File** → **Save** and close the block diagram editor.
- In the Component Manager, click on the **Save** button.

  Your work is not written to disk until you perform this operation.

  When you select **Save** in the block diagram editor, the changes are only stored in the cache memory. It is therefore advisable to click **Save** in the Component Manager regularly as work progresses.

  You can have your changes saved automatically by activating the appropriate user options (see the ASCET online help) for your ASCET session.

As an optional exercise, you could now model the same functionality in *ESDL* (ESDL: *Embedded Software Description Language*). If you continue with this exercise, you will familiarize yourself with the ESDL editor and will learn how to use the external source code editor.

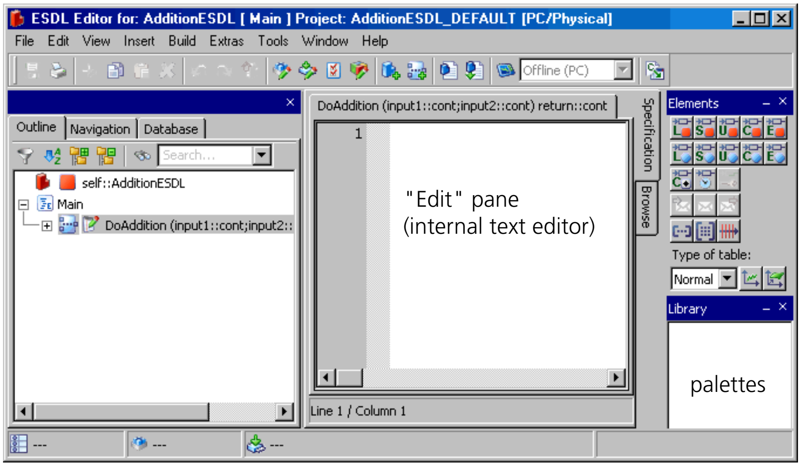
The first step is to copy the module interface to a new module with type ESDL and rename it. Then create the functionality you want either directly in the ASCET ESDL editor or use the external text editor.

To copy and specify the component `Addition`:

- In the "1 Database" pane of the Component Manager, select the component `Addition`.
- From the context menu select **Edit** → **Reproduce As** → **ESDL**.

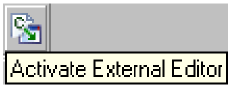
  A copy of the component is created; it is named `Addition1`.
- Rename the new component `AdditionESDL`.
- In the "1 Database" list, double-click on the name of the new component.

  The ESDL editor for `AdditionESDL` opens, making various functionalities available for editing.


ESDL Editor for: AdditionESDL [Main] Project: AdditionESDL_DEFAULT [PC/Physical]
File Edit View Insert Build Extras Tools Window Help
Offline (PC)
Outline Navigation Database
Search...
self::AdditionESDL
Main
DoAddition (input1::cont;input2::
DoAddition (input1::cont;input2::cont) return::cont
1
"Edit" pane
(internal text editor)
Line 1 / Column 1
Specification
Browse
Elements
Type of table:
Normal
Library
palettes

- Now enter this functionality in the "Edit" pane of the internal text editor:

```
return input1 + input2;
```



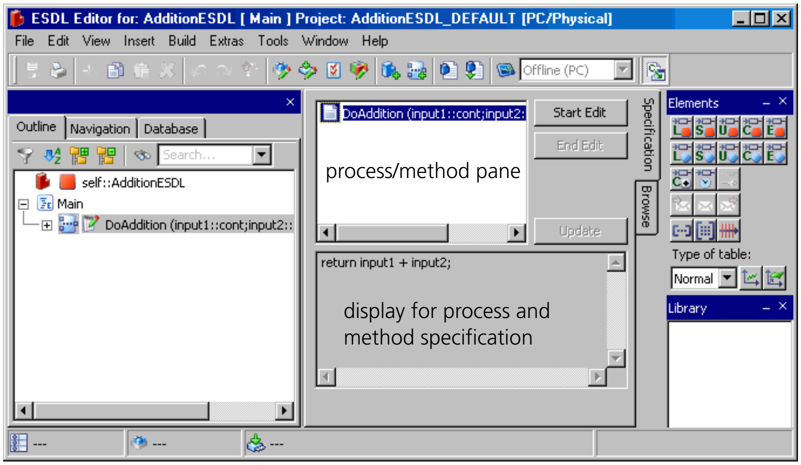
- Use the **Activate External Editor** button to switch to external editor mode.

  You are asked if you want to save your changes.

- Confirm with **Yes**.

  The changes are saved, and the ESDL editor switches to "external editor" mode.

  The editor looks different in "external editor" mode.


ESDL Editor for: AdditionESDL [Main] Project: AdditionESDL_DEFAULT [PC/Physical]
File Edit View Insert Build Extras Tools Window Help
Offline (PC)
Outline Navigation Database
Search...
self::AdditionESDL
Main
DoAddition (input1::cont;input2::
DoAddition (input1::cont;input2:
Start Edit
End Edit
Update
process/method pane
Specification
Browse
display for process and method specification
Elements
Type of table:
Normal
Library


```
return input1 + input2;
```

- In the process/method pane, select the method or process you want to specify.

  The functionality entered previously appears in the specification field, and the **Start Edit** button is activated.

- Activate the external editor with **Start Edit**.

Note

When the external editor starts up, the application associated with the file endings `*.c` and `*.h` in the operating system register database is called. Data transfer is done via temporary files; this is why you have to ensure the files are saved before closing the editor or before transferring to the ESDL editor.

The **End Edit** and **Update** buttons are now activated, whilst the **Start Edit** button is deactivated.

- Edit the functionality in the external editor.
- Save the functionality in the external editor.
- In the ESDL editor, click **Update**, to transmit the data from the external editor.
- After you have finished, click **End Edit** to close the connection to the external editor.

  The external editor remains open after you have clicked on **End Edit**. However, you cannot transmit any more changes to the ESDL editor.
- Click on **Activate External Editor** a second time to end the external editor mode.
- Select **Build** → **Analyze Diagram** to check the code you entered.

  Errors are listed in the ASCET monitor window.

4.1.3 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Opening a database
- Creating and naming a folder
- Creating and naming a component
- Defining the interface for a method
- Placing diagram elements on the drawing area
- Connecting diagram elements

- Editing the layout of a component
- Switching between Specification and Browser views.
- Saving a component.
- Copying a component interface.
- Using the ESDL editor.
- Using the external editor.

4.2 Experimenting with Components

Having created the `Addition` or `AdditionESDL` components, you can now experiment with them. Experimentation allows you to see how the component works, just as it would in a real application. The experimentation environment provides a variety of tools that can show the values of inputs, outputs, parameters and variables within a component.

4.2.1 Starting the Experimentation Environment

The experimentation environment is called from the block diagram or the ESDL editor. First open it with the component you want to experiment with.

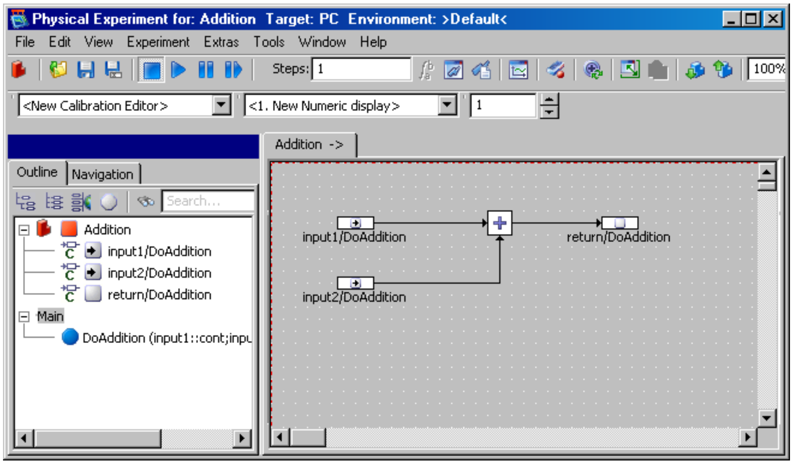
To start the experimentation environment:

- From the ASCET Component Manager, open the block diagram editor for your `Addition` in the `\Tutorial\Lesson1` folder.
- In the block diagram editor, select **Build → Experiment**.

  The code for the experiment is generated. ASCET analyses the model in your specification and generates C code that implements the model. It is possible to generate specific code for different platforms.

  In your example, you simply use the default settings to generate code for the PC.

  After the code has been generated and compiled, the experimentation environment opens.



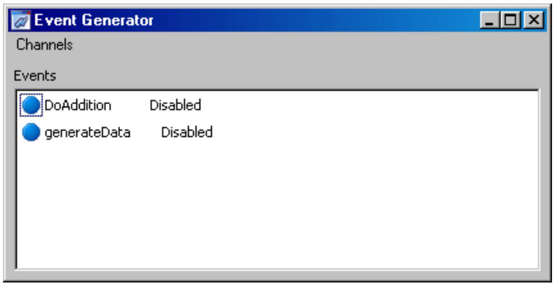
4.2.2 Setting up the Experimentation Environment

Before you can start experimenting, you have to set up the environment, which means determining the input values generated for the experiment and how you want to view the results. You have to carry out three steps. First set up the event generator, then the data generator and finally the measurement system.

To set up the Event Generator:

- Click on the **Open Event Generator** button.

  The "Event Generator" window opens. For each method to be simulated, you need to create an event and also a `generateData` event. The events simulate the scheduling performed by the operating system of a real application.

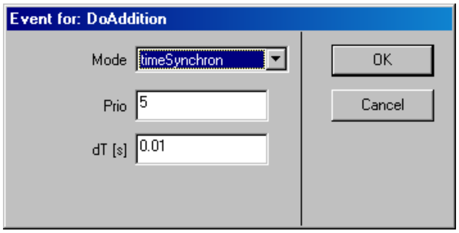


DoAddition	Disabled
generateData	Disabled

- Select the event `DoAddtion`.
- Select **Channels** → **Enable.**
- Select the event `DoAddtion` again.
- Select **Channels** → **Edit**.

  Both functions are also available via the context menu in the "Elements" field.

  The "Event" dialog window opens.



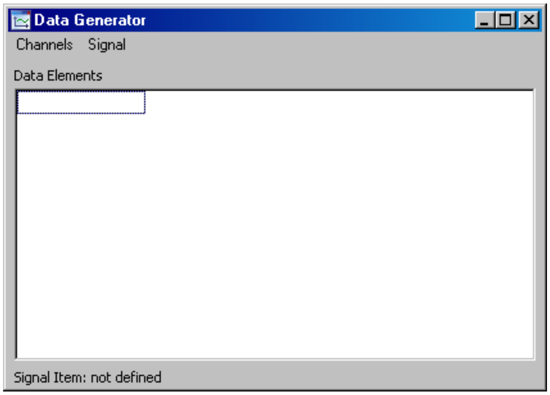
Mode: timeSynchron
Prio: 5
dT [s]: 0.01

- Set the `dT` value to 0.001.
- Click on **OK**.
- In the event generator, select the `generateData` event and set its `dT` value to 0.001.
- Close the "Event Generator" window.

To set up the Data Generator:

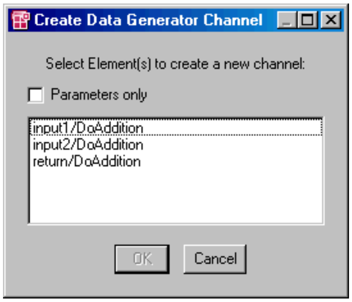
- Click on the **Open Data Generator** button.

  The "Data Generator" window opens.



- Select **Channels** → **Create**.

  The "Create Data Generator Channel" dialog window opens.


Create Data Generator Channel

Select Element(s) to create a new channel:

☐ Parameters only

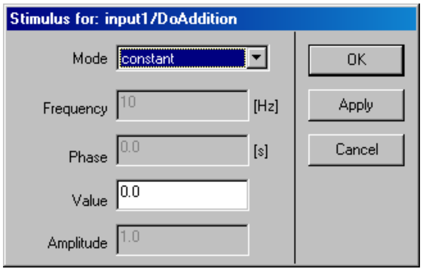
input1/DoAddition
input2/DoAddition
return/DoAddition

- Select the `input1/DoAddition` and the `input2/DoAddition` variables from the list.
- Click on **OK**.

  Now both inputs are listed in the "Data Elements" pane of the "Data Generator" window.

- Select `input1/DoAddition` in the "Data Elements" pane.
- Select **Channels** → **Edit**.

  The "Stimulus" dialog box appears.



Stimulus for: input1/DoAddition

Mode: constant

Frequency: 10 [Hz]

Phase: 0.0 [s]

Value: 0.0

Amplitude: 1.0

- Set the values as follows.

Mode:	sine
Frequency:	1.0 Hz
Phase:	0.0 s
Offset:	0.0
Amplitude:	1.0

- Click on **OK** to close the "Stimulus" dialog pane.
- Set the values for `input2` as follows:

Mode:	sine
Frequency:	2.0 Hz
Phase:	0.0 s
Offset:	0.0
Amplitude:	2.0

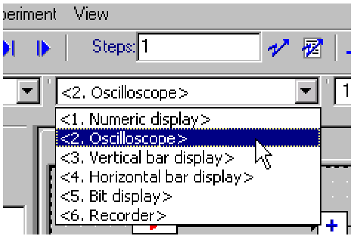
- Close the "Data Generator" window.

With these settings you get two sine waves with different frequencies and different amplitudes. The `Addition` component adds the two waves and displays the resulting curve.

In order to see the three curves displayed on an oscilloscope, you will now set up a measurement system.

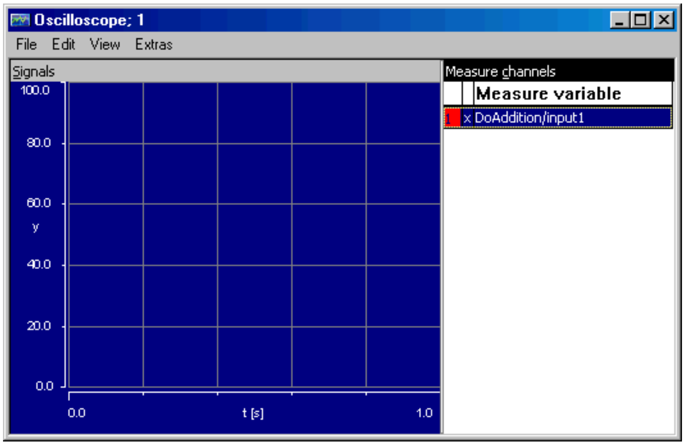
To set up the measurement system:

- In the "Physical Experiment" window, select `<2. New Oscilloscope>` as data display type from the "Measure View" combo box.



- In the "Outline" tab, expand the elements list.
- Select `input1/DoAddition`.
- Select **Extras** → **Measure**.

  An oscilloscope window opens with `input1` as measurement channel. The "Measure view" list in the experimentation environment is updated to display the title of the measurement window.



- In the "Outline" tab of the "Physical Experiment" window, select `input2/DoAddition`.

- Select **Extras** → **Measure**.

  `input2` is added to the oscilloscope as measure channel.
- Add `return/doAddition` to the measurement window.
- In the experimentation environment, select **File** → **Save Environment**.

Now the experimentation environment is set up, and you are ready to start the experiment. Since you have saved the experiment, it is automatically reloaded next time you start the experimentation environment for this component.

4.2.3 Using the Experimentation Environment

The experimentation environment provides a set of tools that allow you to view the values of all the variables in your component and also change the setup while the experiment is running. You can also adjust the way the values are displayed and choose from several ways of displaying them.

To start the experiment:

- In the "Physical Experiment" window, click on the **Start Offline Experiment** button.

  The experiment starts running and the results are displayed in the oscilloscope.
- Click the **Stop Offline Experiment** button to stop the experiment.

You will only see a small portion of the curves on the oscilloscope. To display the curves on the oscilloscope, you need to alter the scale on the value axis.

To change the scale on the oscilloscope:

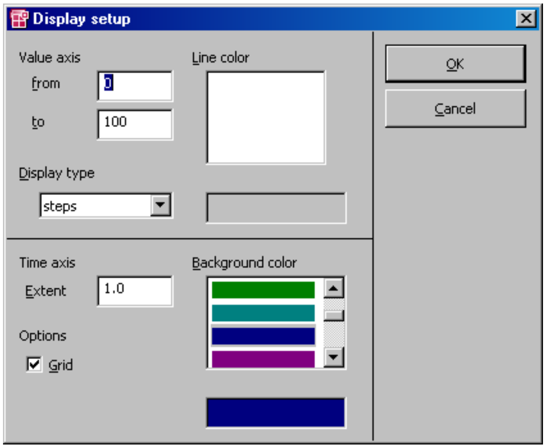
- Select all three channels from the "Measure Channels" list in the oscilloscope window.

  Hold the <CTRL> key while clicking on individual channels to select multiple items.

  Now all the data elements are highlighted, so the changes you make will affect all three of them.

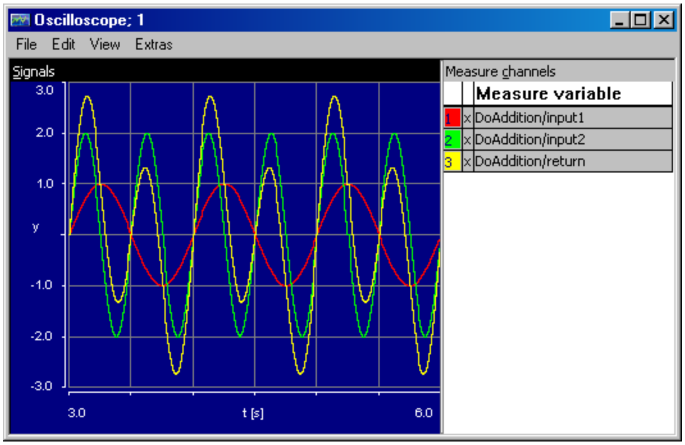
- Select **Extras** → **Setup**.

  The "Display Setup" dialog box appears.



Value axis from: 0
to: 100
Display type: steps
Time axis Extent: 1.0
[✓ Grid]

- Set the "Value Axis" to a range of -3 to 3.
- Set the "Time Axis Extent" to 3.
- Select a background color in the "Background color" list.
- Press <ENTER>.



	Measure variable
1 x	DoAddition/input1
2 x	DoAddition/input2
3 x	DoAddition/return

The oscilloscope now shows the output with the appropriate scaling on the value axis. You will see the two input sine waves, together with the wave resulting from their addition. You can now adjust the input values to see how the output is affected.

To change the input values for experimentation:

- In the "Physical Experiment" window, select **Tools** → **Data Generator** to open the "Data Generator" window.
- In the data generator, select the variable you want to change.
- Select **Channels** → **Edit**.

  The "Stimulus" dialog window opens.
- Adjust the values you want to change.
- Click **Apply**.

The curves in the oscilloscope change according to the new settings. You can change all the settings in the experimentation environment while the experiment is running.

4.2.4 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

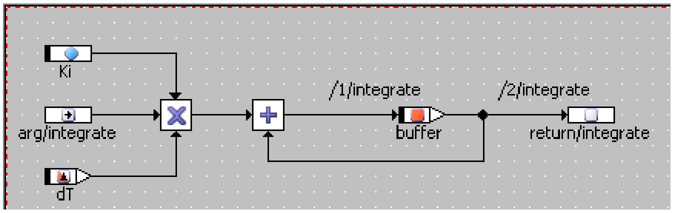
- To call the experimentation environment
- Setting up the event generator
- Setting up the data generator
- Setting up the measuring system
- Starting and stopping the experiment
- Saving the experiment
- Changing stimuli while the experiment is running

4.3 To Specify a Reusable Component

In this lesson you will create a class that implements an integrator, a standard piece of functionality that is often used in microcontroller software. While this is a slightly more complex diagram, the techniques for creating and experimenting with it are the same ones you have learned already.

In this example, you specify an integrator that calculates the distance covered where time and speed are known. The input value will be given in meters per second, and at each interval multiplied with a `dT` in seconds. The value for each time slice is added up in an accumulator. The accumulator stores the distance in meters that has been covered after a certain length of time.

In ASCET, a standard block, such as an accumulator, can be realized with a simple diagram.



4.3.1 Creating the Diagram

Before you start working on the diagram, you need to perform the same steps as for the `addition` component. First create a new folder in the `Tutorial` folder, then add a new class. Finally, you can specify the interface of the methods, then the block diagram and the layout.

You will start by creating the folder and the new class.

To create the integrator class:

- In the Component Manager, open the `Tutorial` folder.
- Create a new folder and call it `Lesson3`.
- In the `Lesson3` folder, create a new class and call it `Integrator`.

To define the integrator interface:

- In the "1 Database" pane, select the element `Integrator`.
- Double-click on the element or select **Edit** → **Open Component**.

  The block diagram editor opens.
- Rename the method `calc` to `integrate`.

- Edit the method `integrate` by adding one argument (type `cont`) and a return value (type `cont`).
- Place the argument and return value from `integrate` on the drawing area.

The integrator uses two new types of elements that we have not used before: a variable and a parameter.

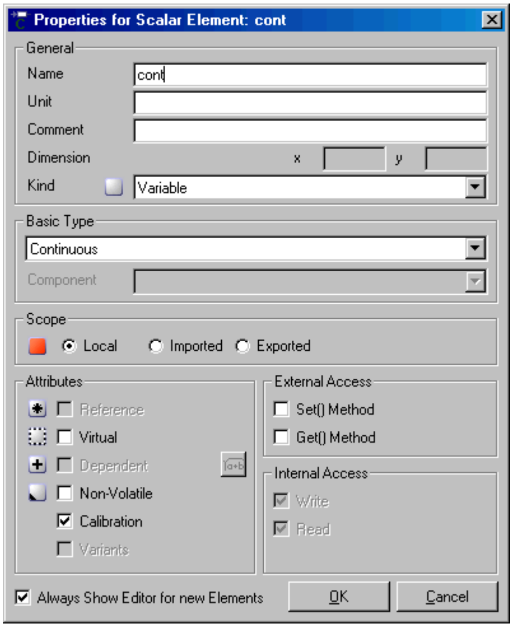
Variables are used in the same way as they are used in programming languages; you can store values in them and read the values for further calculations. In contrast, *parameters* are read-only. They can only be changed from outside, e.g. they can be calibrated in the experimentation environment, but they cannot be overwritten by any of the calculations within the component itself.

In addition, we want to specify a *dependent parameter* in this example. However, it is irrelevant for the functionality of the integrator. A *dependent parameter* is dependent on one or several parameters, i.e. its value is calculated based on a change in another one. The calculation or dependency is only carried out on specification, calibration or application. A dependent parameter behaves in exactly the same way in the target code as a normal parameter.

To create a variable:

- Click on the **Continuous Variable** button in the "Elements" palette.

  The properties editor opens.



Properties for Scalar Element: cont

General

Name: cont

Unit:

Comment:

Dimension x y

Kind: Variable

Basic Type: Continuous

Component:

Scope: [✓ Local] Imported Exported

Attributes: Reference, Virtual, Dependent, Non-Volatile, [✓ Calibration], Variants

External Access: Set() Method, Get() Method

Internal Access: [✓ Write] [✓ Read]

[✓ Always Show Editor for new Elements]

- In the "Name" field, enter the name `buffer`.
- Click **OK**.

  The variable is now named `buffer`. The cursor shape changes to a crosshair. It is loaded with the continuous variable.

- Click inside the drawing area to place the variable.

  The variable is placed in the drawing area. Its name is highlighted in the "Outline" tab.

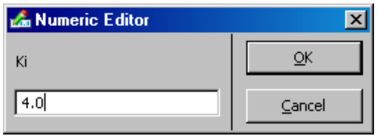
When the properties editor does not open automatically, place the variable in the drawing area. Afterwards, double-click on the variable in the "Outline" tab to open the properties editor manually. Make the required settings and activate the **Always show dialog for new elements** option. The next time you create an element, the properties editor opens automatically.

To create a parameter:

- Click on the **Continuous Parameter** button.

  The properties editor opens.
- In the "Name" field, enter the name `Ki`.
- Click **OK**.
- Click inside the drawing area to place the parameter.
- In the "Outline" tab, right-click on the parameter and select **Data** from the context menu.

  A data configuration window (numeric editor) opens.



- Set the value in the window to `4.0` and click **OK**.

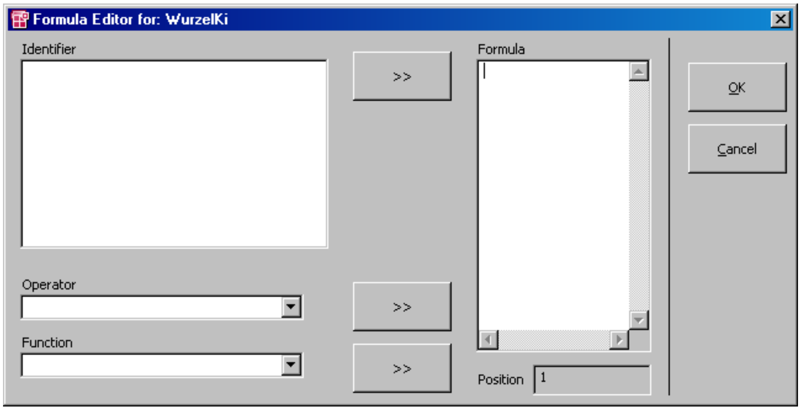
  This value becomes the default value for the parameter. You can assign default values to all parameters or variables in a diagram.

To create a dependent parameter:

- Click on the **Continuous Parameter** button.

  The properties editor opens.
- Name the parameter `WurzelKi`.
- In the "Attributes" field, activate the option **Dependent**.

- Open the formula editor using the **Formula** button.



- Right-click in the "Identifier" field and select **Add** from the context menu.

  A formal parameter is created.

- In the "Identifier" field, enter the name `x` for the new parameter.

- In the "Formula" field, specify the calculation rule.

  You can select different operators from the "Operator" combo box for more complex formulas. They are added to the "Formula" field one by one with the **>>** button next to the "Operator" field.

