SDL RT

specification & description language - real time

Object	Graphical language to specify and design real time and embedded software
Date	May 21st 2002
Version	1.1
Reference	http://www.sdl-rt.org

1 - Introduction

As its name states, SDL-RT is based on SDL standard from ITU extended with real time concepts.

SDL has been developed in the first place to specify telecommunication protocols but experience showed some of its basic principles could be used in a wide variety of real time and embedded systems. Its main benefits are:

- architecture definition,
- graphical finite state machine,
- object orientation.

But SDL was not meant to design real time systems and some major drawbacks prevented it to be widely used in the industry:

- obsolete data types,
- old fashioned syntax,
- no pointer concept,
- no semaphore concept.

SDL being a graphical language it is obviously not suited for any type of coding. Some parts of the application still need to be written in C or assembly language. Furthermore legacy code or off the shelf libraries such as RTOS, protocol stacks, drivers have C APIs. Last but not least there is no SDL compilers so SDL need to be translated into C code to get down to target. So all SDL benefits are lost when it comes to real coding and integration with real hardware and software.

Considering the above considerations a real time extension to SDL needed to be defined that would keep the benefits of SDL and solve its weaknesses. The simpler the better ! SDL-RT was born based on 2 basic principles:

- Replace SDL data types by C,
- Add semaphore support in the behavior diagrams.

The result, SDL-RT, is a:

- simpler,
- object oriented,
- graphical language,
- supporting all basic real time concepts,
- based on standard languages.

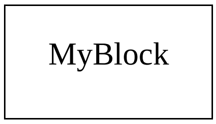
2 - Architecture

2.1 - System

The overall design is called the **system** and everything that is outside the **system** is called the **environment**. There is no specific graphical representation for the **system** but the **block** representation can be used if needed.

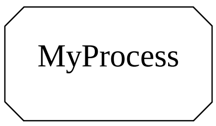
2.2 - Agents

The system can be decomposed in functional **blocks**. A **block** does not imply any physical implementation on the target, it is a structuring element. A **block** can be further decomposed in **blocks** and so on allowing to handle large **systems**. A **block** symbol is a solid rectangle with its name in it:



A simple block example.

When the SDL-RT system is decomposed down to the simplest block, the way the block fulfils its functionality is described with processes. A lowest level block can be composed of one or several processes. To avoid having blocks with only one process it is allowed to mix together blocks and processes at the same level e.g. in the same block.
A process symbol is a rectangle with cut corners with its name in it:

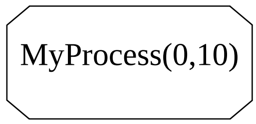


A simple process example.

A process is basically the code that will be executed. It is a finite state machine based task (Cf. “Behavior” on page 13) and has an implicit message queue to receive messages. It is possible to have several instances of the same process running independently. The number of instances present when the system starts and the maximum number of instances are declared between parenthesis after the name of the process. The full syntax in the process symbol is:

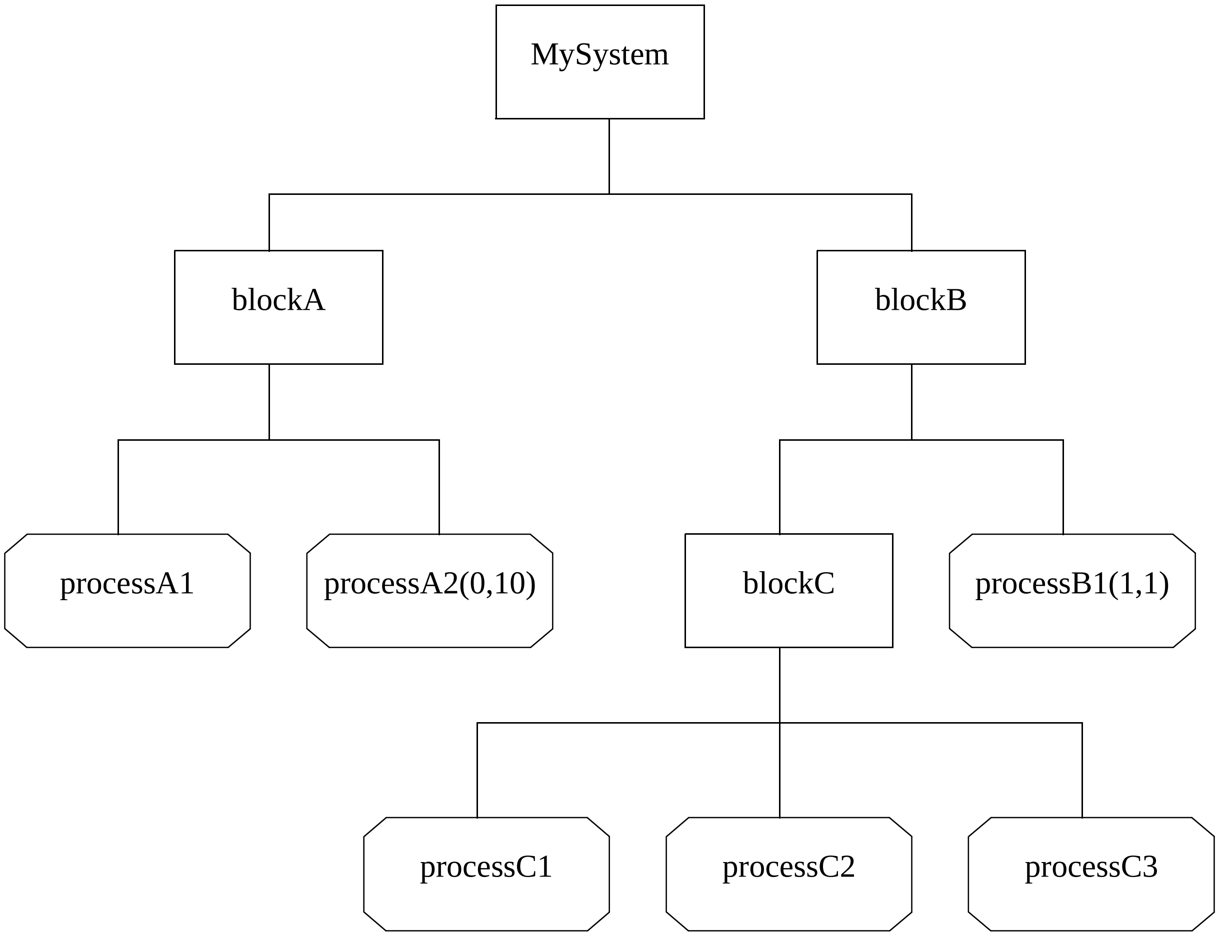
```
<process name>[(<number of instances at startup>, <maximum number of instances>)]
```

If omitted default values are 1 for the number of instances at startup and infinite for the maximum number of instances.



An example process that has no instance at startup and a maximum of 10 instances.

The overall architecture can be seen as a tree where the leaves are the processes.



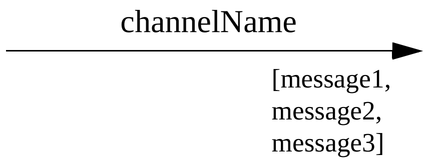
A view of the architecture tree

When viewing a block, depending on the size of the system, it is more comfortable to only represent the current block level without the lower agents.

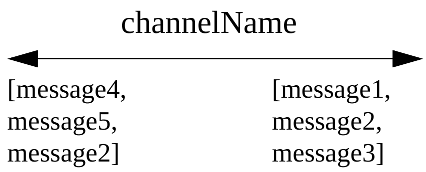
3 - Communication

SDL-RT is event driven, meaning communication is based on message exchanges. A **message** has a name and a parameter that is basically a pointer to some data. Messages go through **channels** that connect agents and end up in the processes implicit queues.
Channels have names and are represented by a one-way or two-ways arrows. A channel name is written next to the arrow without any specific delimiter. The list of messages going in a specific way are listed next to the arrow between brackets and separated by commas. Messages can be gathered in message lists, to indicate a message list in the list of messages going through a channel the message list is surrounded by parenthesis. Note the same message can be listed in both directions.

<ins>aOneWayChannel example:</ins>