  Likewise, various functions can be selected in the "Function" combo box, and inserted into the "Formula" field with the **>>** button next to the "Function" combo box.

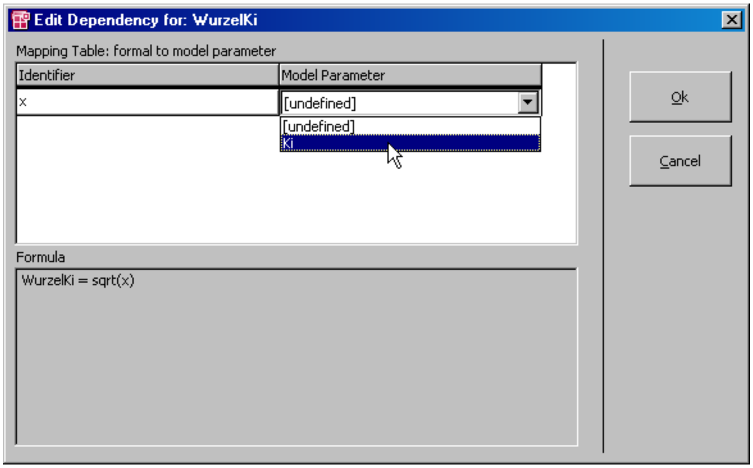
- For the example here, select the root calculation of the formal parameter.

  Formal Parameter: `x`
  Formula: `sqrt(x)`

- Exit with **OK**, and close the properties editor, too.

  The cursor shape changes to a crosshair.

- Click into the drawing area to place the parameter.
- In the block diagram editor, right-click on the `WurzelKi` parameter in the "Outline" tab, and select **Data** from the context menu.
- In the "Dependency Editor" window, assign a model parameter from the combo box to the formal parameter (in this example `Ki`).


Edit Dependency for: WurzelKi

Mapping Table: formal to model parameter

Identifier	Model Parameter
x	[undefined]

Formula

WurzelKi = sqrt(x)

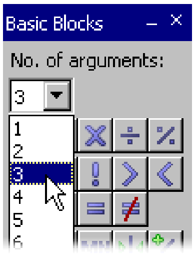
- Complete data entry with **OK**.

  You have now specified a parameter dependent on the parameter `Ki` which on calibration will automatically be calculated based on `Ki`. Later on in the experiment, you can check the dependency or the calculation.

Now that you have added all the elements, you need to specify an integrator. You can proceed by creating the remainder of the diagram.

To create the diagram:

- In the "No. of arguments" combo box in the "Basic Blocks" palette, set the current value to 3 to specify the number of input values for the multiplication operator.

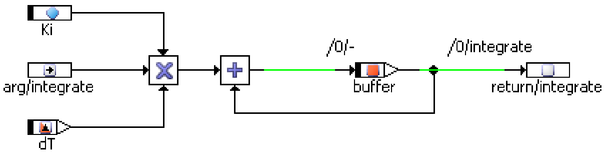


- Create a multiplication operator and place it on the drawing area.
- Click on the **dT** button to create a dT element.

  The properties editor opens. All setting options are deactivated.
- Close the properties editor with **OK**.
- Place the dT element inside the drawing area.
- Create an addition operator with *two* inputs and place it on the drawing area.

  Be sure to set the argument size back to two before you create the operator.
- Connect the elements as shown below.

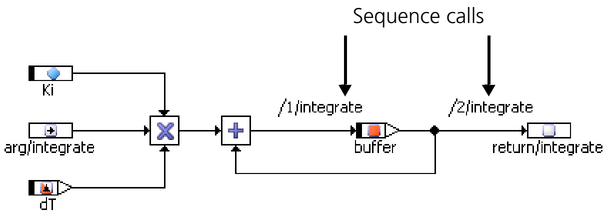
  The input lines for both the buffer and the return value are displayed in green.



Now all the elements of the diagram are in place. Next, you need to determine the sequence of calculation by specifying the sequence calls.

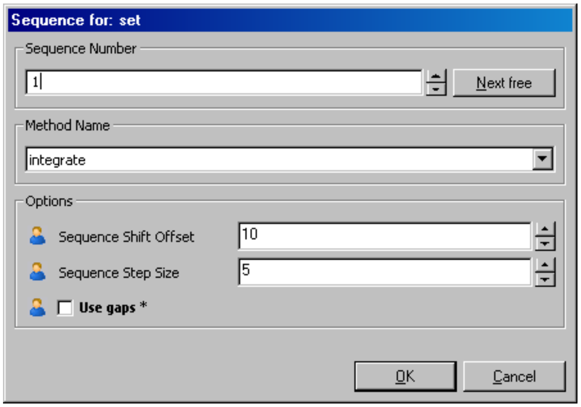
To assign a value to a sequence call:

- Right-click on the sequence call above the variable `buffer`.



- Select **Edit** from the context menu.

  The sequence editor opens.


Sequence for: set

Sequence Number: 1 (Next free)

Method Name: integrate

Options

- Sequence Shift Offset: 10
- Sequence Step Size: 5
- [ ] **Use gaps** *

- Click on **OK** to accept the default settings.

  The assignment comes first in the algorithm for your integrator.

To adjust the sequence number in a sequence call:

- Right-click on the sequence call above the return value for `integrate`.
- Select **Edit** from the context menu.
- In the sequence editor, set the value for "Sequence Number" to 2.

- Click on **OK**.

  The return value is assigned only after the variable `buffer` has been updated.

To adjust the layout:

- Select **Edit** → **Component** → **Layout**.

  The layout editor opens.

  Alternatively you can also get to the layout editor from the "Information/Browse" view by doubleclicking the layout within the "Layout" tab.

- Drag the argument from `integrate` to the middle of the left-hand side of the block.
- Drag the return value to the middle of the right-hand side of the block.
- Click on **OK**.

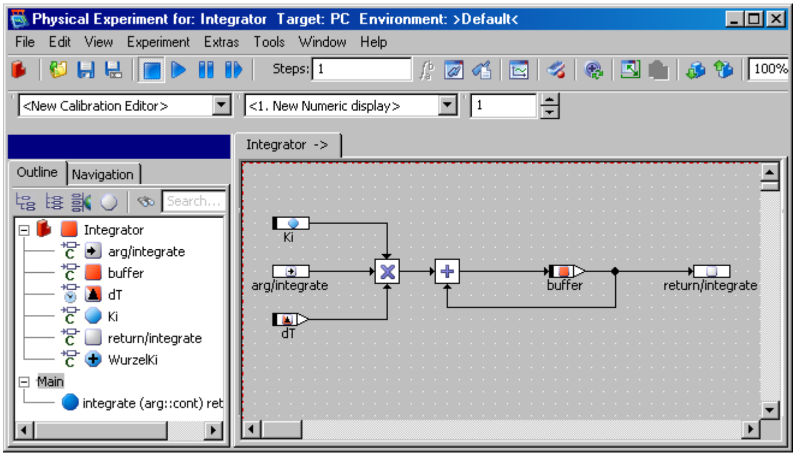
The diagram for the integrator class is now complete. Now save the changes to the diagram by selecting **File** → **Save** in the block diagram editor. Changes that do not affect the diagram itself are stored automatically. Next, save the changes to the database by selecting **File** → **Save Database** in the Component Manager window.

4.3.2 Experimenting with the Integrator

Again, first set up the event generator, then the data generator and finally the measurement system.

To set up the experimentation environment for the integrator:

- Start the experimentation environment by selecting **Component → Offline Experiment.**



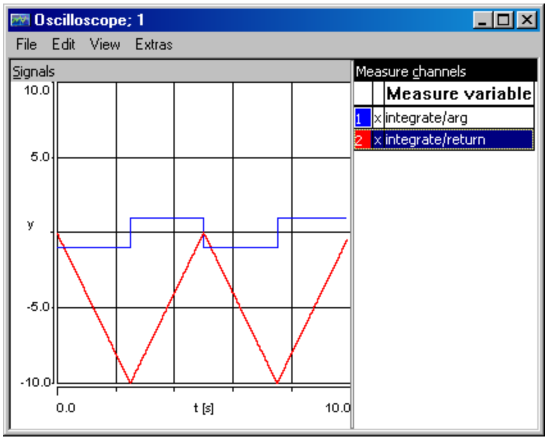
- Click the **Event Generator** button.
- Activate the event `integrate` using the default `dT value` of 0.01.
- Close the "Event generator" window.
- Click on the **Data Generator** button.
- Create a data channel for the `integrate` method by selecting **Channels → Create** and selecting the argument from `integrate`.
- Set the values as follows:

Mode:	pulse
Frequency:	0,2 Hz
Phase:	0.0 s
Offset:	-1.0
Amplitude:	2.0

- Close the Data Generator.

- Open an oscilloscope window with the `arg` and `return` values from the `integrate` method.
- Set the value axis to a range from -10 to 10 and the time axis extent to 10 seconds.
- Click on **Start Offline Experiment** to start the experiment.

The output value of the `integrate` method increases when the argument is positive, and decreases when it is negative. Because the positive and negative parts of the input curve are equal, the output will remain within stable boundaries.



To reset an experiment:

If you stop an experiment, the current values of variables and parameters are stored; they are used again when the experiment is restarted. It may be desirable to reset all variables or parameters to their initial values.

- Select **Extras** → **Reinitialize** → **Variables** or **Parameters** or **Both**.

  Depending on your selection, either all variables or all parameters, or both, are reset to their initialization values.

Next, you should experiment with various settings to illustrate the function of the integrator. You can adjust the `Ki` parameter and change the input.

To experiment with the integrator:

- In the "Outline" tab, expand the `Integrator` element.
- Select the parameter `Ki`.
- Select **Extras** → **Calibrate**.

  A numerical editor opens for the parameter.
- Set the value to `5`.

  The output curve on the oscilloscope becomes steeper.
- Set the value to `3`.

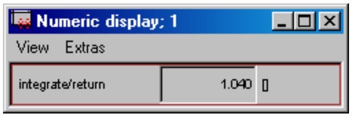
  The output curve now becomes flatter again.
- Set the parameter back to `4` and close the numerical editor.
- Open the "Data Generator" window.
- Set the offset of the input pulse to -0.5.
- Click on **OK**.

Now the positive part is greater, so the output will start to increase. At some point it will exceed the oscilloscope limits. You can adjust the scale of the oscilloscope for each value individually by selecting only that value when you make changes. You can also open a numerical display window to see the output value.

To display a value numerically:

- Select `<1.Numeric Display>` in the "Measure View" combo box in the experimentation environment.
- In the "Outline" tab, select the return value `(return)` from the `integrate` method.
- Select **Extras** → **Measure**.

  A "Numeric display" window shows the current return value.



integrate/return 1.040

- Also display the dependent parameter `WurzelKi`.
- Experiment with changing `Ki` and initiating update using the **Update Dependent Parameters** button.

4.3.3 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Creating a parameter
- Creating and specifying a dependent parameter
- Creating a variable:
- Creating an operator with multiple inputs
- Setting the sequence number of a sequence call
- Assigning a default value
- Calibrating a value during experimentation
- Displaying values in a "Numeric display" window

4.4 A Practical Example

In this lesson you will create a controller based on a slightly enhanced standard PI filter. The controller will be used to keep the rotational speed of an idling car engine constant.

When controlling the idling speed of an engine, you have to make sure that the actual number of revolutions `n` stays close to the nominal value for idling `n_nominal`. The value `n` is subtracted from `n_nominal` to determine the deviation that is to be controlled.

The deviation in the actual number of revolution forms the basis for calculating the value of `air_nominal`, which determines the throttle position, i.e. the amount of air the engine gets.

4.4.1 Specifying the controller

The steps in creating the diagram for your controller are the same as earlier:

- adding a new folder and creating the component in the Component Manager,
- defining the interface and drawing the block diagram.

The major difference is that you will implement the controller as a module. Modules are used as the top-level components in projects. They define the processes that make up a project.

To create the controller component:

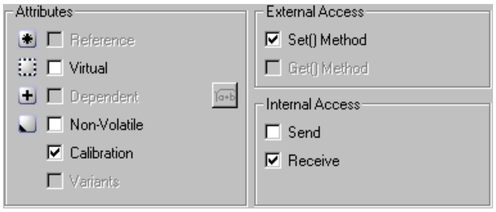
- In the Component Manager, add a new sub-folder to the `Tutorial` folder and rename it `Lesson4`.
- Select the `Lesson4` folder and select **Insert** → **Module** → **Block diagram** to add a new module.
- Rename the new module `IdleCon` and open the block diagram editor.
- In the "Outline" tab, rename the diagram `process` to `p_idle`.

The functionality of modules is specified in processes, which correspond to the methods in classes. Unlike methods, processes do not have arguments or return values. Data exchange (communication) between processes is based on directed messages, which are referred to as *Receive messages* (inputs) and *Send messages* (outputs) in ASCET.

In your controller, you will use a receive message to process the actual number of revolutions `n` and a send message to adjust the throttle position to `air_nominal`.

To specify the interface of the controller:

- Create a receive message by clicking on the **Receive Message** button and name it `n`.
- In the properties editor for the message `n`, activate the **Set() Method** option.


Attributes
- [ ] Reference
- [ ] Virtual
- [ ] Dependent
- [ ] Non-Volatile
- [✓] Calibration
- [ ] Variants

External Access
- [✓] Set() Method
- [ ] Get() Method

Internal Access
- [ ] Send
- [✓] Receive

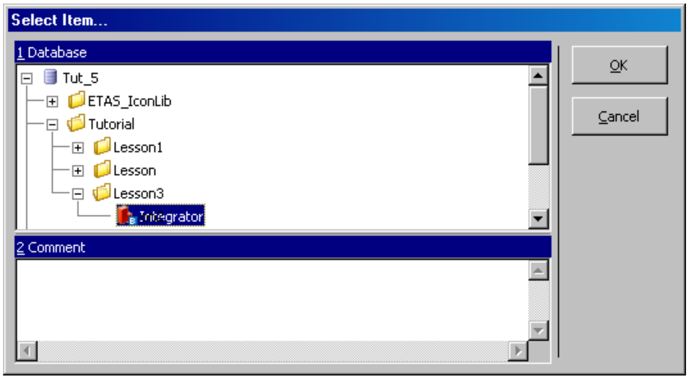
- Click on the **Send Message** button and then inside the drawing area to create a send message.

- Rename it `air_nominal`.
- In the properties editor for the message `air nominal`, activate the **Get() Method** option.

The controller element uses the integrator you created in Lesson 3.

To add the Integrator to the controller:

- Select **Insert** → **Component** to open the "Select item" dialog window.



- In the "1 Database" pane, select the item `Integrator` from the `Tutorial\ Lesson3` folder and click **OK**.

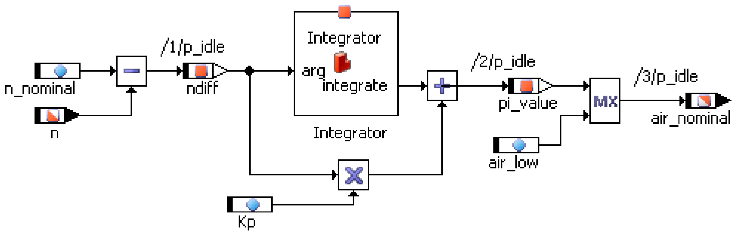
  The integrator is included in the component `IdleCon`. A component is included by reference, i.e., if you change the original specification of the integrator, that change will be reflected in the included component.

In addition to the elements you have added so far, you need to add the following elements to your controller:

- two continuous variables, named `ndiff` and `pi_value`
- three continuous parameters named `n_nominal`, `Kp`, and `air_low`

To specify the remainder of the controller:

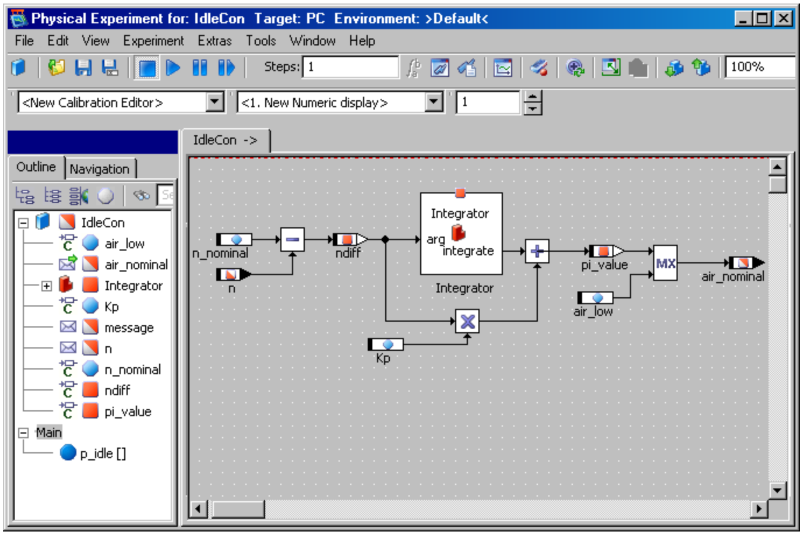
- Create the operators and the other elements needed, then connect them as shown in the block diagram below.



- In the "Outline" tab, select the `n_nominal` parameter, then select **Edit** → **Data**.
- Set the value for `n_nominal` to 900.
- Set the value for `Kp` to 0.5.
- Save your specification in the diagram and apply the changes to the database.

4.4.2 Experimenting with the Controller

Experimentation with modules works like experimentation with other components. First the data and event generators and then the measurement system are set up.



To set up the experimentation environment:

- Select **Build** → **Experiment** to start the experimentation environment.
- Open the "Event Generator" window and enable the event for the process `p_idle` using the default value of 0.01 for `dT`.

  An event for a process works the same as an event for a method.
- Open the "Data generator" window and set up the channel for the receive message `n` with the following values:

Mode:	pulse
Frequency:	1.0 Hz

Phase:	0.0
Offset:	800.0
Amplitude:	200.0

- Set up an oscilloscope with the variables `n_diff` and `air_nominal`.
- In the oscilloscope, set the value axis to -500 to 500 and the time axis extent to 2.
- Click on the **Save Environment** button.

The experiment is now set up to display the relationship between the deviation in the number of revolutions and the throttle position.

To experiment with the controller:

- Start the experiment by clicking the **Start Offline Experiment** button.
- Open a calibration window for the variables `Ki` and `Kp`. From here, you can adjust the values `Ki` and `Kp` and observe their effect on the output.

  From time to time, you may need to reinitialize the model in order to get back to meaningful values.

4.4.3 A Project

A project is the main unit of ASCET software representing a complete software system. This software system can be executed on experimental or microcontroller targets in real-time with an online experiment. Individual components can only be tested in the offline experimentation environment.

Every experiment runs in the context of a project. Whenever code is generated for a project, the operating system code is also generated. The operating system specification is required to run on an ASCET software system in real-time. Running a software system in real-time is called *Online experimentation*. So far, we have experimented *offline* only, i.e. not in real-time.

Note

All ASCET experiments—both online and offline—run within the context of a project. This is clearly seen with offline experiments, which use an (otherwise invisible) default project. Creating and setting up a project for the express purpose of specifying an operating system is only required for online experiments. However, you also have the option of configuring the default project for your own application.

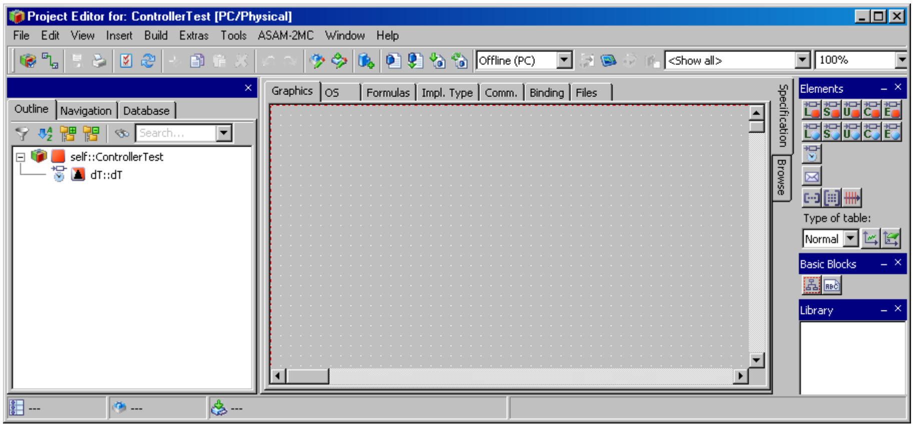
4.4.4 To set up the Project

The project is created in the Component Manager. You can add it to the same folder as the `IdleCon` module.

To create a project:

- In the Component Manager, select **Insert → Project** or click on **Insert Project** to add a new project.
- Name the project `ControllerTest`.
- Select **Edit → Open Component** or double-click the project.

  The project editor opens for the project.


Project Editor for: ControllerTest [PC/Physical]
File Edit View Insert Build Extras Tools ASAM-2MC Window Help
Offline (PC)
<Show all>
100%
Outline Navigation Database
Search...
self::ControllerTest
dT::dT
Graphics OS Formulas Impl. Type Comm. Binding Files
Specification
Browse
Elements
Type of table:
Normal
Basic Blocks
Library

The next step is to add the `IdleCon` controller to the "Outline" tab of the project.

To include components in a project:

- In the project editor, select **Insert** → **Component** to open the "Select item" dialog window.
- From the "1 Database" list, select the component `IdleCon` in the `Tutorial\Lesson4` folder.
- Click on **OK** to add the component.

  The name of the component is shown in the "Outline" tab of the project editor.

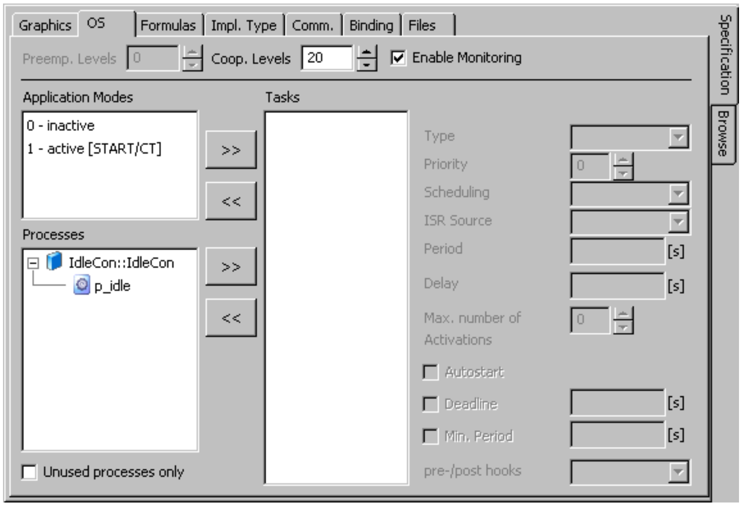
Components are included by reference, i.e. if you change the diagram of an included component, that change will also be effective in the project.

The operating system schedules the tasks and processes of a project. Before you can generate code for the project, you have to create the necessary tasks and assign the processes to them.

The operating system schedule is specified in the "OS" tab of the project editor. You will now specify the operating system schedule to have the `p_idle` process activated every 10 ms.

To set up the operating system schedule for the project:

- Click on the "OS" tab.



Preemp. Levels 0 Coop. Levels 20 ☑ Enable Monitoring

Application Modes
0 - inactive
1 - active [START/CT]

Processes
IdleCon::IdleCon
p_idle

☐ Unused processes only

Tasks

Type
Priority 0
Scheduling
ISR Source
Period [s]
Delay [s]
Max. number of Activations 0
☐ Autostart
☐ Deadline [s]
☐ Min. Period [s]
pre-/post hooks

- Select **Task** → **Add** to create a new task.
- Name it `Task10ms`.

  Newly created tasks are by default alarm tasks, i.e. they are periodically activated by the operating system.
- Assign the task a period of 0.01 seconds in the "Period" field.

  The period determines how often the task is activated, which is every 10 ms in this case.
- In the "Processes" list, expand the `IdleControl` item.
- Select the process `p_idle` and select **Process** → **Assign**.

  The process is assigned to the `Task10ms` task. It is displayed beneath the task name in the "Tasks" list.

In projects, imported and exported elements are used for inter-process communication. They are global elements that correspond to the send and receive messages in the modules. Global elements must be declared in the project and linked to their respective counterparts in the modules included in the project.

To define global elements:

- In the project editor, select **Extras** → **Global Elements** → **Resolve Globals**.

  The necessary global elements are created and automatically linked to their counterparts. Elements with the same name are automatically linked to each other.

4.4.5 Experimenting with the Project

You will now run an offline experiment with this project. Offline experimentation can be performed on the PC without the connection of any additional hardware. Projects run on the PC by default. Therefore you do not have to adjust any settings. Offline experimentation with projects works like offline experimentation with components.

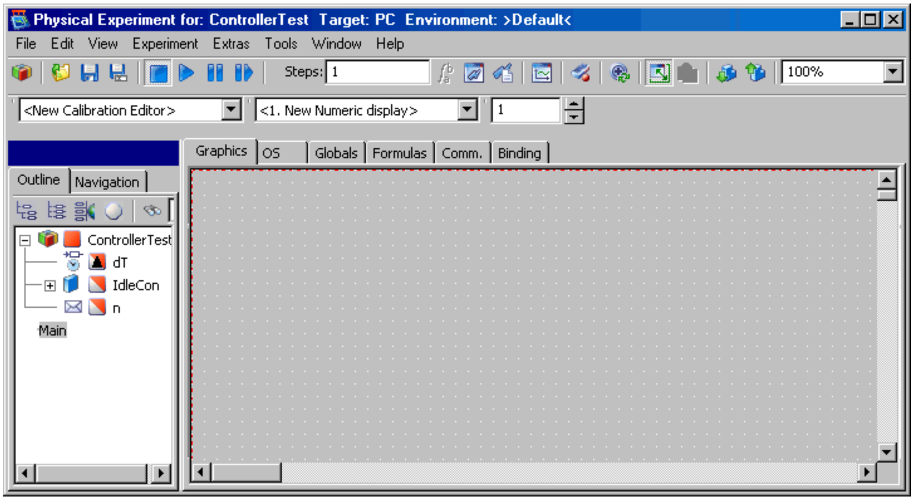
To set up the experimentation environment:

- In the Component Manager, select **File** → **Save Database**.

  It is always a good idea to apply your changes to the database before you start the experimentation environment.

- In the project editor, select **Build** → **Experiment**.

  Code for the project is generated and the offline experimentation environment opens.



- Click on the **Open Event Generator** button.

  In the event generator you see an event for each task you want to use in the experiment, rather than for each method or process, as in experimentation with components.

- Enable the task `generateData` from the event generator and use the default `dT` value of 0.01 seconds.

  The task `Task10ms` is already enabled by default, and both events now have 0.01 seconds as their `dT` value; therefore you do not need to make any further adjustments.

- Close the event generator.

- Set up the data generator and measurement system with the same values as in the previous experiment (cf. "Experimenting with the Controller" on page 81).

- Save the environment by selecting **File → Save Environment**.

To run the experiment:

- Click on the **Start Offline Experiment** button.
- Adjust the `Ki` and `Kp` parameters as in the previous section to see the effect of your changes in the output.

4.4.6 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Creating modules
- Creating messages in modules
- Using components from the Component Manager in a block diagram.
- Creating a project
- Including components in projects.
- Creating tasks and assigning processes to them
- Experimenting with projects

4.5 Extending the Project

In this lesson you will add some refinements to make your controller more realistic. You will create a signal converter that converts sensor readings into actual values. Many sensors, used for instance in automotive applications, return a voltage that corresponds to a particular measurement value, such as temperature, position or number of revolutions per minute. The relationship between the voltage and the measured value is not always linear. ASCET provides characteristic tables to model this kind of behavior efficiently.

4.5.1 Specifying the Signal Converter

The first step in modeling the signal converter is to create a folder and a module that specifies the functionality. The signal converter uses two characteristic lines to map its input values to the corresponding outputs.

To create the module:

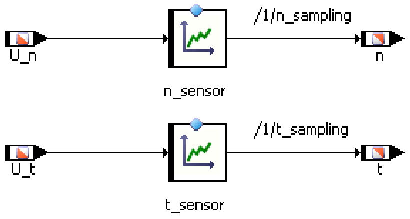
- In the Component Manager, create a new folder `Tutorial\Lesson5`.
- Create a new module and name it `SignalConv`.

- Double-click the element to open the block diagram editor.
- In the block diagram editor, select **Insert** → **Process** to create a second process.
- Name the processes `n_sampling` and `t_sampling`.
- In the "Outline" tab, create two receive messages `U_n` and `U_t` and two send messages `t` and `n`.
- Create a characteristic field by clicking on the **OneD Table** button.

  The properties editor opens.
- Call the table `t_sensor`.
- In the "x" part of the "Dimension" field, enter the value 13.

  The characteristic field can now span a maximum of 13 columns.
  As you have created a one-dimensional characteristic line, the "y" part of the "Dimension" field is inactive.
- Click **OK** to close the properties editor.
- Then click in the drawing area to place the table.

  The table is added to the "Outline" tab.
- Create a second table with a maximum of 2 columns and call it `n_sensor`.
- Connect the elements as shown and edit the sequencing to assign the corresponding processes.



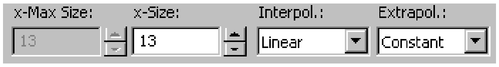
The next step is to edit the data for the two characteristic fields. ASCET provides a table editor for editing arrays, matrices and characteristic fields.

To edit the tables:

- Right-click on the table `t_sensor` and select **Data** from the context menu.

  The table editor opens.

- Adjust the size of the table as follows:



x-Max Size: 13 x-Size: 13 Interpol.: Linear Extrapol.: Constant

  The table is extended to 13 columns with all z-values set to 0 by default.

- Enter the values listed in the following table. The top row corresponds to the X row, the bottom row to the Z row.

0.00	0.08	0.30	0.67	1.17	2.5	5.00	7.50	8.83	9.33	9.70	9.92	10.00
-40.0	-26.0	-13.0	0.0	13.0	40.0	80.0	120.0	146.0	160.0	173.0	186.0	200.0

  You should edit the table by entering the sample points (X values) first, starting from left to right.

- Click on an X value and then enter the new one in the dialog box.

  The new X value must be between the limits set left and right by the sample points.

- Then enter the output values by clicking on a value and typing over the highlighted value.
- Edit the second table in the same way using the following data:

0.0	10.0
0.0	6000.0

- In the block diagram editor, select **File** → **Save**.
- In the Component Manager, click on the **Save** button to store your changes.

In this example, the second table represents a linear relationship between input and output, therefore it needs only two sample points. This works because you have specified the interpolation mode between values as linear.

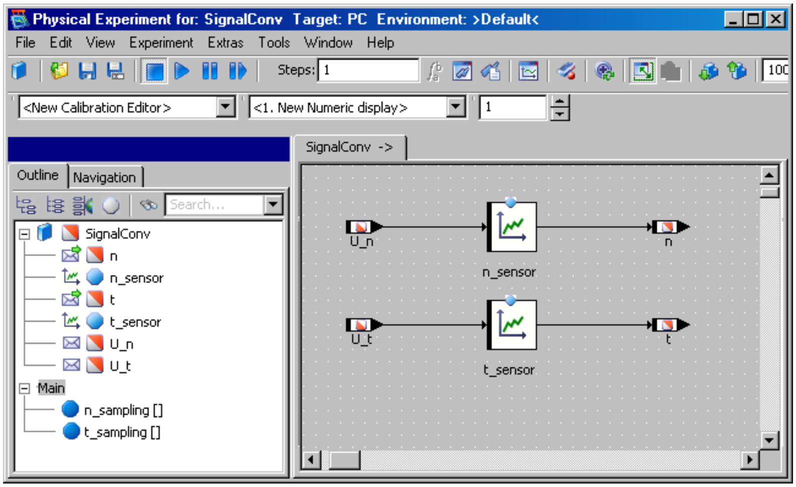
In linear interpolation, for an input value between two sample points the output value is determined from a straight line. In this case, an input of 0 returns 0 and an input of 10 returns 6000. If the input value is 5, the return value is interpolated accordingly as 3000.

4.5.2 Experimenting with the Signal Converter

You can now experiment with the new component to observe the behavior of the tables. Since the two tables have different value ranges, you will set up a separate oscilloscope window for each of them.

To set up the experimentation environment:

- Select **Build** → **Experiment** to open the experimentation environment.



- Create an event for each process in the component (`n_sampling, t_sampling, generateData`) and assign a `dT` value of 4 ms to each event.

- In the data generator create a channel for the message `U_n` and one for `U_t` and set up both channels with the following values:

Mode:	sine
Frequency:	2,0 Hz
Phase:	0.0
Offset:	5.0
Amplitude:	5.0

- Create an oscilloscope window with the messages `n` and `U_n` and a second oscilloscope with the messages `t` and `U_t`.

  Before you create the second oscilloscope, be sure to activate the `<2. New Oscilloscope>` entry in the "Select Measure View" combo box.

The resolution of the sampling points and their corresponding interpolation values differs so much that you should configure each channel in the two oscilloscopes individually in order to optimize the way the behavior of the two tables is displayed.

To set up the oscilloscopes for measuring:

- Activate the oscilloscope for the process `n_sampling` (channels `U_n` and `n`).
- In the "Measure Channels" list, select the message `n` and select **Extras** → **Setup**.

  The "Display Setup" dialog window for the message `n` is displayed.
- Set the range of the value axis to 0 to 6000 and the time axis to 0.5
- Open the "Display Setup" dialog window for the message `U_n`.
- Set its value axis to a range from -1 to 11.

  The time axis must be the same for all variables in an oscilloscope window, so you do not have to change that.

- Activate the oscilloscope for the process `t_sampling` (channels `U_t` and `t`) and set up its channels as follows:

	`U_t`	`t`
Min	-1	-40
Max	11	200
Extent	0.5	0.5

- Select **File** → **Save Environment** to save the experimentation environment.

You are now ready to run the experiment and see how your signal converter works. Observe the differences between the two conversion modes.

To run the experiment:

- Click on the **Start Offline Experiment** button.

  In the `n_sensor` table, only the amplitude of the input sine wave changes. The input here is a voltage signal ranging from 0 to 10 volts, this is mapped to the rotational speed, ranging from 0 to 6000 revolutions per minute. The table `t_sensor` does not represent a linear relationship between the input voltage and the output temperature. It matches the characteristic behavior of temperature sensors commonly used in the automotive industry.

- Change the data generator channels to different wave-forms and observe the effect on both output curves.

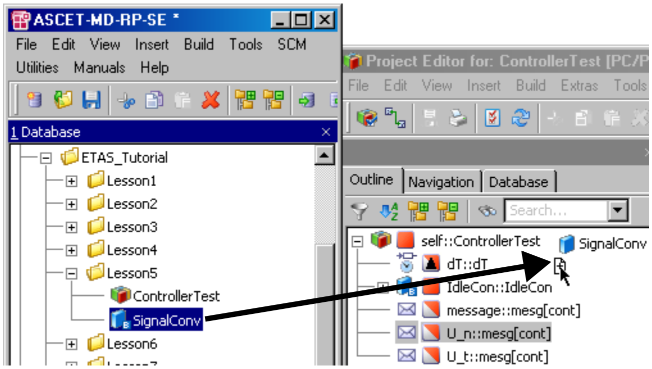
4.5.3 Integrating the Signal Converter into the Project

After you have specified the signal converter, you can integrate it in the project you created in Lesson 4. The output signal for the signal converter is used as the input signal for the motor controller.

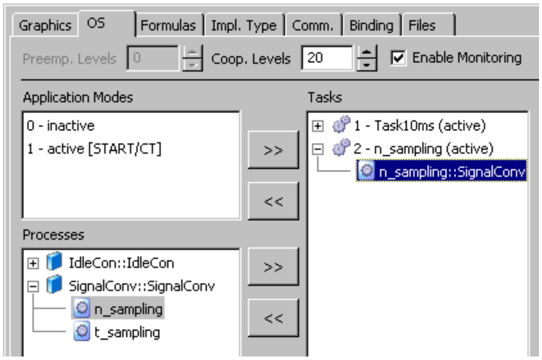
To integrate the signal converter in the project, you will set up another task in the operating system schedule for the new processes and declare and link the global elements necessary for the processes to communicate.

To add the signal converter to the project:

- Open the project editor for the project `ControllerTest`.
- Drag the module `SignalConv` from the "1 Database" list of the Component Manager to the "Outline" tab of the project.



- Click on the "OS" tab to activate the operating system editor.
- Create a new task `n_sampling`.
- Set the period for the new task to 0.004 seconds.
- Assign the process `n_sampling` to the task `n_sampling`.



The project now has two tasks. The first task is activated every 10 milliseconds, the second one every 4 milliseconds. All the processes assigned to a given task are executed at the interval specified. In the example, each task has only one process, but it is possible to have any number of processes per task.

The next step in integrating the signal converter is to resolve communication between the modules. Communication between the processes works through global elements. All global elements used within a project have to be defined as messages in the corresponding modules.

By default, send messages are defined in a module while receive messages are normally only imported into a module so they have to be defined now within the context of the project.

To set up the global elements:

- Select **Extras** → **Global Elements** → **Resolve Globals** to set up automatic links.
- Select **Extras** → **Global Elements** → **Delete Unused Globals** to remove the links from the previous lesson.

All the necessary global elements are created and linked automatically to the corresponding elements with a matching name. The global message `U_n`, for instance, is automatically linked to the message `U_n` in `SignalConv`.

Note that it is necessary to delete unused globals because the message `n` was defined in lesson 4 in the project context while it is now defined in the module `SignalConv`. The message `n` is now used for communication between the processes of the modules.

To experiment with the project:

- Select **Build** → **Experiment** to activate the experimentation environment.
- Open the event generator and enable the task `n_sampling`.
- Set the `dT` value for the task to 4 milliseconds.

  During offline experimentation with projects, the event generator simulates the scheduling that is performed by the operating system during online experimentation.
- Open the data generator and delete the existing data channel.
- Then set up a new channel for the message `U_n`.

- Set up the channel `U_n` as follows:

Mode:	pulse
Frequency:	1.0 Hz
Phase:	0.0
Offset:	4/3
Amplitude:	1/3

- Now activate `U_n`, the output voltage of the rotational speed sensor.

  The signal converter converts the voltage value into the actual value for `n` using the characteristic table `n_sensor`.

  The values given above produce an output range for `n` that matches the range from the previous experiment (without signal processing).

- Click on the **Save Environment** button.
- Start the experiment.

The output curves should be the same as in the example without signal processing. The stimulus created by the data generator is different, but is then processed in the table so that it looks the same as before.

4.5.4 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Creating and using characteristic fields
- Adding components to a project
- Define the communication between different components in a project

4.6 Modeling a Continuous Time System

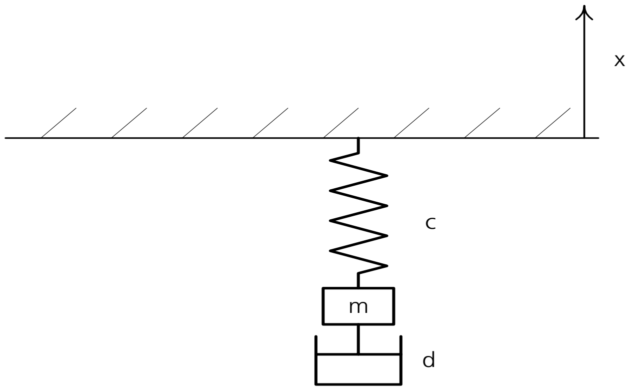
The realistic modeling of physical, mechanical, electrical, and mechatronical processes, often described by differential equations, requires continuous time methods. Before integrating a method like this in the project created in the previous chapters, this chapter covers modeling a time continuous system using a detailed example.

ASCET supports the modeling and simulation of continuous time systems by means of so-called CT blocks. CT stands for "Continuous Time" and refers to items that are modeled or calculated in quasi-continuous time intervals. The continuous time modeling in ASCET is based on state space representation, the standard description form used in the design of continuous time systems. This representation allows the description of CT basic blocks by nonlinear ordinary first-order differential equations and nonlinear output equations. ASCET provides several real-time integration methods to find optimal solutions to these differential equations (refer to the ASCET online help for more information).

The procedure for modeling a continuous time system will now be explained using the example of a mass-spring pendulum with attenuation by the earth's gravity.

4.6.1 Motion Equation

The mass `m` shown in the following illustration is subject to the following forces:



- gravity: `Fg = -mg`
  (`g` = gravitational acceleration)
- Spring force: `FF = - c (x + l0)`
  (`c` = spring rate, `l0` = length of spring at rest, and `x` = position of mass m)
- Attenuation `FD = - d x'`
  (`d` = attenuation constant and `x'` = velocity of mass)

This gives the motion equation as follows:

$mx'' = -mg + F$ or $x'' = -g + F/m$ (with $F = F_F + F_D$)

Breaking the second-order differential equation into two first-order differential equations (`x = x`, `v = x'`) results in:

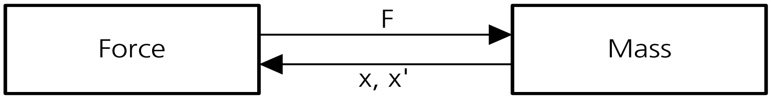
$$x' = v$$

$$v' = -g + F/m$$

These differential equations will be used in the following model design.

4.6.2 Model Design

For simplicity, the model of the mass-spring pendulum will be designed using a single CT block. However, to illustrate the "direct pass-through" or "non-direct pass-through" properties and to demonstrate how to avoid an algebraic loop by skillful setting of these properties, we will design this model using two blocks.



- The `Force` block calculates spring force `F` from the position of the pendulum's mass m and the friction force from the velocity `x'.`
- From the spring force F the `Mass` block calculates the acceleration `x''` from the integration of which the velocity `x'` and the position `x` result.

At first sight, this system looks like an algebraic loop: each block expects an input value from the other block in order to calculate an output value required by the other block.

This algebraic loop can be avoided by clever setting of the *direct pass-through* or *non-direct pass-through* properties:

- In the `Force` block, the output variable `F` via the equation

  $$F = -c(x + l_0) - dx'$$

  is directly dependent on the input variables `x` and `x'`. This block is thus defined as having a direct pass-through.
- In the `Mass` block however, the output variables `x` and `x'` do not depend directly on the input variable `F`, but on the internal state variables of the block. These, at least at the start, have initial values from which the output variables `x` and `x'` can be calculated, when the input variable `F` is unknown. Otherwise the output variables are calculated using the following differential equations:

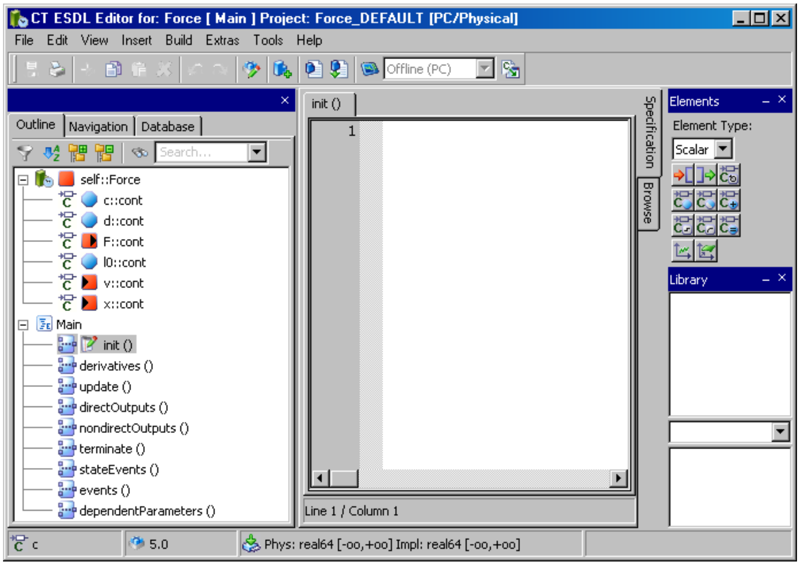
  $$x' = v$$

```
v' = -g + F/m
```

This block is thus defined as having a non-direct pass-through.

Model Creation:

- In the Component Manager, create a folder and call it `Lesson6`.
- In this folder, use **Insert** → **Continuous Time Block** → **ESDL** to create a block `Force` and a block `Mass`.
- Double-click the `Force` block to open the ESDL editor.
- Click on the **Input** button to create two inputs `x` and `v` (type `continuous`).
- Click on the **Output** button to create an output `F` (type `continuous`).
- Click on the **Parameter** button to create the constants `c` (spring rate), `d` (attenuation constant) and `l0` (length of the spring at rest).

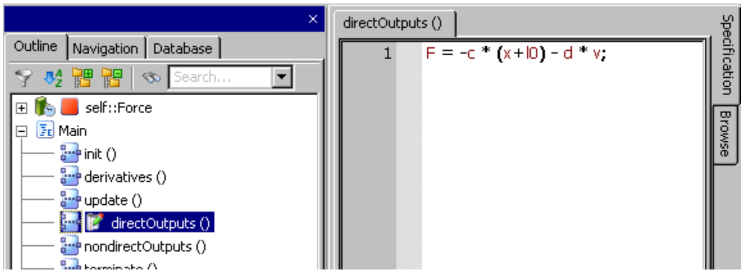


The methods in the "Outline" tab are fixed by default.

- Right-click on each constant in the "Outline" tab in turn and select Data from the context menu.

  The "Numeric Editor" dialog window opens.
- Assign realistic values to the constants (e.g., 5.0 to the spring rate `c`, 1.0 to the attenuation constant `d`, and 2.0 to the length of the spring at rest `l0`).
- In the "Outline" tab, click on the method `directOutputs[]`.
- In the "Edit" field, specify the formula used to calculate the force:

```
F = -c * (x + l0) - d*v;
```



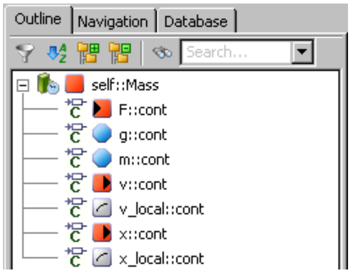
directOutputs ()

```
F = -c * (x+l0) - d * v;
```

- Click on the **Generate Code** button.

  The CT block `Force` is compiled.
- Double-click the `Mass` block to open the ESDL editor.
- As above, create an input `F`, two outputs `x` and `v`, one parameter `m` (mass), and one constant `g` (gravitational acceleration).
- Assign values to `g` and `m` as described above (9.81 to g and, e.g., 2.0 to the mass `m`).

- Click on the **Continuous State** button to create state variables `x_local` and `v_local` for the internal calculation of the outputs.



```
self::Mass
  F::cont
  g::cont
  m::cont
  v::cont
  v_local::cont
  x::cont
  x_local::cont
```

- For the `derivatives[]` method, specify the differential equations required for the calculation:

```
x_local.ddt(v_local);
v_local.ddt(-g + F/m);
```

- In `nondirectOutputs[]` pass the state variables `x_local` and `v_local` to the outputs `x` and `v`:

```
x=x_local;
v=v_local;
```

- In the `init[]` method, you can provide the system with realistic initial values for `x` and `v` using the `resetContinuousState`() function.

```
resetContinuousState(x_local,0.0);
resetContinuousState(v_local,0.0);
```

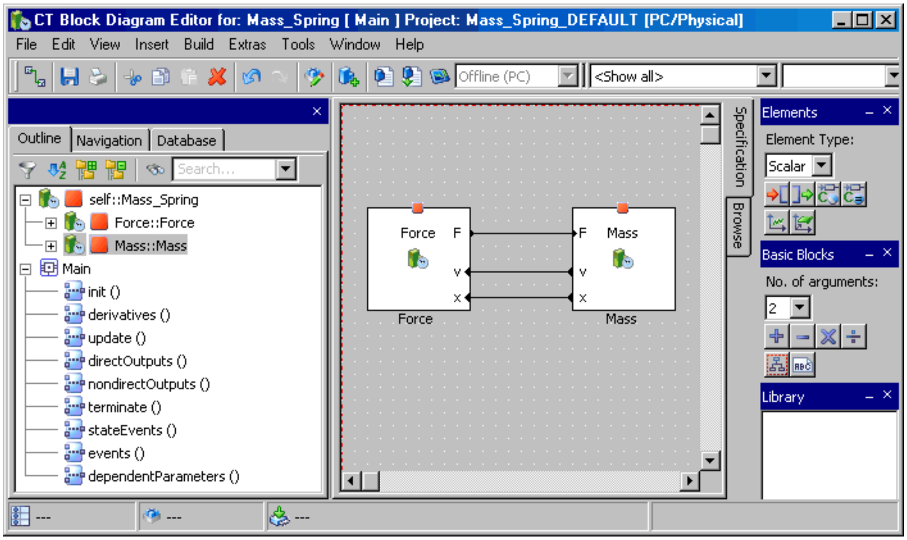
- Click on the **Generate Code** button.

  The CT block `Mass` is compiled.

The combination of the two basic CT blocks into one CT structure block is done using the Block Diagram Editor (BDE).

To combine the two basic CT blocks.

- In the Component Manager, `Lesson6` folder, select **Insert** → **Continuous Time Block** → **Block Diagram** to create a new block `Mass_Spring`.
- Double-click the new block to open it in the Block Diagram Editor.
- In the Component Manager, drag and drop the `Mass` and `Force` blocks (one at a time) to the BDE window and file them.
- Connect the corresponding inputs and outputs with each other.



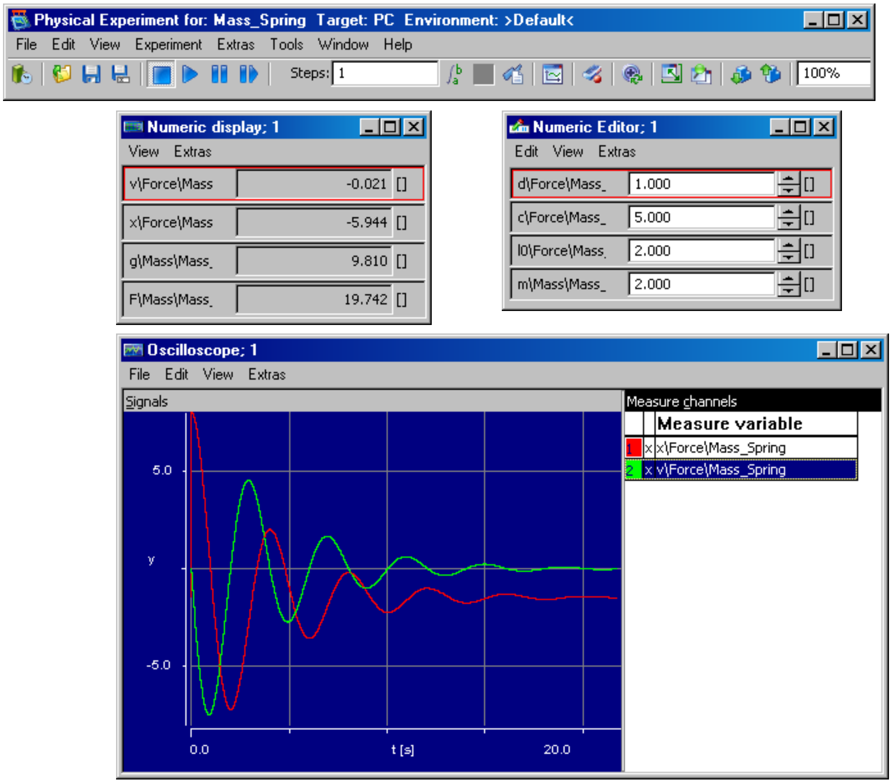
Note

Double-clicking one of the CT basic blocks makes it available for editing. Note, however, that any modification to the blocks affects the entire library, i.e., all structure blocks that use these basic blocks.

- Select **Build** → **Experiment**.

  The CT block is now compiled, and the experiment is started.

- Create the experimentation environment required with numeric editors for the parameters and graphical displays.



v\Force\Mass	-0.021 []
x\Force\Mass	-5.944 []
g\Mass\Mass_	9.810 []
F\Mass\Mass_	19.742 []

d\Force\Mass_	1.000 []
c\Force\Mass_	5.000 []
l0\Force\Mass	2.000 []
m\Mass\Mass_	2.000 []

		Measure variable
1	x	x\Force\Mass_Spring
2	x	v\Force\Mass_Spring

- Scale the channels in the oscilloscope separately, from -10 to 0 for x, from -8 to +8 for v.

4.6.3 Summary

After finishing this lesson, you should be able to carry out the following tasks in ASCET:

- Creating a model to simulate a process
- Using the ESDL editor to create CT blocks with direct and non-direct pass-through
- Using the Block Diagram Editor to combine CT blocks
- Performing the physical experiment

4.7 A Process Model

Following the introduction of CT blocks in the last chapter, you will now use them for testing your controller. In ASCET you can develop a model of the technical process to be controlled, and then experiment with a closed control loop. This means that way the controller can be thoroughly tested before it is used in a real vehicle.

In our example here, the motor is the technical process. It returns a value `U_n` which is a sensor reading of the rotational speed of the engine. This value is processed by the controller, which returns a value `air_nominal`. The controller output value determines the throttle- position of the engine, and thus in turn influences the rotational speed.

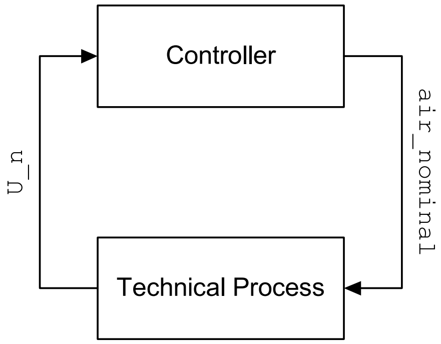


Fig. 4-1 A closed-loop experiment

You will use a CT block for this process model. This type of component is particularly suitable for process models. The model is based on the following differential equation, which models a PT2 - system:

$$T^2 s'' + 2DTs' + s = Ku$$

Equ. 4-1 A PT2 - system

The parameters T, D and K have to be set up with appropriate values.

4.7.1 Specifying the Process Model

Creating continuous time components is different from creating other components. They have inputs and outputs which are the equivalent of arguments and return values. The main difference is that a continuous time block can have multiple inputs and outputs which are not tied to a particular method. There is a fixed set of methods defined in each continuous time block, that cannot be modified by the user.

You will use ESDL Code for the example here. The syntax of the ESDL code is similar to C++ or Java. An object method is called with the name of the object, a dot, the name of the method and the arguments in brackets followed by a semicolon. The method used for deriving is called `ddt()`. For example, the equation $sp = \dot{s}$ is equivalent to the ESDL statement `s.ddt(sp);`.

To create a continuous time component:

- In the Component Manager create the folder `Tutorial\Lesson7`.
- To add a continuous time block, select **Insert** → **Continuous Time Block** → **ESDL**.
- Name the new component `ProcModel`.
- Select **Edit** → **Open Component** to open the ESDL editor.

  You can, of course, also use the external text editor. There are instructions for this in the first part of the tutorial.

To edit the process model, first add the elements required and then edit the methods `derivatives` and `non directOutput`.

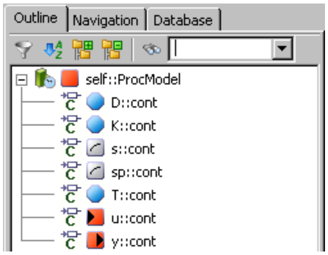
To edit the process model:

- In the ESDL editor, use the **Continuous State** button to create two continuous states.
- Name the states `s` and `sp`.
- Create an input `u`.
- Create an output `y`.

  Both elements are of type `cont`.

- Create the parameters `D`, `K` and `T`.

  The "Outline" tab for the process model should look like this:



```
self::ProcModel
    D::cont
    K::cont
    s::cont
    sp::cont
    T::cont
    u::cont
    y::cont
```

- Adjust the parameters as follows:

```
D = 0.4,
K = 0.002,
T = 0.05.
```

- In the "Outline" tab, select the `deriva-tives` method and edit the code as follows:

```
s.ddt(sp);
sp.ddt((K*u-2*D*T*sp-s)/(T*T));
```

Note

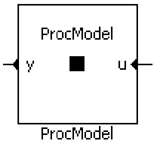
See the ASCET online help for specifying CT blocks for information on how to resolve a differential equation.

- Select the `nondirectOutputs` method and type in the following text.

```
y = s;
```

- Adjust the layout in the layout editor.

  Note that in a process model it is preferable to put the outputs on the left and the inputs on the right.



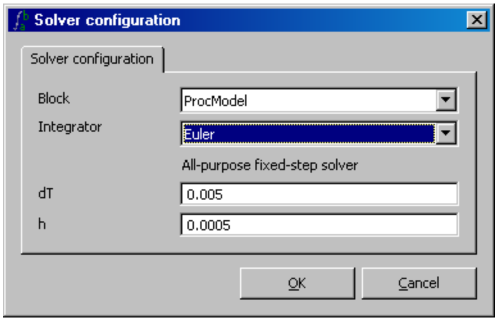
- Select **Edit** → **Save**.
- In the Component Manager, click on the **Save** button to save the process model.

You can now start experimenting with the new model.

To experiment with the model:

- In the ESDL editor, select **Build** → **Experiment** to open the experimentation environment.
- Click on the **Open CT Solver** button to open the "Solver Configuration" dialog pane.

  The configuration is displayed as follows:



Block: ProcModel
Integrator: Euler
All-purpose fixed-step solver
dT: 0.005
h: 0.0005

- Click **OK** to accept the default configuration.
- Open the data generator and create a channel for the input `u`.
- Set up the channel `u` with the following values:

Mode:	pulse
Frequency:	0.5 Hz
Phase:	0.0 s
Offset:	-0.5
Amplitude:	1.0

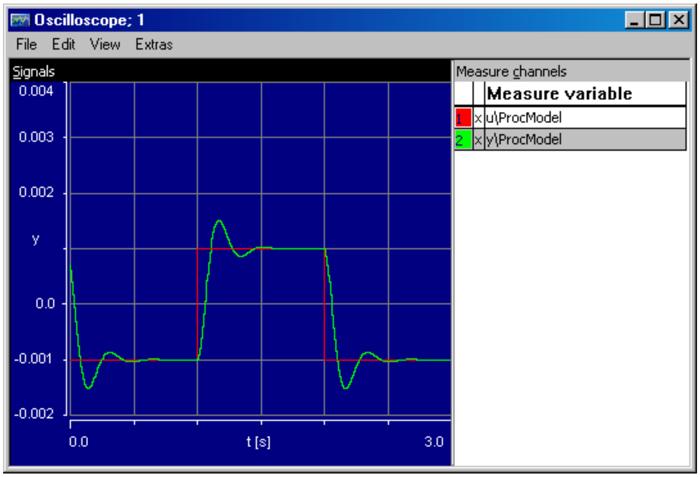
- Open an oscilloscope window with the channels `u` and `y`.

- Set the Measure Channels for the oscilloscope as follows:

	u	**y**
Min	-1	-0.002
Max	2	0.004
Extent	3.0	3.0

- Click on the **Save Environment** button.
- Start the experiment.

  The output should look like this:



		Measure variable
🟥 1	x	u\ProcModel
🟩 2	x	y\ProcModel

4.7.2 Integrating the Process Model

To create a closed control loop, we will now integrate the process model into the controller project we created earlier. The steps required are the same as before: including the module, setting up the operating system and linking the global elements.

Note

The process model is added to the same project for simplicity. This is often useful in the early stages of testing closed loop simulation. In regular projects, the process model would be distributed over a network in another project since they are not part of the same embedded system.

To include the process model:

- From the Component Manager, open the project editor for `ControllerTest`.
- In the project editor, add the component `ProcModel` to the "Outline" tab.
- Activate the "OS" tab of the project editor to specify the scheduling for the CT tasks.
- Select the task `simulate_CT1` and set the value in the "Period" field to 0.01 s.

  The controller and the process model both run in the same time interval.

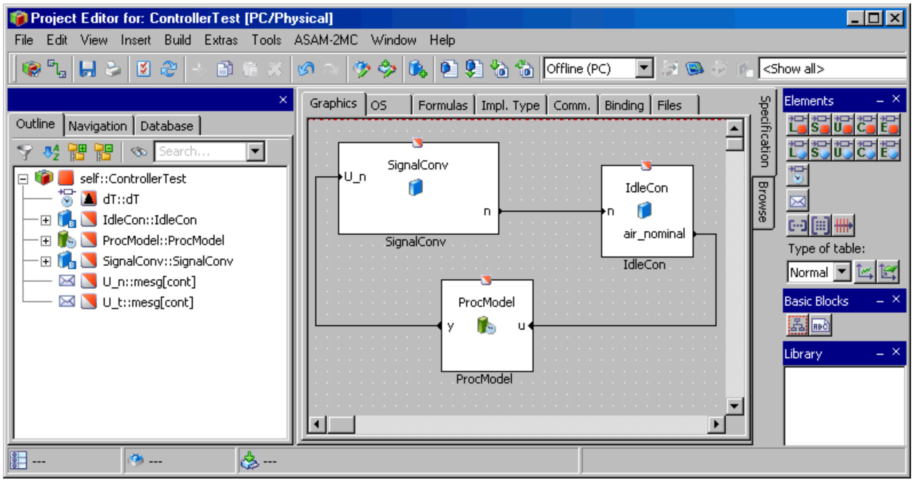
Linking the continuous time blocks and the modules cannot be done automatically. They have to be connected explicitly in a block diagram.

To adjust the linking between modules and CT block:

- Click the "Graphics" tab.
- From the "Outline" tab, drag the three components and drop them into the drawing area.
- Connect the messages of the modules with the corresponding input and output of the CT block.

  To construct the example, connect the output `y` of `ProcModel` with the global message `U_n` and connect the input `u` of `ProcModel` with the global message `air_nominal`.

- Right-click on each component and select **Unconnected Ports** to remove these ports from the diagram.



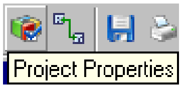
Linking the messages for communicating between modules is done automatically. Messages that have the same name are linked with each other.

The project is now complete and ready for experimentation. We will now experiment online, which requires an ASCET-RP installation and a real-time target (e.g. ES1000). If you do not have both, you will have to continue by experimenting offline as before.

Note

If you continue by experimenting offline, be sure to remove the global message `U_n` *from the data generator.*

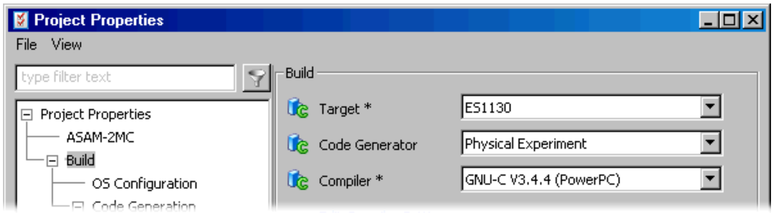
To set up the project for online experimentation:



- Click on the **Project Properties**button.

- In the "Project Properties" dialog window, "Build" node, select the target `ES1130` and the `GNU-C V3.4.4 (Power-PC)` compiler.

  These options specify the hardware and the corresponding compiler for code generation.



Build

Target * ES1130

Code Generator Physical Experiment

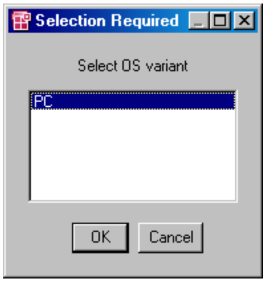
Compiler * GNU-C V3.4.4 (PowerPC)

- Click **OK** to close the "Project Properties" dialog window.

  The buttons **Reconnect to Experiment of selected Experiment Target** and **Select Hardware** are now available.

- Click on the "OS" tab to activate the operating system editor.

- To copy the schedule you created earlier, select **Operating System** → **Copy From Target**.



Select OS variant

PC

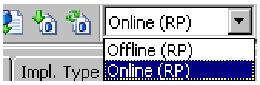
- From the "Selection Required" dialog, select `PC` and click **OK**.

  The project for the new target now has the same scheduling as that specified before for the offline PC simulation.

There are several differences from the offline experiment. In the online experiment, there is no event or data generator. The event generator serves to simulate the scheduling of the operating system tasks generated for online experiments.

In the online experiment the experimentation code and the measurements are started separately, and have separate buttons in the toolbar. This is because the measurements may influence the real-time behavior of the experiment, so it may sometimes be necessary to switch them off.

To experiment with the project online:

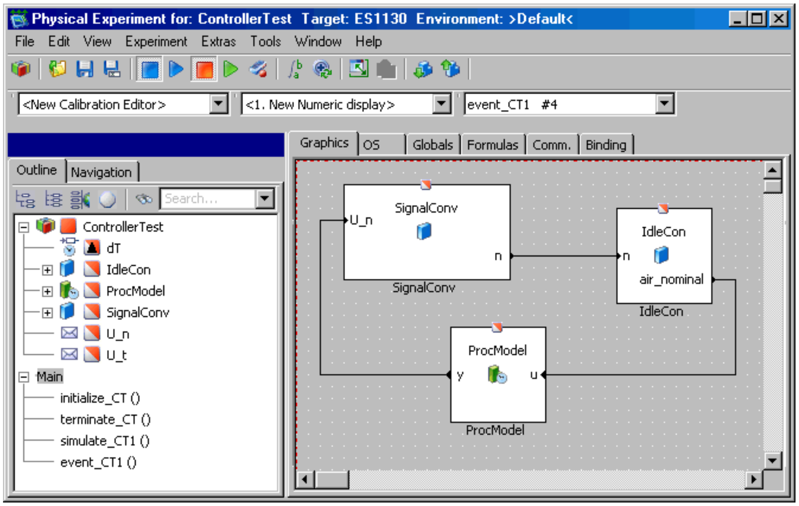


- Select `Online (RP)` from the "Experiment Target" combo box.

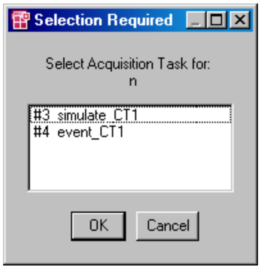
  `Offline (RP)` is intended for offline experiments on the target.

- Select **Build** → **Experiment**.

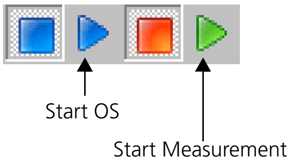
  The code for the experiment is generated and the experiment opens with the same environment as defined previously.



If your project contains several tasks, you could well be prompted to select one acquisition task for each measure value.



- In the "Selection Required" window, select the `#3 simulate_CT1` task and click **OK**.
- Include `n` and `n_nominal` in the existing oscilloscope and set their value range from 0 to 2000.
- Open numeric editors for the variables `n_nominal`, `Ki` and `Kp`.



- Click on the **Start OS** button and then click on the **Start Measurement** button.

  The experiment starts and the results are displayed on the oscilloscope. The value for `n` should quickly approach `n_nominal` and stay there.
- Modify `n_nominal` in the numeric editor.

  The value `n` should change in line with all the changes to `n_nominal`.
- You can optimize the behavior of the control loop by adjusting the `Ki` and `Kp` parameters.

4.7.3 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Creating and specifying continuous time blocks
- Experimenting with continuous time blocks
- Integrating continuous time blocks in a project

- Creating variable links
- Switching between different targets
- Experimenting online with a project

4.8 State Machines

State machines are useful for modeling systems that move between a limited number of distinct states. ASCET provides a powerful mechanism for specifying components as state machines. In this lesson we will specify and test a simple state machine that implements a temperature dependent change in the nominal number of revolutions of an idling engine. That state machine will then be integrated into our project. In the next chapter we will then construct hierarchical state machines.

If the engine is cold, it has to idle at a higher speed to keep it turning over. Once the engine has warmed up, the rotational speed for idling can be decreased to reduce fuel consumption. Our state machine thus has two states: one when the engine is cold, and one when it is warm. It represents a two-phase control.

4.8.1 Specifying the State Machine

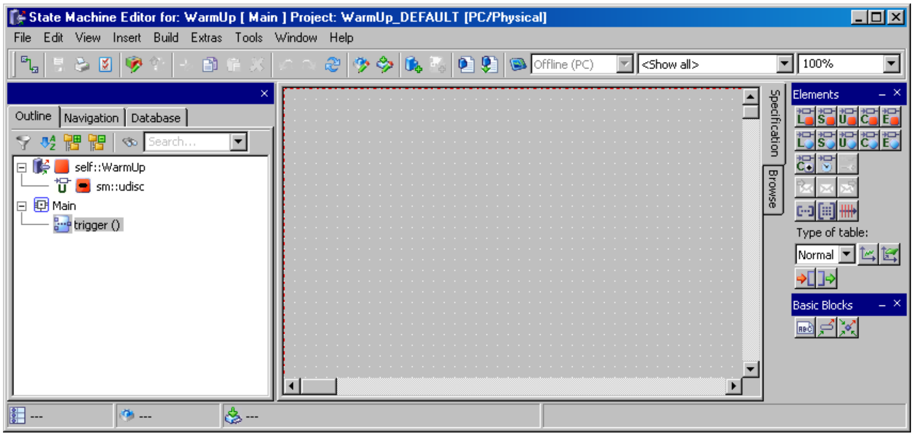
A state machine consists of the state graph itself and a number of specifications of actions and conditions. The actions and conditions can be specified using either block diagrams or ESDL code. They determine what happens in the various states and during the transitions between states.

The diagrams are specified in the block diagram editor. Another possibility is to write ESDL code directly in a text editor which can be opened for every state and every transition (i.e., *without* opening the ESDL editor). State machines have inputs and outputs for data transfer with other components.

To create a state machine:

- In the Component Manager, create the folder `Tutorial\Lesson8`.
- Select **Insert** → **State Machine** or click on the **Statemachine** button to create a new state machine.
- Name it `WarmUp`.

- In the "1 Database" list, double-click on the name of the state machine to open the state machine editor.


State Machine Editor for: WarmUp [Main] Project: WarmUp_DEFAULT [PC/Physical]
File Edit View Insert Build Extras Tools Window Help
Offline (PC)
<Show all>
100%
Outline Navigation Database
Search...
self::WarmUp
sm::udisc
Main
trigger ()
Specification
Browse
Elements
Type of table:
Normal
Basic Blocks

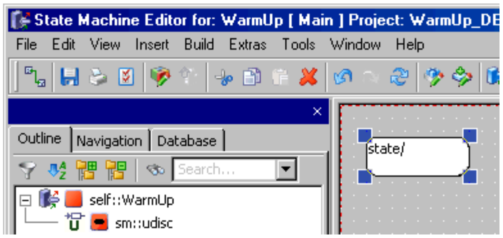
When you create a state machine, you specify the state graph diagram first and then define the various actions and conditions associated with states and state transitions.

The state machine controlling your motor has two states: one for when the motor is cold and one for when the motor is warm.

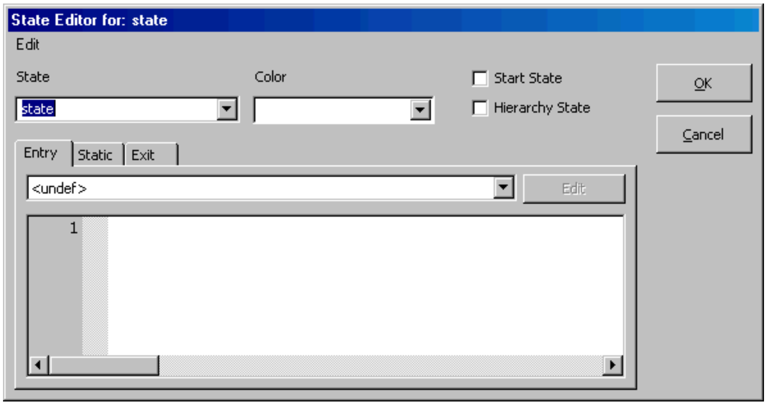
To specify the state diagram:

- Click on the **State** button to load the cursor with a state item.
- Click inside the drawing area, where you want to place the state.

  A state symbol is drawn where you clicked.


State Machine Editor for: WarmUp [Main] Project: WarmUp_DE
File Edit View Insert Build Extras Tools Window Help
Outline Navigation Database
Search...
self::WarmUp
sm::udisc
state/

- Create a second state symbol and place it below the first one in the drawing area.
- Right-click on the state symbol you created first and select **Edit State** from the context menu to open the State Editor.



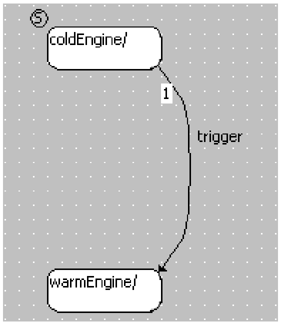
- In the "State" field, enter the name `coldEngine`.
- Activate the **Start State** option to determine the state the machine is in when it is first started.

  There must be start state for each state machine.
- Click on **OK** to close the State Editor.

  The name is displayed in the state symbol.
- Name the second state symbol `warmEngine`.
- Right-click in the drawing area, outside any symbol, to activate the connection mode.

- Click in the right half of the `coldEngine` state symbol to begin a connection, then click in the right half of the `warmEngine` state symbol to connect the two states.

  A line is drawn between the two state symbols. It has an arrow at one end, pointing from the top to the bottom symbol. The lines represent possible transitions between states.



- Create another transition from left half of the bottom to the left half of the top symbol.
- Select **File** → **Save** to store the diagram.
- In the Component Manager, select **File** → **Save Database** to save the database.

The next step in building the state machine is to specify its interface. You need an input for the temperature value and an output for the number of revolutions. In addition, parameters are required that specify high and low temperature and number of revolutions per minute.

To specify the interface of the state machine:

- Create an input by clicking the **Input** button.
- Name the input `t`.
- Create an output by clicking on the **Output** button.
- Name the output `n_nominal`.
- Use the **Continuous Parameter** button to create four parameters.

- Name the parameters and set their values as follows:

  `t_up` = 70

  `t_down` = 60

  `n_cold` = 900

  `n_warm` = 600

You can now proceed by specifying the actions and conditions for both the states and the transitions between states. You can specify three actions for each state:

- The entry action is executed each time the state is entered.
- The exit action is executed each time the state is left.
- The static action is executed while the state machine remains stationary.

Similarly, a trigger event, a condition, a priority and an action can be specified for each transition. The name of the trigger and of the condition appear next to the transition. *One* trigger is automatically created when the state machine is created.

The actions and conditions are specified in ordinary diagrams or in ESDL code. In this example you will use ESDL code.

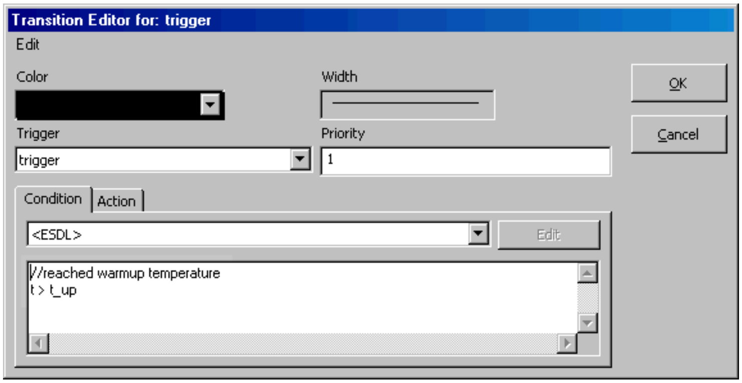
To specify the trigger actions and conditions:

- Right-click on the transition from the `coldEngine` state to `warmEngine`.
- From the context menu, select **Edit Transition** to open the Transition Editor.

  The condition for a transition from cold to warm is that the actual temperature value `t` is greater than `t_up`.
- On the "Condition" tab, select `<ESDL>` from the combo box.

  Note that you can influence the predefined choice of options in this combo box.

- Enter the code shown below in the code pane of the condition:



Trigger: trigger

Priority: 1

<ESDL>

```
//reached warmup temperature
t > t_up
```

Note

In the Transition Editor, the condition is not terminated with a semicolon. This is also true for regular ESDL code where conditions appear in parentheses.

If the condition evaluates to `true`, the idle speed of the engine is set to `n_warm`.

Note that this code is displayed in the state machine diagram. In this example, an alias name is created for the transition condition and shown in the diagram.

- Select `<ESDL>` for the action, too, and enter the following code:

```
n_nominal = n_warm;
```

- Click **OK** to close the Transition Editor.
- Look at the diagram. Note that the condition and the action from the state machine can be seen.
- Open another editor for the transition from `warmEngine` to `coldEngine`.
- Select `<ESDL>` for the condition and enter the following code:

```
t < t_down
```

Note that this time the complete code is shown in the diagram as no alias was assigned (in a comment).

- Select `<ESDL>` for the action, too, and enter the following code:

```
n_nominal = n_cold;
```

- Close the transition editor and select **File** → **Save**.

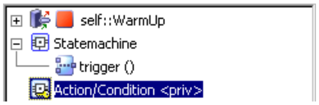
You can also specify the actions and conditions as block diagrams instead of ESDL code. For that purpose, you first create a separate diagram for actions and conditions.

To create a diagram for actions/conditions:

- In the state machine editor, select **Insert** → **Diagram** → **Actions/Conditions BDE**.

  A diagram named `ActionCondition_BDE` is created in the "Outline" tab.

- Accept the default name.



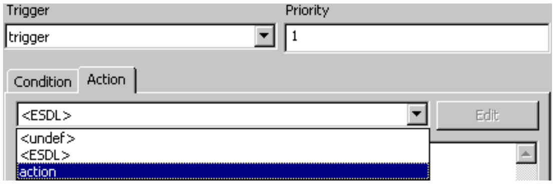
Now you can add, and specify, actions and conditions.

To specify the action/condition as block diagram:

- In the "Diagrams" field, click on the `Action-Condition` diagram.

- Use **Insert** → **Action** or **Insert** → **Condition** to create new actions and conditions.

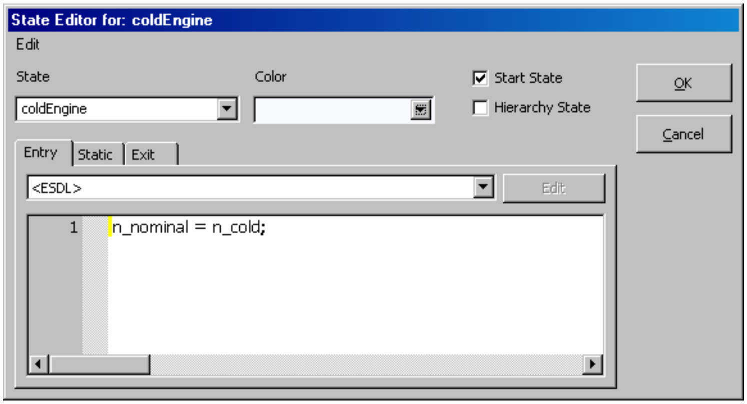
  You can then select these actions and conditions from the combo boxes in the tabs in the Transition Editor. Use the **Edit** button to go directly to the graphical specification in the BDE.



The initial value for the output `n_nominal` is still missing. Unlike the parameter values, this cannot be set. Instead you need to specify an action for the `coldEngine` start state. Since the entry action of the start state is *not* executed at the fist activation of a state machine, you have to specify the initial value in the static action.

To specify an entry action:

- Right-click on the `coldEngine` start state.
- From the context menu, select **Edit State** to open the State Editor.



State: coldEngine
Color:
[✓] Start State
[ ] Hierarchy State
<ESDL>

```
n_nominal = n_cold;
```

- Select `<ESDL>` from the combo box on the "Entry" tab to specify the entry action.

  Note that you can influence the predefined choice in this combo box via the "Defaults" node in the ASCET options window.
- Enter `n_nominal = n_cold;` in the code pane to set the initial value of `n_nominal` to 900.
- Click on **OK** to close the state editor.

That completes the specification of your state machine. Before you start experimenting with it, you should understand the way it works.

4.8.2 How a State Machine Works

While it is usually easy to understand what a standard component does from its graphical specification, the function of a state machine may, at first, be less obvious. This section explains the principles of state machines using the example from the previous section. A detailed description of state machines and their functionality is given in the ASCET online help for the state machine editor.

Each state of a state machine has a name, an entry action, a static action and an exit action. It has transitions to and from other states. Each transition has a priority, a trigger, an action and a condition. All actions are optional.

Each state machine needs a start state. When the state machine is first called up, it is in the start state. It then checks the conditions in all the transitions pointing away from it. In our example there is just one such transition with the condition `t > t_up`. This condition checks whether the input value exceeds the value of the `t_up` parameter. If that is the case, the condition is true, and a transition takes place.

The parameters `t_up` and `t_down` determine the temperature that the engine has to reach, before the nominal rotational speed can be changed. In our example, if the engine temperature rises above 70 degrees, the speed can be reduced to 600 revolutions per minute. If it then falls below 60 degrees, the nominal speed must be reset to 900 revolutions per minute.

Whenever a transition takes place, the transition action specified for the transition is executed. In our example the transition action `n_nominal = n_warm`, which is executed when a transition from the state `coldEngine` to `warmEngine` takes place, sets the variable `n_nominal` to 600. The transition action `n_nominal = n_cold` sets it to 900 in the reverse case. When a transition occurs, the state machine also executes the exit action of the state it leaves, and the entry action of the state it enters. In our example, these are empty and nothing happens.

Once the state machine has entered the second state, it stays in that state until the condition in the transition from the second to the first state is fulfilled. While the state machine stays in one state, the static action is executed every time the state machine is triggered. Triggering is always an outside event which starts *one* pass through the state machine.

A pass through a state machine consists of first testing all the conditions on transitions leading away from the current state. Transitions and their conditions are tested in order of their priorities. If a condition is true, the corresponding transition is performed and the exit, transition and entry actions are executed. Once the first condition checks out true, any other transitions leading from the same state but having lower priorities are not tested. If no condition is true, the machine remains in the current state and performs the static action once for each pass.

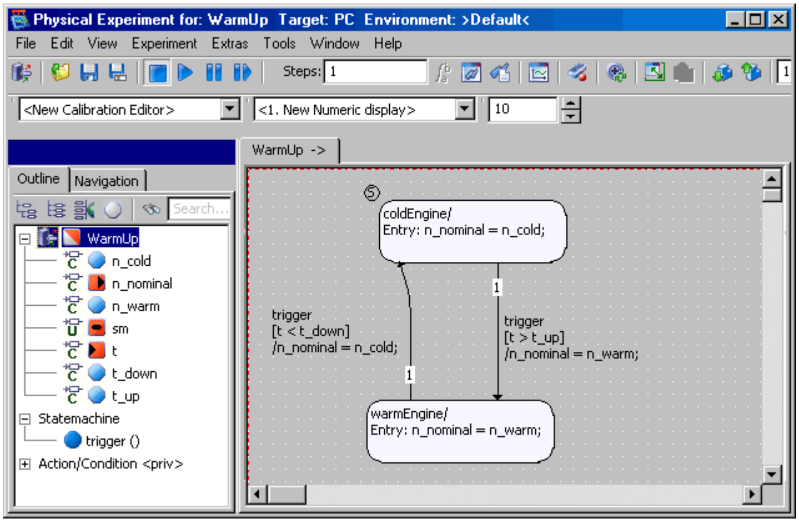
Once the condition in the second transition of our state machine is true, i.e. if the input value falls below the threshold, the state machine returns to the first state. The machine then remains in that state (doing nothing, because there is no static action) until the input value grows larger than the threshold again.

4.8.3 Experimenting with the State Machine

The experimentation environment works the same for state machines as for other types of components. One extra feature for experimenting with state machines is their animation, i.e. the current state is highlighted in the state machine diagram while the experiment is running.

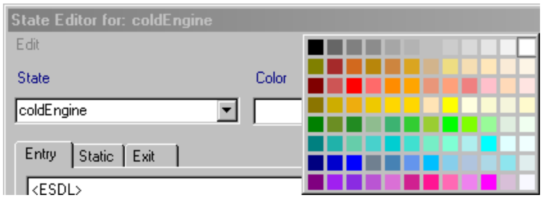
To experiment with the state machine:

- In the state machine editor, select **Build → Experiment** to open the experimentation environment**.**



- Right-click on one of the states and select **Animate States** from the context menu.
- Enable the `trigger` event.
- In the data generator, create a channel for the variable `t`.
- Assign a sine-wave with frequency 1 Hz, off-set 70, and amplitude 20 to the channel.
- Open an oscilloscope window for `t` and `n_nominal`.
- Click on the **Start Offline Experiment** but-ton to experiment with the state machine.
- Change the colors of the individual states to improve clarity.
- To do this, use the **Exit to Component** but-ton to leave the experimentation environ-ment, and call the state editor.

- Select the color in the "Color" combo box.



- Start the experiment anew.

The value of `n_nominal` changes according to whether the sine-wave exceeds or falls below the corresponding temperature threshold value. You can change the threshold using the calibration system to observe the effect of different values on the output. Also, in the state diagram the current state is highlighted.

4.8.4 Integrating the State Machine in the Controller

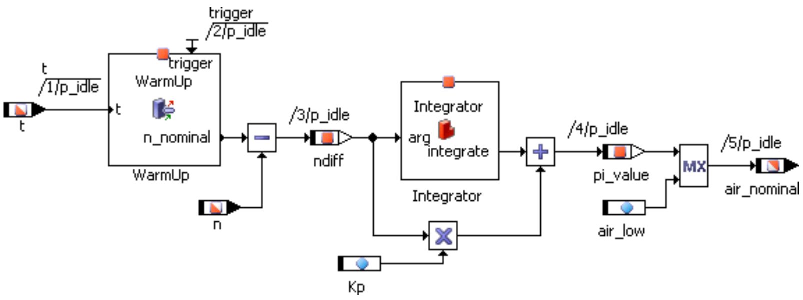
Like all other components in ASCET, a state machine can be used as a building block within another component of any type. You can now integrate the state machine into your controller module to adjust the rotational speed to the engine temperature.

To integrate the state machine:

- From the Component Manager, open the module `Lesson4\IdleCon` in a block diagram editor.
- Remove the parameter `n_nominal` from the diagram and then from the "Outline" tab.

  You will replace the parameter with the state machine in the block diagram.
- Select **Insert** → **Component** and add the state machine to the "Outline" tab of the controller.
- Create a receive message and name it `t`.
- Connect the output of the `WarmUp` component with the subtraction operator in place of the deleted variable, and connect the input of `WarmUp` with the receive message `t`.

- Adjust the diagram as shown below. Be sure to adjust the sequencing in the diagram to include all items in the correct order.

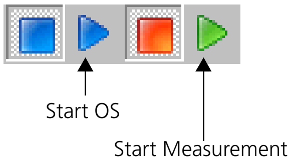


- Save the diagram and click on the **Save** button in the Component Manager.

In order to make the modified controller work with our project, we have to make some adjustments to the project. At this point we will also integrate the temperature sensor, which has been left unused so far.

To modify the project:

- Open the project editor for the project `ControllerTest`.
- Switch to the "OS" tab.
- Assign the process `t_sampling` to the task `Task10ms`.
- Use the command **Task** → **Move Up** to make the process `t_sampling` the first in that task.
- Select **Build** → **Experiment**.
- Open an additional scalar calibration window for the value `U_t`.
- Add the variable `t` to the oscilloscope.
- Click on the **Start OS** button.
- Click on the **Start Measurement** button.
- Adjust the value `U_t` and observe its effect.



If the value of `t` exceeds the 70 degree limit, the state machine switches to nominal value for `n` to the lower value of 600. If the temperature falls to below 60 degrees (simulated by adjusting `U_t`), the nominal value for `n` regains the original value of 900.

4.8.5 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Creating a state diagram
- Creating and assigning conditions, actions and triggers
- Experimenting with state machines
- Integrating state machines into other components

4.9 Hierarchical State Machines

Now that you have familiarized yourself with the way state machines work in the preceding lesson, we shall look at creating a more complex system. This unit concentrates on hierarchical state machines. You will also learn how to use the system libraries and components supplied with ASCET, such as timers.

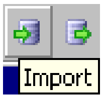
ASCET permits structuring of state machines in closed and open hierarchies. With closed hierarchies, the internal functionality is concealed, with open hierarchies the substates are also shown graphically.

You will build a traffic light control system to run through the individual phases of a traffic light using parameterizable timing. The traffic light will also have an error status where it will flash.

4.9.1 Specifying the State Machine

First you will import the libraries you need and prepare for the task.

To import the system library:



- In the Component Manager, click on **Import**.

  The "Select Import File" window opens.
- In the "Import File" field, use the button to select the file `SystemLibETAS.exp` from the Export directory of your ASCET installation (e.g. `C:\etas\ASCET6.0\export`).

  The **OK** button is now available.

- Click **OK** to start the import.

  The "Import" window opens. All objects contained in the file are selected.
- Confirm the import of all files with **OK**.

  The files are imported. This can take up to several minutes. When the import procedure is finished, all imported items are listed in the "Imported Items" window.

The second step is to specify the two main states possible for the traffic light (`NormalMode` and `ErrorMode`).

To create the state machine:

- In the Component Manager, create the folder `Tutorial\Lesson9`.
- Select **Insert** → **State Machine** to create a new state machine, and call it `Light`.
- Select **Edit** → **Open Component** to open the state machine editor.

  You can start specifying the state machine that will control your traffic light.
- Create the two states `ErrorMode` and `NormalMode`.

Then add a timer to your project from the system library.

To add the timer object:

- Select **Insert** → **Component**.
- In the "Select Item" dialog, select the timer object `Timer` from the `Counter_Timer` folder of the `SystemLib_ETAS` library.
- Confirm your selection with **Ok**.

  You have now added an object `Timer` to the "Outline" tab for your state machine.

To specify the state diagram:

- Specify the necessary data elements as follows:
  - An input `error` of type `Logic`,

- three outputs (`yellow`, `green`, `red`) of type `Logic` to symbolize traffic light colors,
- four continuous parameters (`BlinkTime`, `YellowTime`, `GreenTime`, `RedTime`) for the different traffic light phases.

To get more practice with dependent parameters, you will configure the parameters so that only the green phase is specified; the other parameters are given values dependent on that:

```
RedTime = 2 * GreenTime

YellowTime = GreenTime/3

BlinkTime = YellowTime/10
```

- Now specify calculations and dependencies of the individual parameters.
- To do this, activate the **Dependent** option under "Dependency" in the properties editor for the parameters `RedTime`, `YellowTime` and `BlinkTime`.

  The properties editor is started with a double-click on the element name or via the **Edit** context menu.
- Click on the **Formula** button to start the formula editor.
- Using the formula editor, specify the calculation for each of the dependent parameters by first creating a formal parameter `x` and then entering the calculation in the formula pane.

```
Redtime : 2*x
YellowTime : x/3
BlinkTime : x/10
```

- Close the formula editor and the properties editor.
- Open the dependency editor via the context menu **Edit Data.**

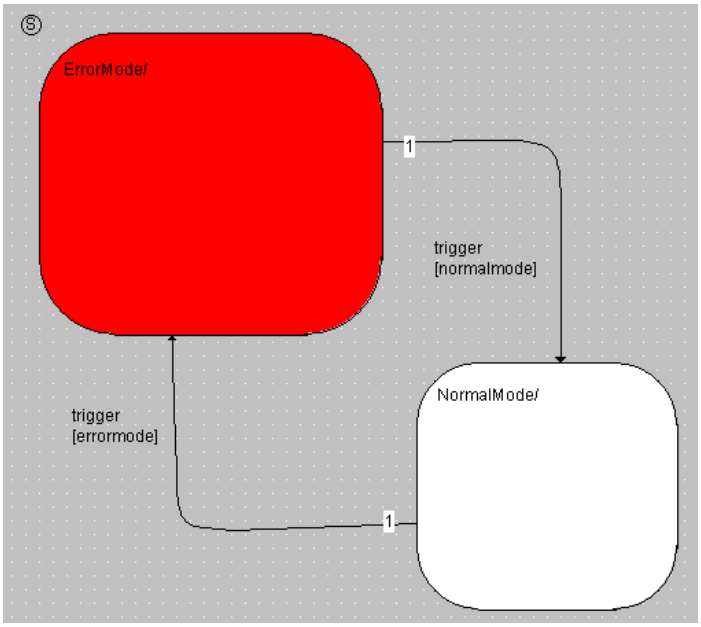
- Assign the corresponding model parameter to the formal parameter `x` for each of the dependent parameters.

  ```
  RedTime : x = GreenTime
  YellowTime : x = GreenTime
  BlinkTime : x = YellowTime
  ```

- Give the data elements meaningful values (e.g. `GreenTime = 5`).
- Open the state editor for the `ErrorMode` state.

  You can open the state editor either by doubleclicking on a state or via the **Edit State** context menu.
- Define this state as the initial state and color it red.
- Enlarge both states so that the hierarchies can be inserted.
- Create the transitions between the two states.
- Open the transition editor via the **Edit Transition** context menu or with a double-click on the graphic.
- Specify the transitions between the two states by entering conditions in the transition dialog. Enter the conditions in ESDL so that the normal state `NormalMode` is activated when the

input `error` is `false` (i.e. there has not been an error), and `ErrorMode` is activated when there is an error.



- Select **File** → **Save**.
- Save your work in the Component Manager by selecting **File** → **Save Database**.
- You might like to experiment with the main states.

The next step towards creating the traffic light control system is to specify the substates. First specify the performance in the error mode (state `ErrorMode`). In this state, a yellow flashing light will be output. To do this, introduce two substates `YellowOff` and `YellowOn`; with the timer as switch between them. In the `YellowOn` state, the output `yellow` will be set to `true`, while the `YellowOff` state sets it back to `false`.

To specify the substates for the error mode

- Create the states `YellowOff` and `YellowOn` and place them inside the state `ErrorMode`.

- Define `YellowOff` as start state and color `YellowOn` yellow.
- Define the response of the state `YellowOff` in the state editor.

  To do this, call the state editor either via the **Edit State** context menu or with a double-click on the state.
- For the entry action, select `ESDL` in the combo box for the "Entry" tab and enter the following code:

  ```
  green = false;
  red = false;
  yellow = false;
  Timer.start(BlinkTime);
  ```
- For the static action, enter the following code on the "Static" tab:

  ```
  Timer.compute();
  ```
- Now define and describe the `YellowOn` state in the same way.

  Entry action:

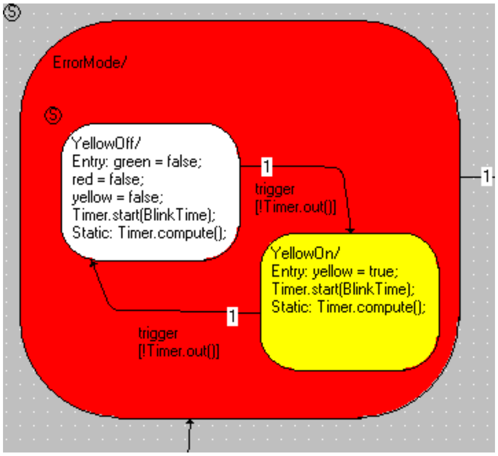
  ```
  yellow = true;
  Timer.start (BlinkTime);
  ```

  Static action:

  ```
  Timer.compute();
  ```

- Now define the transitions between the two substates.

  The condition for a state transition is that the timer has run out (`Timer.out() == false`).



This means that the `ErrorMode` state is started in the `YellowOff` state. As well as switching off the color signals, the entry action starts the timer with the parameterizable flashing time. The static action of the `YellowOff` state calls the timer function `compute()` each time, which decrements the timer counter. When this counter is 0, the timer function `out()` returns the code `false`, thus fulfilling the transition condition. The state `YellowOn` works in a similar way, however, in the entry action, the `Yellow` color signal is switched on.

The next step is to specify the performance in normal operation. To do this, create a start state, `AllOff`, and place it within the `NormalMode` state. Use the exit action to set all the color signals to a defined state. Now think about a suitable response for the traffic light control system.

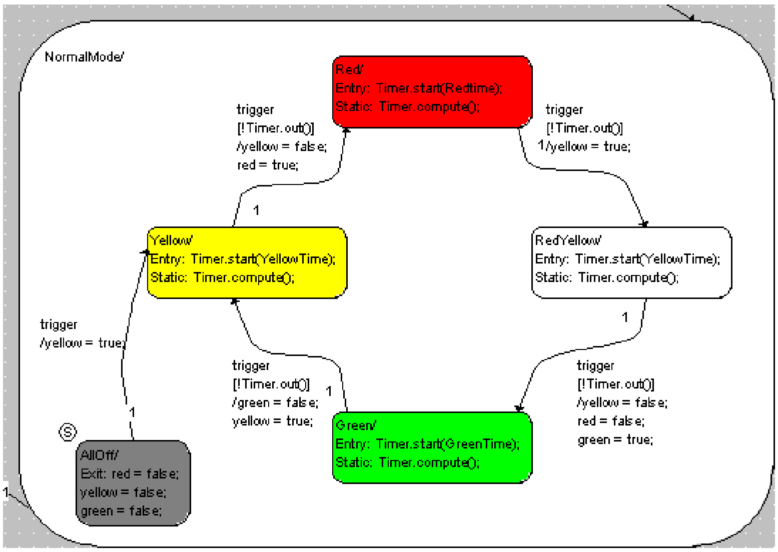
In this example, you should describe the activation or deactivation of the individual color signals in the transition actions, not in the entry actions of the states.

To specify the substates in normal operation

- Create the states `AllOff` (start state), `Yellow`, `Red`, `RedYellow` and `Green` and place them inside the `NormalMode` state..

- Specify the response for the states by starting the appropriate timer for each color (entry action) and initiating timer processing in the static action. (`Timer.compute()`).
- Define the state transitions and describe the response of the states within the transition actions.

  The transition from `AllOff` to `Yellow` should generally occur, all other transitions should happen after the relevant timer has run out.



- Enter the actions for each color signal in the "Action" tab of the transition editor.
- Close the transition editor and select **File** → **Save**.

That completes the specification of your traffic light control system. Before you can experiment with it, you should enter meaningful values for the parameters in the various color timers.

4.9.2 Experimenting with the Hierarchical State Machine

You can experiment with the hierarchical state machine in the same way as with the basic state machine. Please do not forget to activate the animation in the experiment.

Experimenting with the State Machine:

- In the state machine editor, select **Build → Experiment** to open the experimentation environment**.**
- Right-click on one of the states and select **Animate States** from the context menu.
- Enable the `trigger` event.
- Click on the **Start Offline Experiment** button to experiment with the state machine.
- Experiment with the state machine by changing the `GreenTime` parameter and then updating the dependent parameters via **Update Dependent Parameter**.
- Occasionally, set the `error` input to `true`.

4.9.3 How Hierarchical State Machines Work

Hierarchical state machines work in the same way as normal state machines. In principle, hierarchical state machines only represent a graphic structure of the total set of responses. As an extra task, consider or demonstrate how the response described could be achieved without a hierarchy.

The traffic light example is constructed with two hierarchical states. The system switches between the two states `ErrorMode` and `NormalMode` using the logical input variable `error`. The sub-responses are defined within these states.

To understand this, look at the processing in the `ErrorMode` hierarchy state. Each time the trigger is called, the condition for the transition from the hierarchy state `ErrorMode` to the hierarchy state `NormalMode` is checked (condition: `!error`). If no transition is necessary, the transitions from substate `YellowOff` to `YellowOn` or vice versa are checked, and the necessary actions are performed.

If you now look at NormalMode, this means that, again, for each trigger call it is first checked whether the input error is true, and therefore a transition to ErrorMode is necessary. Only if this is not the case, the transitions from the substates (AllOff, Yellow, Red, RedYellow, Green) are checked. In the traffic light example, it is checked whether the timer has run out.

You can have a look at the code generated from the state diagram to clarify this process.

Displaying generated code:

- In the state machine editor, select **Build** → **View Generated Code** to display the code generated**.**

  The code from the components is written to a temporary file and then opened with an application defined in the operating system register database.

Note

In order to display the code generated, a search is made in the operating system register database for an application with associated files of type *.c *and* *.h*. Depending on the file endings registered, the relevant editor is started.*

4.9.4 Summary

After completing this lesson you should be able to perform the following tasks in ASCET:

- Create hierarchical state diagrams
- Describe the way the states behave in actions and also in the transition actions.
- Import modules, classes or components
- Import system components from ASCET libraries
- Use the Timer system component
- Use of dependent parameters
- Displaying generated code

5 Glossary

In this glossary the technical terms and abbreviations used in the ASCET documentation are explained. Many terms are also used in a more general sense, but only the meaning specific to ASCET is explained here.

The terms are listed in alphabetic order.

5.1 Abbreviations

ASAM-MCD

Association for **S**tandardisation of **A**utomation- and **M**easuring Systems, with the working groups **M**easuring, **C**alibration, **D**iagnosis (German: **A**rbeitskreis zur **S**tandardisierung von **A**utomations- und **M**esssystemen, mit den Arbeitsgruppen **M**essen, **C**alibrieren und **D**iagnose)

ASCET

Development tool for control unit software

ASCET-MD

ASCET Modeling and Design

ASCET-RP

ASCET Rapid Prototyping

ASCET-SE

ASCET Software Engineering

AUTOSAR

Automotive **O**pen **S**ystem **Ar**chitecture; see http://www.autosar.org/

BDE

Block **D**iagram **E**ditor

CPU

Central **P**rocessing **U**nit

ECU

Embedded **C**ontrol **U**nit

ERCOS^{EK}

ETAS real-time operating system, OSEK-compliant

ESDL

Embedded **S**oftware **D**escription **L**anguage

ETK

emulator test probe (German: **E**mulator**t**ast**k**opf)

FPU

Floating **P**oint **U**nit

HTML

Hyper**t**ext **M**arkup **L**anguage

INCA

Integrated **C**alibration and **A**cquisition Systems

INTECRIO

A new ETAS product family. INTECRIO integrates code from various behavioral modeling tools, facilitates all necessary configurations, allows the generation of executable code, and provides an experiment environment for the execution of the Rapid Prototyping experiment.

OS

Operating **S**ystem

OSEK

Working group "open systems for electronics in automobiles" (German: Arbeitskreis **O**ffene **S**ysteme für die **E**lektronik im **K**raftfahrzeug)

RAM

Random **A**ccess **M**emory

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 ASCET.

ROM

Read-**O**nly **M**emory

RTA-RTE

AUTOSAR runtime environment by ETAS

RTE

AUTOSAR runtime environment; provides the interface between software components, basic software, and operating systems.

SWC

Atomic AUTOSAR **s**oft**w**are **c**omponent; the smallest non-dividable software unit in AUTOSAR.

UML

Unified **M**odeling **L**anguage

XML

E**x**tensible **M**arkup **L**anguage

5.2 Terms

Action

An action is part of a state machine and associated with states or transitions of the state machine. An action is a piece of functionality, whose execution is triggered by the state machine.

Application Modes

An application mode is part of the operating system of ASCET. An operating mode describes different conditions a system can be in, e.g. EEPROM-programming mode, warm-up, or normal mode.

Argument

An argument is the input to a method of a class. Arguments can only be used in the specification of the method they belong to, and not in other methods of the class.

Arithmetic Services

User-defined C functions to optimize elementary operations, such as addition operations, and to extend such operations with special properties, such as value limits.

Array

An array is a one dimensional static list of elements of the basic scalar type `continuous` or `discrete`, indexed by the basic scalar type `discrete`.

ASAM-MCD-2MC file

Default exchange format used for projects in ASCII format for the description of measurement and calibration values. The files have the extension `*.a2l`.

Basic Model Types

Basic model types are used to model physical behavior. There are three types: `continuous`, `discrete` and `logical`. A number of operations, such as addition or comparison, are defined for the basic model types. The implementation is used to transform the model types to implementation types.

Block Diagram

A block diagram is a graphical description for a component in which the various elements, operators and inputs/arguments and outputs/return values are connected by directed lines. A block diagram consists of several diagrams. The description in terms of block diagrams is a physical description in contrast to the description with C-Code.

Bypass Experiment

In a bypass experiment, ASCET is directly connected to a microcontroller, and parts of the microcontroller software are simulated by ASCET.

Calibration

Calibration is the manipulation of the values (physical / implementation) of elements during the execution of an ASCET model (experiment).

Calibration Window

ASCET working window which can be used to modify parameters.

C Code

C code is an implementation dependent description of a component.

Characteristic

General term used for characteristic map, curve and value (see also "Parameter".

Characteristic Line

Two-dimensional parameter.

Characteristic Map

Three-dimensional parameter.

Characteristic value

One-dimensional parameter (constant).

Class

A class is one of the component types in ASCET. Classes in ASCET are like object-oriented classes. The functionality of a class is described by methods.

Code

The executable code is the "actual" program with the exception of the data (contains the actual algorithms). The code is the program part which can be executed by the CPU.

Code Generation

Code generation is the first step in the transformation of a physical model to executable code. The physical model is transformed into ANSI C-Code. Since the C-Code is compiler (and therefore target) dependent, different code for each target is produced.

Component

A component is the basic unit of reusable functionality in ASCET. Components can be specified as classes, modules, or state machines. Each component is built up of elements which are combined with operators to build up the functionality.

Component Manager

Working environment in which the user can set up ASCET and manage the data he created and which are stored in the database.

Condition

A condition is used to describe the control flow in a state machine. It returns a logical value which determines, whether a transition from one state to another takes place.

Configuration dialog box

Dialog box used to configure the individual measuring and calibration windows as well as the variables contained therein.

Constant

A constant is an element that cannot be changed during execution of an ASCET model.

Container

Containers serve as containers for projects, classes and modules. Their purpose is to structure models and databases and place different database items under a common version control.

Data

The data is the variables of a program used for calibration.

Data Generator

The data generator is part of the experimentation environment. It is used to stimulate the inputs or variables in the model under experimentation.

Data Logger

With the data logger measurement data can be read from an experiment and stored to disk for further analysis.

Data Set

A data set contains/references the initial data for all elements of a component or project.

Database

All information specified or produced with ASCET is stored in a database. A database is structured into folders.

Description file

Contains the physical description of the characteristics and measured values in the control unit (names, addresses, conversion formulae, functional assignments, etc.).

Diagram

A diagram is used for the graphical specification of components as block diagrams or state machines.

Dimension

The dimension is used to describe the ‘size’ of basic elements. The dimension can either be scalar (zero dimensional), array (one dimensional) or characteristic line/table.

Distribution

A distribution contains the sample points for one or more group characteristic lines/maps.

Editor

See Calibration Window.

Element

An element is a part of a component which reads or writes data, for instance a variable, parameter or other component used within a component.

Event

An event is an (external) trigger that starts an action of the operating system, e.g., a task.

Event Generator

The event generator is part of the experimentation environment. It is used to describe the order and the timing in which events are generated for the activation of tasks (methods/processes/time frames) in the case of an offline experiment.

Experiment

An experiment defines the settings in the experiment environment that are used to test the proper functioning of components or projects. It contains information about the size, position and content of the measurement and calibration windows, as well as the settings of the event generator, data generator and the data logger. An experiment can be executed either offline (non real-time) or online (real-time) and can be used to control a technical process in a bypass or fullpass application. In all cases, instrumented code generated from an ASCET specification is used for experiment execution.

Experiment environment

Main working environment in which the user performs his experiments.

Fixed Point Code

From the physical specification, fixed point code can be generated which can be executed on processors without a floating point unit.

Folder

A folder is a management unit for structuring an ASCET database. A folder contains items of any kind.

Formula

A formula is part of an implementation describing the transformation from the model types to the implementation (data) types.

Fullpass Experiment

In a fullpass experiment, ASCET is directly connected with an experimental microcontroller, and the entire application is simulated by ASCET.

Group Characteristic Line/Map

Group characteristic lines/maps are characteristic lines/maps that share the same distribution of axis points but have different return values. The distribution of axis points and the individual group tables are specified as separate elements.

HEX file

Exchange format of a program version as Intel Hex or Motorola S Record file.

Hierarchy

A hierarchy block is used to structure the graphical specification of a block diagram.

Icon

Icons can be used to illustrate the function of ASCET components.

Implementation

An implementation describes the transformation of the physical specification (model) to executable fixed point code. An implementation consists of a (linear) transformation formula and a bounding interval for the model values.

Implementation Cast

Element that provides the users the possibility to control the implementations of intermediate results in arithmetic chains without changing the physical representation of the elements in question.

Implementation Data Types

Implementation data types are the data types of the underlying C programming language, e.g., `unsigned byte` (`uint8`), `signed word` (`sint16`), `float`.

Implementation Types

Implementation templates. Implementation types contain the main specifications of an implementation; they are defined in the project editor and can be assigned to individual elements in the implementation editors.

Intel Hex

Exchange format used for program versions.

Interface

An interface of a component describes how the component exchanges data with other components. It can be compared to the `.h` file in C.

Kind

There are three kinds of elements: variables, parameters, and constants. Variables can be read and written. Parameters can only be read but can calibrated during experimentation. Constants can only be read and not written to during experiments.

L1

The message format for exchanging data between the host and the target, where the experiment is run. Data is transferred, e.g. for displaying values in measure windows.

Layout

A component has a graphical representation that shows pins for the inputs/arguments, outputs/return values and time frames/methods/ processes. Additionally, the layout contains an icon that graphically represents the component when used within other components.

Literal

A literal is used in the description of components. A literal contains a string that is interpreted as a value, e.g. as a continuous or logical value.

Measuring

Recording of data which is either displayed or stored, or both displayed and stored.

Measure window

ASCET working window which displays measured signals during a measurement.

Measured signal

A variable to be measured.

Measurement

A measurement is the representation of values (physical / implementation) of variables/parameter during an experiment. The values can be displayed with various different measurement windows like oscilloscopes, numeric displays, etc.

Measuring channel parameters

Parameters which can be set for the individual channels of a measuring module.

Message

A message is a real time language construct of ASCET for protected data exchange between concurrent processes.

Method

A method is part of the description of the functionality of a class in terms of object oriented programming. A method has arguments and one return value.

Model Type

Each element of an ASCET component specification is either a component of its own or is of a model type In contrast to implementation types, model types represent physical values.

Module

A module is one of the component types in ASCET. It describes a number of processes that can be activated by the operating system. A module cannot be used as a subcomponent within other components.

Monitor

With a monitor the data value of an element can be displayed in a diagram during an experiment.

Motorola-S-Record

Exchange format used for program versions.

Offline experiment

During offline experimentation the code generated by ASCET can be run on the PC or an experimental target, but it does not run in real-time. Offline experimentation focuses on testing the functional specification of a system.

Online experiment

In the online experiment the projects are executed in real-time with the behavior defined in the real-time operating system. The code always runs on an experimental target in real-time. The online experiment focuses on the operating system schedule and the corresponding real-time behavior of the control system.

Operating System

The operating system is used to schedule the execution/activation of an ASCET software system. The operating system also provides services for communication (messages) and access to reserved parts of the hardware (resources). The ASCET operating system is based on the real-time operating system ERCOS^{EK}.

OSEK operating system

Operating system conforming to OSEK.

Oscilloscope

An oscilloscope is a type of measurement window that graphically displays data values during experiments.

Parameter

A parameter (characteristic value, curve and map) is an element whose value cannot be changed by the calculations executed in an ASCET model. It can, however, be calibrated during an experiment.

Priority

Every task has a priority in the form of a number. The higher the number, the higher the priority. The priority determines the order in which tasks are scheduled.

Process

A process is a concurrently executable piece of functionality that is activated by the operating system. Processes are specified in modules and do not have any arguments/inputs or return values/outputs.

Program

A program consists of code and data and is executed as a unit by the CPU of the control unit.

Project

A project describes an entire embedded software system. It conains components which define the functionality, an operating system specification, and a binding mechanism which defines the communication.

Resource

A resource is used to model parts of an embedded system that can be used only mutually exclusively, e.g. timers. When such a part is accessed, it has to be reserved and then released again, which is done using resources.

Runnable entity

see RE

Runtime environment

see RTE

Scheduling

Scheduling is the assigning of processes to tasks and the definition of task activation by the operating system.

Scope

An element has one of two scopes: local (only visible inside a component) or global (defined inside a project).

State

A state is a part of a state machine. A state machine is always in a one of its states. One of the states is marked as the start state which is the initial state of the state machine. Each state is connected to other states by arcs. A state has an entry action (that is executed upon entry of a state), an static action (that is executed the state remains unchanged) and an exit action (that is executed upon exit of the state).

State Machine

A state machine is one of the component types in ASCET. The behavior is described with a state graph consisting of states connected by transitions.

Target

A target is the hardware an experiment runs on. A target can either be an experimental target (PC, Transputer, PowerPC) or a microcontroller target.

Task

A task is an ordered collection of processes that can be activated by the operating system. Attributes of a task are its operating modes, its activation trigger, its priority, the mode of scheduling. On activation the processes of the task are executed in the given order.

Trigger

A trigger activates the execution of a task (in the scope of the operating system) or of a state machine.

Transition

A transition is a connection between states. Transitions describe possible state changes. Each transition is assigned to a trigger of the state machine, has a priority, a condition, and an action.

Type

Variables and parameters are of type `cont` (continuous), `udisc` (unsigned discrete), `sdisc` (signed discrete) or `log` (logic). `Cont` is used for physical quantities that can assume any value; `udisc` for positive integer values, `sdisc` for negative integer values, and `log` is used for Boolean values (true or false).

User profile

A set of user-specific option settings.

Variable

A variable is an element that can be read and written during the execution of an ASCET model. The value of a variable can also be changed with the calibration system.

Also: General term used for parameters (characteristics) and measured signals.

Window elements

General term used for calibration and display elements.

6 Appendix A: Troubleshooting ASCET Problems

This chapter gives some information of what you can do when problems arise during your work with ASCET.

6.1 Support Function for Feedback to ETAS in Case of Errors

While developing ASCET, the functional safety of the program was utmost importance. Should an error occur nevertheless, please forward the following information to ETAS:

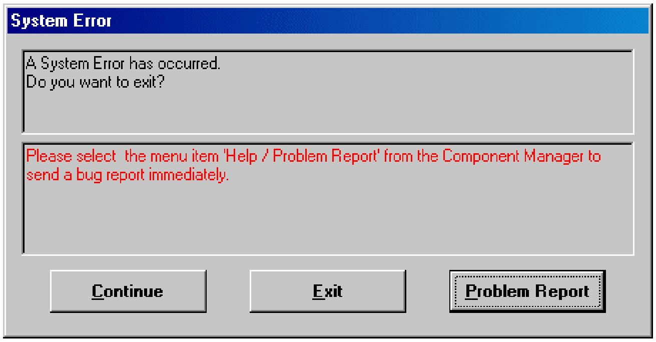
- Which step were you about to perform with ASCET when the error occurred?
- What kind of error occurred (wrong function, system error or system crash)?
- Which model element or model was edited at the time of the error?

Note

To allow ASCET to be updated and developed further, it is important that you report any errors which have occurred with an application to ETAS. You can use the "Problem Report" method for this purpose.

When you use the support function, ASCET compresses the entire contents of the "log" directory (all `*.log` files) including a textual description into an archive file named `EtasLogFiles00.zip` in the `...\ETAS\LogFiles\` subdirectory. For additional archive files, the file name is incremented automatically (up to `19`) to avoid that older archive files are immediately overwritten.

If a critical system error occurs, the following window is displayed:


System Error

A System Error has occurred.
Do you want to exit?

Please select the menu item 'Help / Problem Report' from the Component Manager to send a bug report immediately.

What to do in case of an error:

1. **Problem Report** button

   - Click on the **Problem Report** button.

     The support function is started.

   - Describe the error and forward the information—together with the model—to ETAS.

2. **Exit** button

   - Click on the **Exit** button.

     ASCET is closed; all modifications that have not been saved will be lost.

     Close any message boxes prompting you to save data without saving any data.

   - Restart ASCET.

3. **Continue** button

Note

Use the **Continue** *button only if you have to save important configuration data. Subsequent errors or incorrect configurations cannot be excluded!*

   - Click on the **Continue** button.

     The application continues to run; the program jumps back to the location where it was before the error occurred.

   - Save your data.
   - Exit ASCET.
   - Restart ASCET.

It is generally advisable to close the program (without saving) and to restart it. Thus, the risk of possible subsequent errors is omitted.

7 Appendix B: Troubleshooting General Problems

This chapter gives some information of what you can do when problems arise that are not specific to an individual software or hardware product.

7.1 Problems and Solutions

7.1.1 Network Adapter cannot be selected via Network Manager

Cause: APIPA is disabled

The alternative mechanism for IP addressing (APIPA) is usually enabled on all Windows 2000, XP and Vista systems. Network security policies, however, may request the APIPA mechanism to be disabled. In this case, you cannot use a network adapter which is configured for DHCP to access ETAS hardware. The ETAS Network Manager displays a warning message.

The APIPA mechanism can be enabled by editing the Windows registry. This is permitted only to users who have administrator privileges. It should be done only in coordination with your network administrator.

To enable the APIPA mechanism:

- Click **Start** and then click **Run**.
- Enter `regedit` and click **OK**

  The registry editor is displayed.
- Open the folder
  `HKEY_LOCAL_MACHINE\SYSTEM\`
  `CurrentControlSet\Services\`
  `Tcpic\Parameters\`
- Select **Edit** → **Find** to search for the key `IPAutoconfigurationEnabled`.
- Set the value of this key to `1` to enable the APIPA mechanism.

  You may find several instances of this key in the Windows registry which either apply to the TCP/IP service in general or to a specific network adapter. You only need to change the value for the corresponding network adapter.
- Close the registry editor.
- Restart your workstation in order to make your changes take effect.

If you cannot find any instances of the registry key mentioned, the APIPA mechanism has not been disabled on your system.

7.1.2 Search for Ethernet Hardware fails

Cause: Personal Firewall blocks Communication

For a detailed description on problems caused by personal firewalls and possible solutions see "Personal Firewall blocks Communication" on page 154.

Cause: Client Software for Remote Access blocks Communication

PCs or notebooks which are used outside the ETAS hardware network sometimes use a client software for remote access which might block communication to the ETAS hardware. This can have the following causes:

- A firewall which is blocking Ethernet messages is being used (see „Cause: Personal Firewall blocks Communication“ on page152)
- By mistake, the VPN client software used for tunneling filters messages. As an example, Cisco VPN clients with versions before V4.0.x in some cases erroneously filtered certain UDP broadcasts.

  If this might be the case, please update the software of your VPN client.

Cause: ETAS Hardware hangs

Occasionally the ETAS hardware might hang. In this case switch the hardware off, then switch it on again to re-initialize it.

Cause: Network Adapter temporarily has no IP Address

Whenever you switch from a DHCP company LAN to the ETAS hardware network, it takes at least 60 seconds until ETAS hardware can be found. This is caused by the operating system’s switching from the DHCP protocol to APIPA, which is being used by the ETAS hardware.

Cause: ETAS Hardware had been connected to another Logical Network

If you use more than one PC or notebook for accessing the same ETAS hardware, the network adapters used must be configured to use the same logical network. If this is not possible, it is necessary to switch the ETAS hardware off and on again between different sessions (repowering).

Cause: Device driver for network card not in operation

It is possible that the device driver of a network card is not running. In this case you will have to deactivate and then reactivate the network card.

Deactivating and reactivating the network card:

- To deactivate the network card first select in the Windows start menu the following item:
  - Windows 2000: **Settings** → **Network and dial-up connections**
  - Windows XP: **Settings** → **Network Connections**
  - Windows Vista: **Settings** → **Control Panel** (classic view) → **Network and Sharing Center** → **Manage Network Connections**
- Right-click on the used network adapter and select **Deactivate** or **Disable** in the context menu.
- In order to reactivate the network adapter right-click on it again and select **Activate** or **Enable**.

Cause: Laptop energy management deactivates the network card

The energy management of a laptop computer can deactivate the network card. Therefore you should turn off energy monitoring on the laptop.

Switching off Energy Monitoring on Laptop

- From the Windows Start Menu, select
  - Windows 2000: **Settings** → **Control Panel** → **System**
  - Windows XP: **Settings** → **Control Panel** → **System**
  - Windows Vista: **Settings** → **Control Panel** (classic view) → **System** → **Advanced system settings** (menu item)
- Select the **Hardware** tab and click on **Device Manager**.
- In the Device Manager open the tree structure of the entry **Network Adapter**.
- Right-click on the used network adapter and select **Properties** in the context menu.
- Switch off energy monitoring as follows:

  - Windows 2000:
    Select the **Energy Management** tab and deactivate the **Allow computer to switch off device to save energy** option.
  - Windows XP:
    Select the **Energy Management** tab and deactivate the **Computer can switch off device to save energy** option.
  - Windows Vista:
    Select the **Power Manager** tab and deactivate the **Allow the computer to turn off the device to save power** option.
- Select the **Extended Settings** tab. If the property **Autosense** is included, deactivate it also.
- Click **OK** to apply the settings.

Cause: Automatic disruption of network connection

It is possible after a certain period of time without data traffic that the network card automatically interrupts the Ethernet connection. This can be prevented by setting the registry key `autodisconnect`.

Setting the Registry Key autodisconnect:

- Open the Registry Editor.
- Select under `HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\lanmanserver\parameters` the Registry Key `auto-disconnect` and change its value to `0xffffffff`.

7.1.3 Personal Firewall blocks Communication

Cause: Permissions given through the firewall block ETAS hardware

Personal firewalls may interfere with access to ETAS Ethernet hardware. The automatic search for hardware typically cannot find any Ethernet hardware at all, although the configuration parameters are correct.

Certain actions in ETAS products may lead to some trouble if the firewall is not properly parameterized, e.g. upon opening an experiment in ASCET or searching for hardware from within INCA or HSP.

If a firewall is blocking communication to ETAS hardware, you must either disable the firewall software while working with ETAS software, or the firewall must be configured to give the following permissions:

- Outgoing limited IP broadcasts via UDP (destination address 255.255.255.255) for destination ports 17099 or 18001
- Incoming limited IP broadcasts via UDP (destination IP 255.255.255.255, originating from source IP 0.0.0.0) for destination port 18001
- Directed IP broadcasts via UDP to the network configured for the ETAS application, destination ports 17099 or 18001
- Outgoing IP unicasts via UDP to any IP in network configured for the ETAS application, destination ports 17099 through 18020
- Incoming IP unicasts via UDP originating from any IP in the network configured for the ETAS application, source ports 17099 through 18020, destination ports 17099 through 18020
- Outgoing TCP/IP connections to the network configured for the ETAS application, destination ports 18001 through 18020

Note

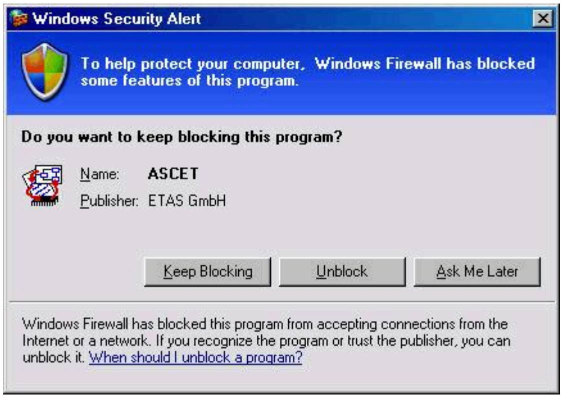
The ports that have to be used in concrete use cases depend on the hardware used. For more precise information on the port numbers that can be used please refer to your hardware documentation.

Windows XP and Windows Vista come with a built-in personal firewall. On many other systems it is very common to have personal firewall software from third party vendors, such as Symantec, McAffee or BlackIce installed. The proceedings in configuring the ports might differ for each personal firewall software used. Therefore please refer to the user documentation of your personal firewall software for further details.

As an example for a firewall configuration, you will find below a description on how to configure the widely used Windows XP/Vista firewall if the hardware access is prohibited under Windows XP with Service Pack 2 or Windows Vista.

Solution for Windows XP and Vista Firewall, Users with Administrator Privileges

If you have administrator privileges on your PC, the following dialog window opens if the firewall blocks an ETAS product.


Windows Security Alert

To help protect your computer, Windows Firewall has blocked some features of this program.

Do you want to keep blocking this program?

Name: ASCET
Publisher: ETAS GmbH

Windows Firewall has blocked this program from accepting connections from the Internet or a network. If you recognize the program or trust the publisher, you can unblock it. When should I unblock a program?

To unblock a product:

- In the "Windows Security Alert" dialog window, click on **Unblock**.

  The firewall no longer blocks the ETAS product in question (in the example: ASCET). This decision survives a restart of the program, or even the PC.

Instead of waiting for the "Windows Security Alert" dialog window, you can unblock ETAS products in advance.

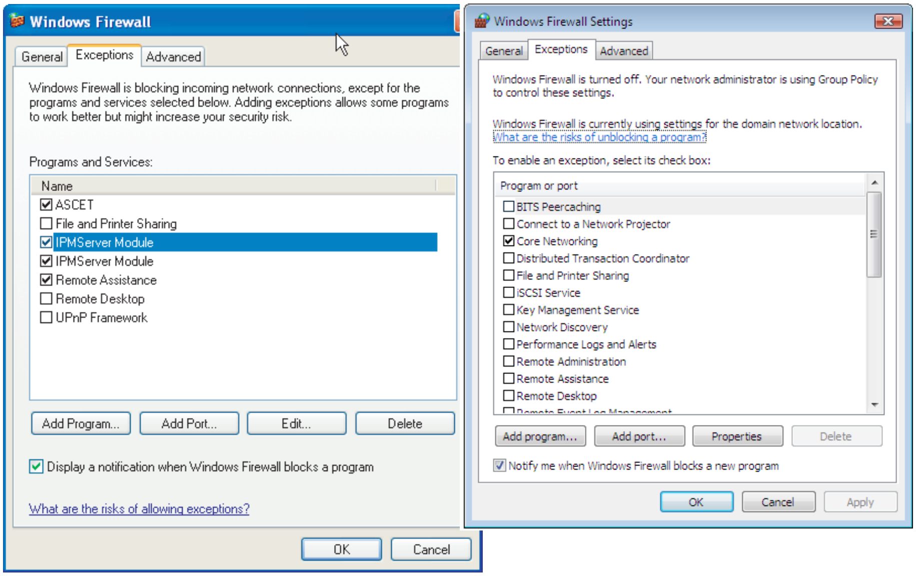
Unblocking ETAS products in the firewall control:

1. Windows XP:
   - From the Windows Start Menu, select **Settings** → **Control Panel**.
   - In the control panel, double-click the **Windows Firewall** icon to open the "Windows Firewall" dialog window.
2. Windows Vista:
   - From the Windows Start Menu, select **Settings** → **Control Panel** → **Security** → **Windows Firewall**.

- In the "Windows Firewall" window, click on **Allow program through Windows Firewall** to open the "Windows Firewall Settings" window.

3. both

- In the "Windows Firewall [Settings]" dialog window, open the "Exceptions" tab.



Windows Firewall

General | Exceptions | Advanced

Windows Firewall is blocking incoming network connections, except for the programs and services selected below. Adding exceptions allows some programs to work better but might increase your security risk.

Programs and Services:

Name
- ☑ ASCET
- ☐ File and Printer Sharing
- ☑ IPMServer Module
- ☑ IPMServer Module
- ☑ Remote Assistance
- ☐ Remote Desktop
- ☐ UPnP Framework

Add Program... | Add Port... | Edit... | Delete

☑ Display a notification when Windows Firewall blocks a program

What are the risks of allowing exceptions?

OK | Cancel

Windows Firewall Settings

General | Exceptions | Advanced

Windows Firewall is turned off. Your network administrator is using Group Policy to control these settings.

Windows Firewall is currently using settings for the domain network location.
What are the risks of unblocking a program?

To enable an exception, select its check box:

Program or port
- ☐ BITS Peercaching
- ☐ Connect to a Network Projector
- ☑ Core Networking
- ☐ Distributed Transaction Coordinator
- ☐ File and Printer Sharing
- ☐ iSCSI Service
- ☐ Key Management Service
- ☐ Network Discovery
- ☐ Performance Logs and Alerts
- ☐ Remote Administration
- ☐ Remote Assistance
- ☐ Remote Desktop

Add program... | Add port... | Properties | Delete

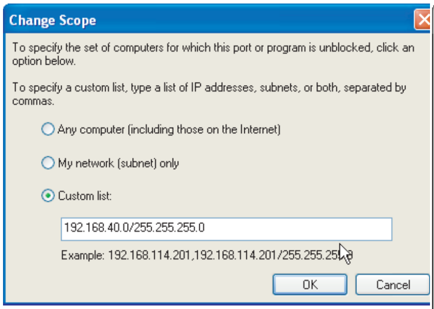
☑ Notify me when Windows Firewall blocks a new program

OK | Cancel | Apply

This tab lists the exceptions not blocked by the firewall. Use **Add Program** or **Edit** to add new programs, or edit existing ones.

- Make sure that the ETAS products and services you want to use are properly configured exceptions.

– Open the "Change Setup" (XP) or "Change Scope" (VISTA) window.


Change Scope

To specify the set of computers for which this port or program is unblocked, click an option below.

To specify a custom list, type a list of IP addresses, subnets, or both, separated by commas.

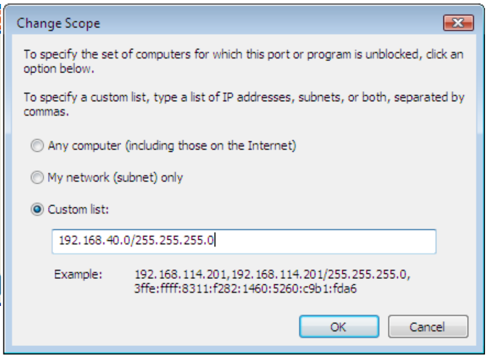
Any computer (including those on the Internet)

My network (subnet) only

[✓ Custom list:]

192.168.40.0/255.255.255.0

Example: 192.168.114.201,192.168.114.201/255.255.255.0


Change Scope

To specify the set of computers for which this port or program is unblocked, click an option below.

To specify a custom list, type a list of IP addresses, subnets, or both, separated by commas.

Any computer (including those on the Internet)

My network (subnet) only

[✓ Custom list:]

192.168.40.0/255.255.255.0

Example: 192.168.114.201,192.168.114.201/255.255.255.0, 3ffe:ffff:8311:f282:1460:5260:c9b1:fda6

– To ensure proper ETAS hardware access, make sure that at least the IP addresses `192.168.40.xxx` are unblocked.

– Close the "Change Setup" or "Change Scope" window with **OK**.

- Close the "Windows Firewall" dialog window with **OK**.

  The firewall no longer blocks the ETAS product in question. This decision survives a restart of the PC.

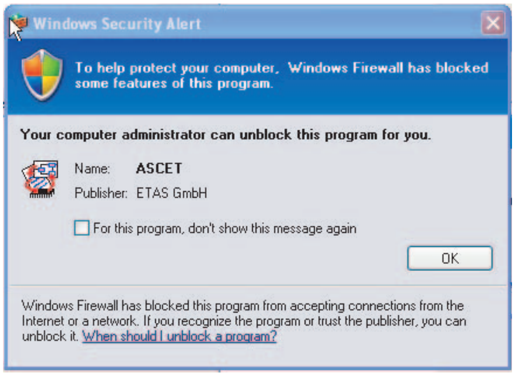
Solution for Windows XP/Vista Firewall, Users without Administrator Privileges

This section addresses users with restricted privileges, e.g., no system changes, write restrictions, local login.

Working with an ETAS software product requires "Write" and "Modify" privileges within the `ETAS`, `ETASData`, and ETAS temporary directories. Otherwise, an error message opens if the product is started, and a database is opened. In that case, no correct operation of the ETAS product is possible because the database file and some `*.ini` files are modified during operation.

The ETAS software has to be installed by an administrator anyway. It is recommended that the administrator assures that the ETAS program/processes are added to the list of the Windows XP/Vista firewall exceptions, and selected in that list, after the installation. If this is omitted, the following will happen:

- The "Window Security Alert" window opens when one of the actions conflicting with a restrictive firewall configuration is executed.



Windows Security Alert

To help protect your computer, Windows Firewall has blocked some features of this program.

Your computer administrator can unblock this program for you.

Name: ASCET

Publisher: ETAS GmbH

☐ For this program, don't show this message again

Windows Firewall has blocked this program from accepting connections from the Internet or a network. If you recognize the program or trust the publisher, you can unblock it. When should I unblock a program?

To unblock a program (no Admin privileges):

- In the "Windows Security Alert" dialog window, activate the option **For this program, don't show this message again**.
- Click **OK** to close the window.

  An administrator has to select the respective ETAS software in the "Exceptions" tab of the "Windows Firewall" dialog window (Windows XP) or the corresponding window in Windows Vista to avoid further problems regarding hardware access with that ETAS product.

8 Appendix C: AUTOSAR

8.1 Basic Principles

The creation of an atomic software component in AUTOSAR is done in two steps. In the first step, the interface of the component is defined. The interface is specified in an authoring tool and exchanged via XML. The XML file(s) are then given to a component API generator which transforms the interface description into a header file. This header file contains all access macros which the internal behavior of the atomic software component has to use. As a rule, the component API generator is the contract phase part of an RTE[1] generator.

In a second step, the application software component developer provides the internal behavior in terms of C files respecting and using the interfaces as defined in the header file. Now the `*.h` and the `*.c` file of the atomic software components are defined and can be compiled for checking. The access macros will only be resolved during the RTE generation phase where the RTE generator knows the OS schedule and all component (instances) mapped to the ECU the RTE is generated for.

For atomic software components, ASCET can be used as authoring tool and behavioral modeling tool. In the authoring approach, the AUTOSAR modeling elements supported in ASCET 6.0, i.e. Modegroup, Interface, Atomic Software Component, are created and maintained in the ASCET database. This means that these elements have an ASCET OID, can carry different implementations and data and can be (re-)used in several projects.

AUTOSAR elements reference each other in an XML file. For example, data element prototypes have a type and are used in sender-receiver interface types. In the same manner, interface types are used as port prototype in atomic software component types. In ASCET 6.0, one creates atomic software component types. Atomic software components have a so-called internal behavior. The internal behavior is composed of runnable entities. Runnable entities resemble ASCET processes because in an AUTOSAR ECU integration they are mapped to operating system tasks, hence, they represent a "partial" behavior of the component.

ASCET can be used as behavioral modelling tool too. In ASCET 6.0, the internal behavior of atomic software components is specified by means of a block diagram editor. The internal behavior can consist of variables, class instances, parameters and sequence calls. Messages and modules are supported for migration purposes too.

1. runtime environment

AUTOSAR XML and code generation is performed by ASCET projects. This means that the ASCET project in the AUTOSAR use case will contain ONE atomic software component type. AUTOSAR code generation works exclusively for the target `RTE-AUTOSAR` which is a production code target. During code generation, the C code with access macros are found in the cgen-folder of ASCET. If one wants to obtain both the generated `*.c` and `*.arxml` files, one has to use the export-generated-code feature of ASCET.

8.2 AUTOSAR Modelling Elements in ASCET

8.2.1 Modes

ASCET supports the AUTOSAR mode management as of release 2.1. A mode type resembles an ASCET enumeration because it has so-called mode declarations. Typical mode declarations are init, run, diagnostics, etc. In contrast to enumerations, the representing integer cannot be set explicitly. Modes are maintained in the database; the first mode declaration in the editor is the init mode.

8.2.2 Interfaces

In ASCET V6.0, only *sender-receiver interfaces* are supported. Sender-receiver interfaces resemble, from their editor, layout classes without methods. Sender-receiver interfaces have *data element prototypes*. The data element prototypes are of an ASCET model type, which means that an interface type can have several ASCET implementations. The ASCET implementation of a sender-receiver interface is defined by the implementation of its data element prototypes. The ASCET implementation of the data element prototype defines an ASCET implementation type (e.g. `uint16`) to an ASCET model type (e.g. `cont`). The range of the ASCET implementation type is given by the physical range of the model type `cont` and the applied implementation formula. The range of the ASCET implementation type determines the primitive AUTOSAR type of the data element prototype. In AUTOSAR release 2.1, the RTE then translates the AUTOSAR types in C types. This translation is described in section 5.2.4.2 in the RTE specification[1]. These data types match with implementation types of ASCET.

All available built-in ASCET model types as well as the user-defined types enumeration and record can be chosen as data type for a data element prototype. Arrays cannot be directly used, they have to be encapsulated in a record. Modes can only be used in sender-receiver interfaces when there are no other data element prototypes with another type but mode. This means that if a sender-receiver interfaces contains modes as data element prototypes, then *all*

1. AUTOSAR_SWS_RTE release 2.1, available at www.autosar.org.

data element prototypes must be of type mode. And for these *mode interfaces*, the data element prototypes are called *mode declaration group prototype*.

8.2.3 Atomic Software Component Types

Atomic software components are a mixture of hierarchical ASCET classes and modules. An atomic software component (SWC) can instantiate interface types as so-called *port prototype*. This means that within one SWC there might be several port prototypes with the same interface type. port prototypes can be provided or required, thus realizing a role. A port prototype with a sender-receiver interface is a *required port* if the data element prototypes are "received" by the component. A port prototype with a sender-receiver interface is a *provided port* if the data-elements are "sent" by the component.

Port prototypes are elements of a SWC and hence their role can be selected in the properties editor. If the role is set appropriately, the data element prototypes resemble to ASCET messages. While sending and receiving of messages in ASCET modules is performed by messages, AUTOSAR SWCs use runnable-entities to perform the access to the data element prototypes of port prototypes.

The internal behavior of SWCs is therefore given by a number of runnable entities. Each time a runnable entity reads a data element prototype, it performs a data-read access. A similar scheme can be found for the sending of data element prototypes where a data-write access is performed by the runnable entity. In contrast to ASCET messages, there are different flavors of data-element access. The most common flavors are implicit and explicit.

In the elements list of a SWC in ASCET, the port prototypes appear as well as all other included elements like variables, parameters, class instances, modules and messages. SWCs have diagrams, too. Runnable entities are defined in diagrams. Besides runnable entites, an ASCET SWC also supports methods.

Runnable entities use sequence calls to model graphical assignments. For example, to read a data element prototype implicitly, the port prototype is drawn to a diagram. Now, one can connect the pin of the data element prototype to operations of an expression, which might end up in a variable or in a write access to data element prototype in a provided port. The assignment will be performed by a sequence call, and the sequence call is triggered by a runnable entity (or by a method). Explicit data-read access, also called data-receive point, will need a dedicated access operator and a variable or message where the data is stored. The sequence call of the variable or the message will have a runnable entity or a method as trigger.

8.3 Applying ASCET Implementations to AUTOSAR

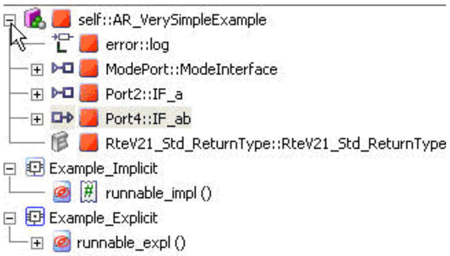
As written above, data element prototypes of sender-receiver interfaces in ASCET are supporting ASCET model types whereas the AUTOSAR type can only be determined after the ASCET model type has been implemented. In particular, this means that one sender-receiver interface entry in the ASCET database will represent as many different AUTOSAR interface types as there are implementations of the ASCET interface! Since SWCs in ASCET employ ASCET sender-receiver interfaces in their port prototypes, they have different implementations, too. As a result, one ASCET atomic software component type will has as many different AUTOSAR atomic software component type as there are ASCET implementations defined.

8.3.1 Subpackages

AUTOSAR in its release 2.1 only supports shortnames of 32 character length in its XML description. This means that the classical ASCET approach to distinguish different implementations in the generated code by concatenating the implementation name to the ASCET model name has its limitations. This limitation is overcome by the introduction of subpackages in the XML file. There is one package generated for the atomic software component as well as the interface, but before going to the elements there will be a subpackage for each implementation. ASCET 6.0 will only generate C code and the XML description for one implementation of the atomic software component; hence there will be only one subpackage. The implementation is selected at the project prior to code generation. The ASCET XML generator takes care that all references are set appropriately, e.g. the type reference from a port prototype in subpackage `impl-1` to an interface in subpackage `impl-2`. Please note that atomic SWC and the interfaces are different AUTOSAR packages.

8.4 Example

In a very simple example, a very simple atomic software component has two port prototoypes for data communication (`port2` with interface type `IF_a` and `port4` with interface type `IF_AB`). On top of these ports, there is a mode port. The software component has two runnable enties, `runnable_expl` and `runnable_impl`. The elements of the atomic software components are shown in Fig. 8-1. Besides the AUTOSAR elements, there is an `error` variable to be examined by the runnable entity with explicit data-access, and an `enumeration` return type tailored for RTE-access.



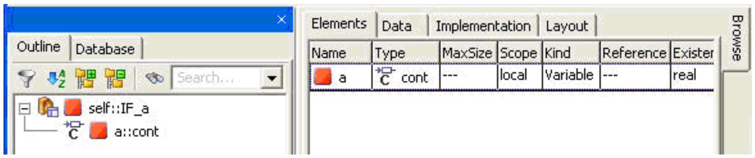
```
self::AR_VerySimpleExample
    error::log
    ModePort::ModeInterface
    Port2::IF_a
    Port4::IF_ab
    RteV21_Std_ReturnType::RteV21_Std_ReturnType
Example_Implicit
    runnable_impl ()
Example_Explicit
    runnable_expl ()
```

Fig. 8-1 Elements of a simple atomic software component

Interface `IF_a` and interface `IF_ab` group data element prototypes of the embedded ASCET model type `cont`. This is shown for interface type `a` in Fig. 8-2, where one sees, in the left, the data element prototypes in the elements list.

If one selects the `AR_16bit` implementation, and then has a look at the "Implementation" tab, one sees that with a chosen conversion formula the implementation type has changed to a signed 16 bit integer. For this setting, the code as well as the AUTOSAR XML files are generated.

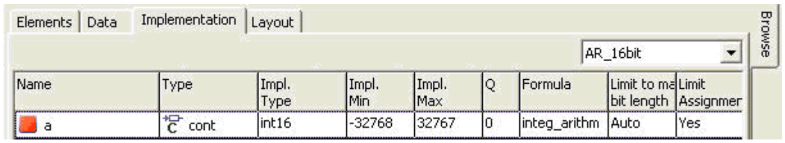
An excerpt of the generated XML file is shown in Fig. 8-4: First of all, one recognizes the subpackage `AR_16bit` below the AR-Package `ASCET interfaces`. The data element prototype `a` is embedded in the `AR_16bit` subpackage and (type-)references the implementation type `sint16` from the `autosar_types.arxml` file.



```
self::IF_a
    a::cont
```

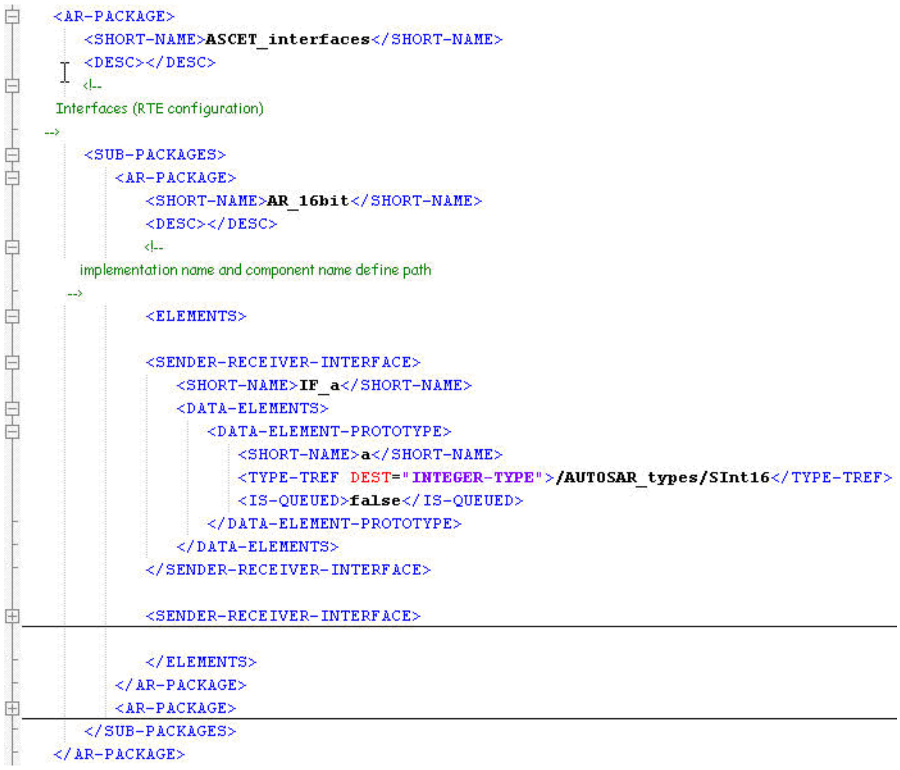
Name	Type	MaxSize	Scope	Kind	Reference	Exister
🟥 a	cont	---	local	Variable	---	real

Fig. 8-2 Interface `IF_a`



Name	Type	Impl. Type	Impl. Min	Impl. Max	Q	Formula	Limit to ma bit length	Limit Assignmer
🟥 a	cont	int16	-32768	32767	0	integ_arithm	Auto	Yes

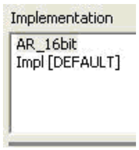
Fig. 8-3 Interface `IF_a` with integer implementation



```
<AR-PACKAGE>
    <SHORT-NAME>ASCET_interfaces</SHORT-NAME>
    <DESC></DESC>
    <!--
Interfaces (RTE configuration)
-->
    <SUB-PACKAGES>
        <AR-PACKAGE>
            <SHORT-NAME>AR_16bit</SHORT-NAME>
            <DESC></DESC>
            <!--
    implementation name and component name define path
  -->
            <ELEMENTS>

            <SENDER-RECEIVER-INTERFACE>
                <SHORT-NAME>IF_a</SHORT-NAME>
                <DATA-ELEMENTS>
                    <DATA-ELEMENT-PROTOTYPE>
                        <SHORT-NAME>a</SHORT-NAME>
                        <TYPE-TREF DEST="INTEGER-TYPE">/AUTOSAR_types/SInt16</TYPE-TREF>
                        <IS-QUEUED>false</IS-QUEUED>
                    </DATA-ELEMENT-PROTOTYPE>
                </DATA-ELEMENTS>
            </SENDER-RECEIVER-INTERFACE>

            <SENDER-RECEIVER-INTERFACE>

            </ELEMENTS>
        </AR-PACKAGE>
        <AR-PACKAGE>
    </SUB-PACKAGES>
</AR-PACKAGE>
```

Fig. 8-4 Generated Interface in `AR_16bit` Subpackage

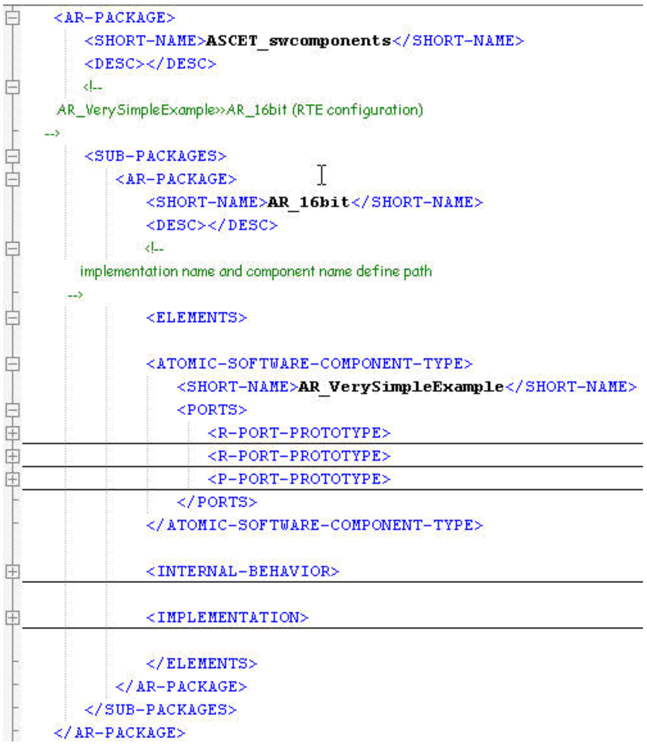
As written above and shown in Fig. 8-1, the port prototype of the name `port2` is of the interface type `IF_a`. As with all ASCET modelling elements, atomic software component have several implementations when used for production code generation. In this example, the `AR_VerySimpleExample` component has two implementations. First, there is the real 64 bit default implementation `impl` for the continuous model, whereas the `AR_16bit` implementation uses signed `int16` types. In this example, the integer implementation was chosen for code generation as shown in Fig. 8-5.



Implementation
AR_16bit
Impl [DEFAULT]

Fig. 8-5 Selection of the 16 bit integer implementation

An excerpt of the generated AUTOSAR XML file is shown in Fig. 8-6. The atomic software component `AR_VerySimpleExample` is embedded in the subpackage which has the same name as the ASCET implementation.



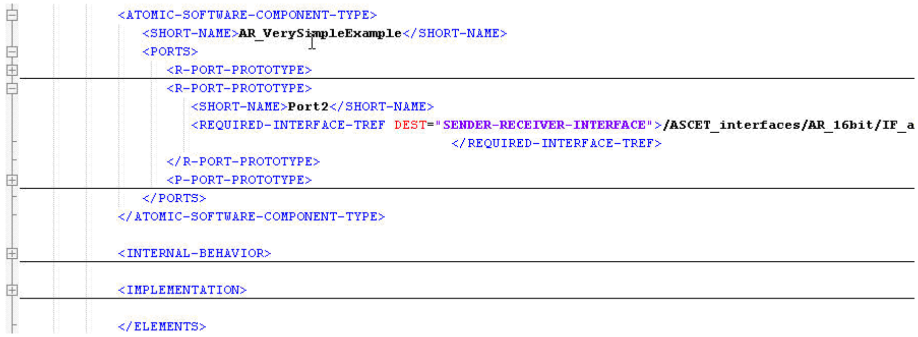
```
<AR-PACKAGE>
    <SHORT-NAME>ASCET_swcomponents</SHORT-NAME>
    <DESC></DESC>
    <!--
 AR_VerySimpleExample»AR_16bit (RTE configuration)
-->
    <SUB-PACKAGES>
        <AR-PACKAGE>
            <SHORT-NAME>AR_16bit</SHORT-NAME>
            <DESC></DESC>
            <!--
 implementation name and component name define path
-->
            <ELEMENTS>

            <ATOMIC-SOFTWARE-COMPONENT-TYPE>
                <SHORT-NAME>AR_VerySimpleExample</SHORT-NAME>
                <PORTS>
                    <R-PORT-PROTOTYPE>
                    <R-PORT-PROTOTYPE>
                    <P-PORT-PROTOTYPE>
                </PORTS>
            </ATOMIC-SOFTWARE-COMPONENT-TYPE>

            <INTERNAL-BEHAVIOR>

            <IMPLEMENTATION>

            </ELEMENTS>
        </AR-PACKAGE>
    </SUB-PACKAGES>
</AR-PACKAGE>
```

Fig. 8-6 Generated Atomic Software Component in `AR_16bit` Subpackage

From the AUTOSAR package point of view, using this kind of ASCET implementation representation requires that the type references for all aggregated elements will find its appropriate package. An example for this kind of "subpackage-referencing" is shown in Fig. 8-7. To find the interface `IF_a` in its `AR_16bit` implementation, the type-reference of `port2` in the atomic software component `AR_VerySimpleExample` references not only to the `ASCET_interfaces` package, but also to its subpackage `AR_16bit`.

An authoring or ECU integration tool is expected to work with subpackages. Please keep in mind that the subpackage structure does not have any influence on the code generation or the RTE access itself.

The reason for choosing the sub-package representation lies in the 32-character limitation of AUTOSAR Release 2.1. The classical ASCET way of concatenating element name and implementation name is seen as too restrictive.



```
<ATOMIC-SOFTWARE-COMPONENT-TYPE>
   <SHORT-NAME>AR_VerySimpleExample</SHORT-NAME>
   <PORTS>
      <R-PORT-PROTOTYPE>
      <R-PORT-PROTOTYPE>
         <SHORT-NAME>Port2</SHORT-NAME>
         <REQUIRED-INTERFACE-TREF DEST="SENDER-RECEIVER-INTERFACE">/ASCET_interfaces/AR_16bit/IF_a
                                 </REQUIRED-INTERFACE-TREF>
      </R-PORT-PROTOTYPE>
      <P-PORT-PROTOTYPE>
   </PORTS>
</ATOMIC-SOFTWARE-COMPONENT-TYPE>

<INTERNAL-BEHAVIOR>

<IMPLEMENTATION>

</ELEMENTS>
```

Fig. 8-7 Subpackage Referencing in AUTOSAR XML Files

The internal behavior of ASCET software components is realized by means of the block diagram editor. In this example, there are two diagrams holding one runnable entity each. In the first diagram, there is a runnable entity realizing only implicit access to the port prototypes `port2` and `port4`. The corresponding block diagram is shown in Fig. 8-8. The require port prototype `port2` is shown on the left side. Its data element prototype `a` is accessed by the sequence call number 5 of the runnable entity `runnable_impl` and used in the graphical expression. The result of this expression is written to the data element prototype `a` of the port prototype `port4` by the sequence call number 5. Data element prototype `a` of port prototype `port2` is also accessed by the sequence call number 10 whose expression just adds 1 (in the physical model) to `a` and writes the result implicitly to the data element prototype `b` of the port prototype `port4`.

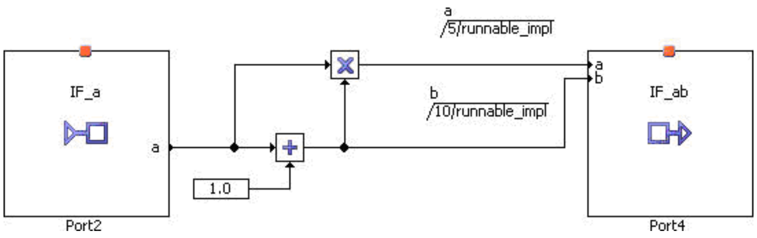
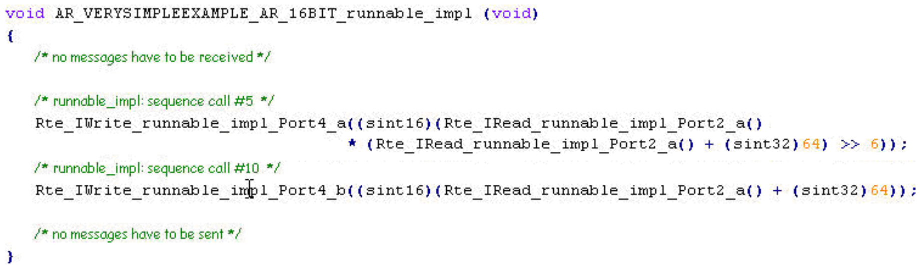


Fig. 8-8 Internal Behavior of the "Implicit" Runnable-Entity

The generated code with its implicit RTE access macros is shown in Fig. 8-9. One can see that, for implicit communication, the RTE_IREAD access macro can be used in an expression, and the expressions are realized in integer arithmetic. Graphically, implicit data element access is shown by a direct connection to the port prototypes which is seen as the default access.



```
void AR_VERYSIMPLEEXAMPLE_AR_16BIT_runnable_impl (void)
{
    /* no messages have to be received */

    /* runnable_impl: sequence call #5 */
    Rte_IWrite_runnable_impl_Port4_a((sint16)(Rte_IRead_runnable_impl_Port2_a()
                                        * (Rte_IRead_runnable_impl_Port2_a() + (sint32)64) >> 6));
    /* runnable_impl: sequence call #10 */
    Rte_IWrite_runnable_impl_Port4_b((sint16)(Rte_IRead_runnable_impl_Port2_a() + (sint32)64));

    /* no messages have to be sent */
}
```

Fig. 8-9 Generated Code of the Implicit Runnable-Entity

Explicit data access is implemented in the diagram Example_Explicit as depicted in Fig. 8-10. This diagram uses an RTE access block. In this block, one can choose for implicit, explicit, and explicit-with-status access to a data element prototype of a port prototype. While the implicit communication without this access block is the default case, this access block is mandatory for explicit communication. Therefore, the default access method in the RTE access block is explicit. This access method is used for the data elements a in port2 and port4, while data element b in port4 uses the access method explicit-with-status. In this case, there is an additional output pin available which has the same semantics as the else part of an if-then-else block in the ASCET BDE language. In particular, this else part can be used to trigger data flows as setting an error flag or calling an error function.

It is necessary that the runnable entity which uses an explicit data-read-access provides a kind of memory where the data is stored when fetched from the RTE. In this example, a runnable-local variable was chosen. Alternatives are variables in the atomic software component type, classes, and, last but not least, messages. Messages can be used for migration projects, i.e. when modules are imported into atomic software components, but have a slightly different semantic as in OSEK projects.

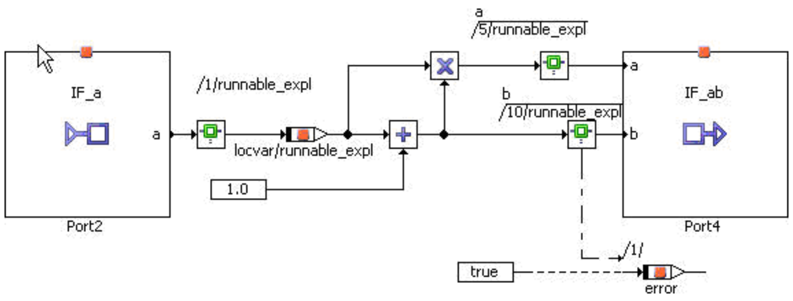


Fig. 8-10 Internal Behavior of the Explict Runnable Entity

The generated code is shown in Fig. 8-11. One can see that the data element `a` is read via the `RTE_Read` macro from `port2` and written to the memory location of the runnable-entity-local variable `locvar`. It can also bee seen that only one RTE access is necessary in contrast to two accesses in the implicit example of Fig. 8-9 on page 169. "Data-Distribution" to the expressions is done in the `runnable_expl` example via the local variable and not via the RTE.

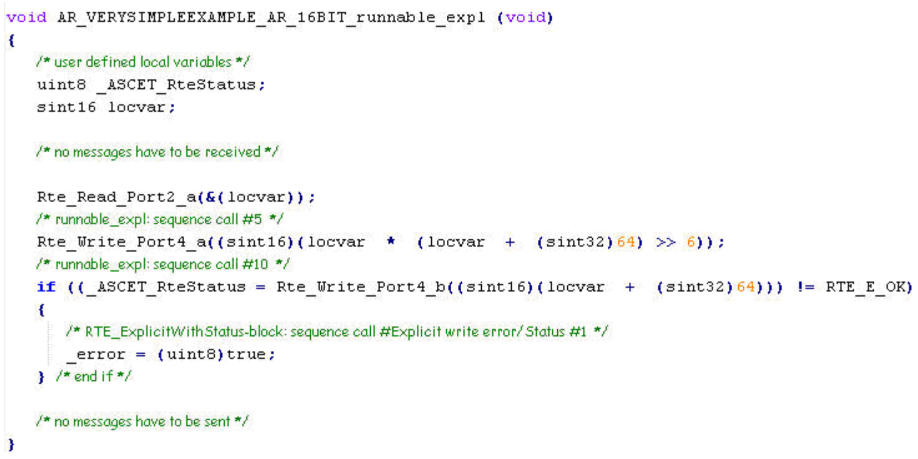
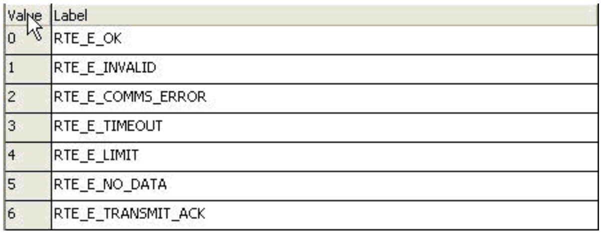

```
void AR_VERYSIMPLEEXAMPLE_AR_16BIT_runnable_expl (void)
{
   /* user defined local variables */
   uint8 _ASCET_RteStatus;
   sint16 locvar;

   /* no messages have to be received */

   Rte_Read_Port2_a(&(locvar));
   /* runnable_expl: sequence call #5 */
   Rte_Write_Port4_a((sint16)(locvar  *  (locvar  +  (sint32)64) >> 6));
   /* runnable_expl: sequence call #10 */
   if ((_ASCET_RteStatus = Rte_Write_Port4_b((sint16)(locvar  +  (sint32)64))) != RTE_E_OK)
   {
      /* RTE_ExplicitWithStatus-block: sequence call #Explicit write error/Status #1 */
      _error = (uint8)true;
   } /* end if */

   /* no messages have to be sent */
}
```

Fig. 8-11 Code of the Implicit Runnable Entity

For explicit communication, it is necessary to create an enumeration representing possible return values of the RTE access macros as specified in section 5.4.1 of the RTE specification[1]. Such an enumeration type is shown in Fig. 8-12.



Value	Label
0	RTE_E_OK
1	RTE_E_INVALID
2	RTE_E_COMMS_ERROR
3	RTE_E_TIMEOUT
4	RTE_E_LIMIT
5	RTE_E_NO_DATA
6	RTE_E_TRANSMIT_ACK

Fig. 8-12 RTE standard retun-type

To get a runnable entity executed by the RTE, it has to be triggered by an event. At least one event has to be specified for each runnable entity. The RTE generator then takes this information to assign the runnable entities to the appropriate tasks. In ASCET, events are specified in the "Event Specification" tab of an atomic software component. In this example, two timing events are specified:

- `Ev_Timing_Explicit_10ms`
- `Ev_Timing_Implict_10ms`

When adding an event, one has to be aware of the naming restrictions given by AUTOSAR. Both runnable entities and events are part of the package-internal behavior. Within one package, names of elements are required to be unique. This means that the names for an event A triggering a runnable entity A have to be differently, e.g. the corresponding event for runnable `A` is named `ev_A`.

Note

*In version 6.0, ASCET does **not** ensure or check that events and runnable entities have different names.*

[1] AUTOSAR_SWS_RTE release 2.1, available at www.autosar.org.

The association between the explicit timing event and the explicit runnable entity is shown in Fig. 8-13.

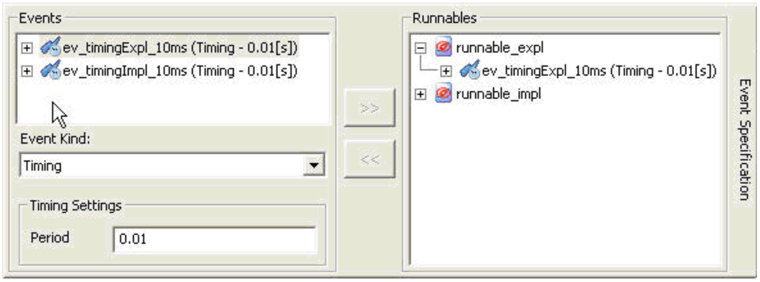

Events
ev_timingExpl_10ms (Timing - 0.01[s])
ev_timingImpl_10ms (Timing - 0.01[s])
Event Kind: Timing
Timing Settings
Period 0.01
Runnables
runnable_expl
ev_timingExpl_10ms (Timing - 0.01[s])
runnable_impl

Fig. 8-13 Mapping of Events to Runnable Entities

The AUTOSAR runtime execution concept has the notations of modes. For application software components, the execution of a runnable entity can be coupled to a so-called mode-disabling dependency. It defines under which modes the RTE will NOT execute a runnable entity. Modes are communicated to an atomic software component by means of port prototypes.

In this example, there are two modes defined. This is achieved by creating a mode declaration group (or *mode group* for short) with the name `OnOff-Mode`, see Fig. 8-14.

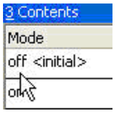
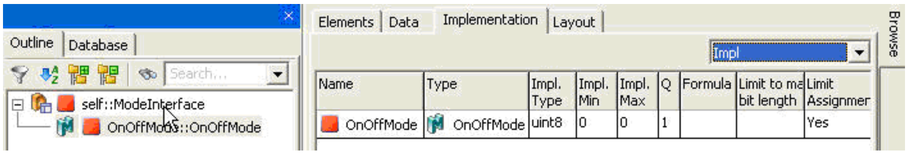

3 Contents
Mode
off <initial>
on

Fig. 8-14 Mode Declaration Group

This mode group is instantiated in a sender-receiver interface named `ModeInterface` as mode declaration group prototype, as shown in Fig. 8-15. The `ModeInterface` is then instantiated in a port prototype called `ModePort` in the atomic software component of this example. It can be seen in the elements list in Fig. 8-1 on page 165.

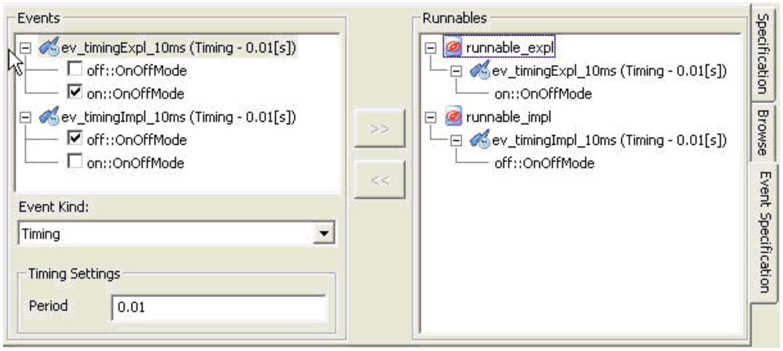


self::ModeInterface
OnOffMode::OnOffMode

Name	Type	Impl. Type	Impl. Min	Impl. Max	Q	Formula	Limit to ma bit length	Limit Assignmer
OnOffMode	OnOffMode	uint8	0	0	1			Yes

Fig. 8-15 Mode Declaration Group Prototype in a Sender-Receiver Interface

The association of modes with RTE events is done automatically, meaning that when an atomic software component type has aggregated a port prototype with a "mode interface", then all runnable entitites of this component are assumed to be associated to a mode-disabling dependency. The constellation shown in Fig. 8-16 means that the event `ev_timingExpl_10ms` is enabled in `OnMode` while the event `ev_timingImpl_10ms` is enabled in `OffMode`.



ev_timingExpl_10ms (Timing - 0.01[s])
- [ ] off::OnOffMode
- [x] on::OnOffMode

ev_timingImpl_10ms (Timing - 0.01[s])
- [x] off::OnOffMode
- [ ] on::OnOffMode

Event Kind: Timing

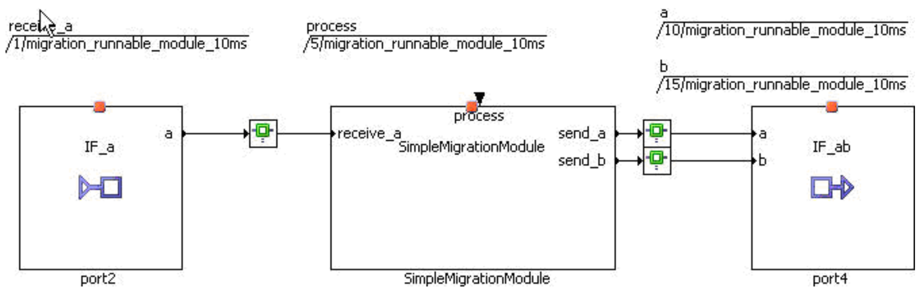
Timing Settings
Period 0.01

runnable_expl
ev_timingExpl_10ms (Timing - 0.01[s])
on::OnOffMode
runnable_impl
ev_timingImpl_10ms (Timing - 0.01[s])
off::OnOffMode

Fig. 8-16 Event Specification Editor

8.5 Migration of Legacy Projects

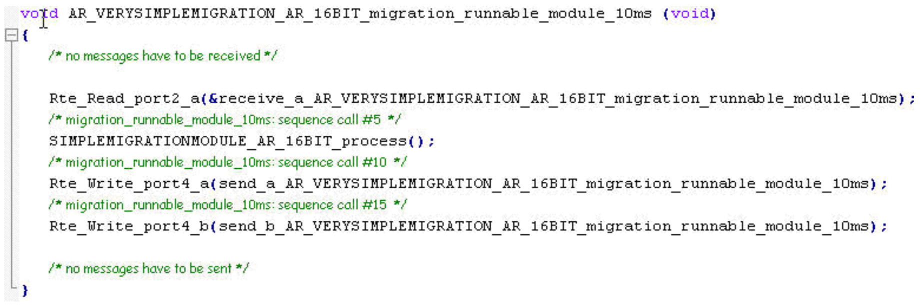
The classical modelling means of ASCET are modules and classes. Both means can still be used in atomic software components. Fig. 8-17 shows a possibility how to re-use a module. The module is named `SimpleMigrationModule`. Its message `receive_a` has its set method activated and the messages `send_a` and `send_b` have their get method enabled. In this case, the messages become "visible" in the atomic software component as send/receive messages. As a result, the receive message in the module can be used to store the data element prototype `a` of `port2` from the data-receive point of the runnable entity `migration_runnable_module_10ms`. The send messages of the module can be used as arguments in the data-send points.



receive_a
/1/migration_runnable_module_10ms
process
/5/migration_runnable_module_10ms
a
/10/migration_runnable_module_10ms
b
/15/migration_runnable_module_10ms
IF_a
a
port2
process
receive_a
SimpleMigrationModule
send_a
send_b
SimpleMigrationModule
a
b
IF_ab
port4

Fig. 8-17 Integration of a Module into an Atomic Software Component

As one can see from sequence call number 5, processes can be called like methods in the block diagram editor of the atomic software component. The generated code is shown in Fig. 8-18. From the module point of view, all receive messages are read from the RTE, then the processes are called while the send messages are written to the RTE.



```
void AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_module_10ms (void)
{
    /* no messages have to be received */

    Rte_Read_port2_a(&receive_a_AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_module_10ms);
    /* migration_runnable_module_10ms: sequence call #5 */
    SIMPLEMIGRATIONMODULE_AR_16BIT_process();
    /* migration_runnable_module_10ms: sequence call #10 */
    Rte_Write_port4_a(send_a_AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_module_10ms);
    /* migration_runnable_module_10ms: sequence call #15 */
    Rte_Write_port4_b(send_b_AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_module_10ms);

    /* no messages have to be sent */
}
```

Fig. 8-18 Generated Code of a Module in an Atomic Software Component

As can be seen in Fig. 8-19, the algorithm in the process is not aware of being used in an atomic software component type. This means that existing modules and even projects can be migrated easily to one atomic software component type. In case of two runnable entities calling two processes sharing a common message, the ASCET code generator will guard the message by generating a surrounding exclusive area. The concept of inter-runnable variable is not supported in ASCET 6.0. Messages can be used for this purpose even in atomic-software-component types which do not use modules at all. An alternative is the use of ASCET resources.

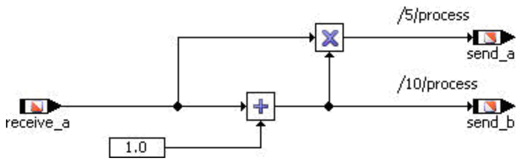


Fig. 8-19 Simple Algorithm in an ASCET Module

Besides modules, classes can be used for a hierarchical structuring of the internal behavior of atomic software component types. This is shown in Fig. 8-20. The simple algorithm is modelled as ASCET class, shown in Fig. 8-21, using one method `calc` with no return value and two methods providing the return values `a` and `b`. One can see that the `SimpleMigrationClass` needs to have a member-variable to store the input argument which is then employed in the statements of the methods providing a return value each. When using implicit access mechanisms in the runnable entities, the return value of the data read access macro can directly be used as argument in the `calc` method, and the return values of the other methods can directly be used in the data write access macros. The generated code is shown in Fig. 8-22.

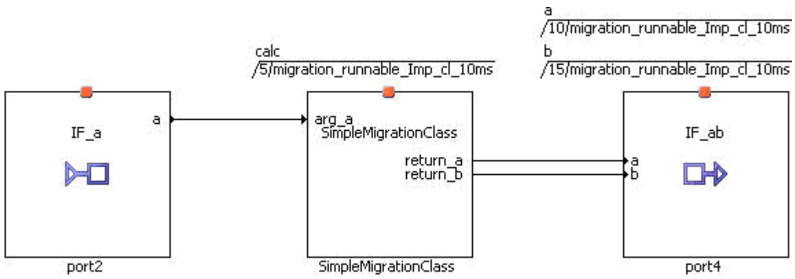

a
/10/migration_runnable_Imp_cl_10ms
calc
/5/migration_runnable_Imp_cl_10ms
b
/15/migration_runnable_Imp_cl_10ms
IF_a
a
arg_a
SimpleMigrationClass
return_a
return_b
IF_ab
a
b
port2
SimpleMigrationClass
port4

Fig. 8-20 Use of an ASCET Class Instance with several methods in an Atomic Software Component

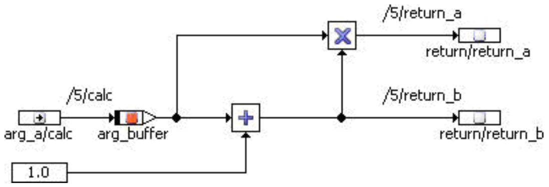
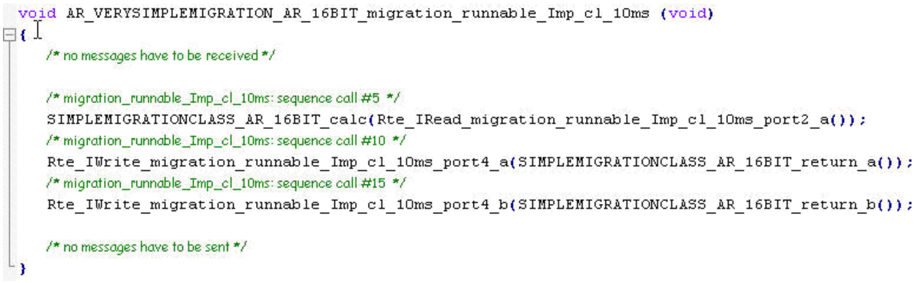


Fig. 8-21 Simple Algorithm partitioned into methods



```
void AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_Imp_cl_10ms (void)
{
    /* no messages have to be received */

    /* migration_runnable_Imp_cl_10ms: sequence call #5 */
    SIMPLEMIGRATIONCLASS_AR_16BIT_calc(Rte_IRead_migration_runnable_Imp_cl_10ms_port2_a());
    /* migration_runnable_Imp_cl_10ms: sequence call #10 */
    Rte_IWrite_migration_runnable_Imp_cl_10ms_port4_a(SIMPLEMIGRATIONCLASS_AR_16BIT_return_a());
    /* migration_runnable_Imp_cl_10ms: sequence call #15 */
    Rte_IWrite_migration_runnable_Imp_cl_10ms_port4_b(SIMPLEMIGRATIONCLASS_AR_16BIT_return_b());

    /* no messages have to be sent */
}
```

Fig. 8-22 Generated Code when using a class with classic ASCET methods

Besides the classical method modelling of classes, ASCET 6.0 provides out-parameters in methods. This feature is used in Fig. 8-23, where a method `calc_return` with one input and two output arguments is used instead of three classical ASCET methods in Fig. 8-20.

As in C or other programming languages, the output parameters are passed by reference to the methods. This means that memory has to be allocated before calling the method. In this example, there are two local variables (`return_a` and `return_b`) of the `migration_runnable_Expl_class_10ms` where the results of the algorithm are written to. The algorithm itself is shown in Fig. 8-24. Since it works exclusively on argument values, it does not need an additional member-variable as the algorithm shown in Fig. 8-21 on page 176.

Since additional variables, even as runnable-local variables, are necessary at all, explicit communication appears to be the preferred solution for RTE access. Therefore, an additional (runnable-local) variable `arg_a` is used in this example. The generated code is shown in

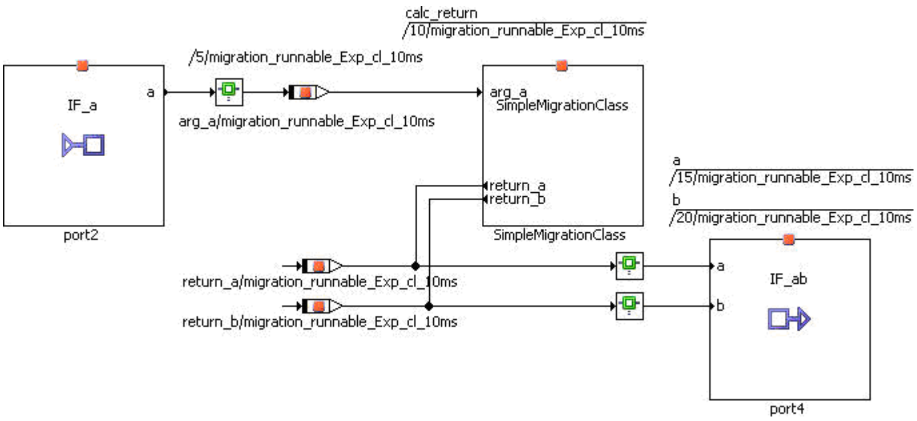

calc_return
/10/migration_runnable_Exp_cl_10ms
/5/migration_runnable_Exp_cl_10ms
IF_a
a
port2
arg_a/migration_runnable_Exp_cl_10ms
arg_a
SimpleMigrationClass
return_a
return_b
SimpleMigrationClass
a
/15/migration_runnable_Exp_cl_10ms
b
/20/migration_runnable_Exp_cl_10ms
return_a/migration_runnable_Exp_cl_10ms
return_b/migration_runnable_Exp_cl_10ms
a
b
IF_ab
port4

Fig. 8-23 Use of an ASCET class Instance with one method

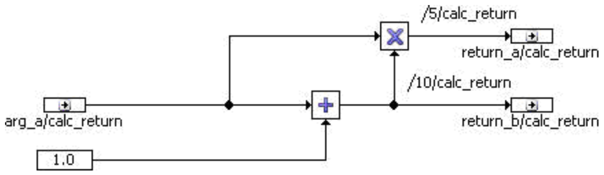
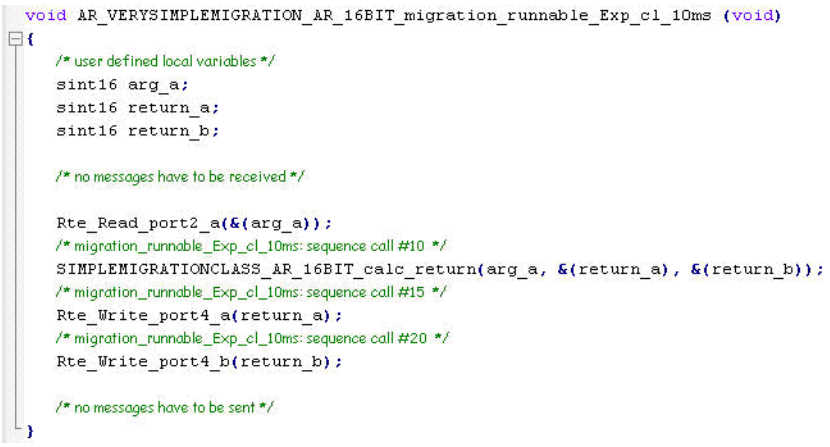


Fig. 8-24 Simple Algorithm in one Method



```
void AR_VERYSIMPLEMIGRATION_AR_16BIT_migration_runnable_Exp_cl_10ms (void)
{
    /* user defined local variables */
    sint16 arg_a;
    sint16 return_a;
    sint16 return_b;

    /* no messages have to be received */

    Rte_Read_port2_a(&(arg_a));
    /* migration_runnable_Exp_cl_10ms: sequence call #10 */
    SIMPLEMIGRATIONCLASS_AR_16BIT_calc_return(arg_a, &(return_a), &(return_b));
    /* migration_runnable_Exp_cl_10ms: sequence call #15 */
    Rte_Write_port4_a(return_a);
    /* migration_runnable_Exp_cl_10ms: sequence call #20 */
    Rte_Write_port4_b(return_b);

    /* no messages have to be sent */
}
```

Fig. 8-25 Generated Code for an Atomic-Software Component using an ASCET class instance with one method

9 ETAS Contact Addresses

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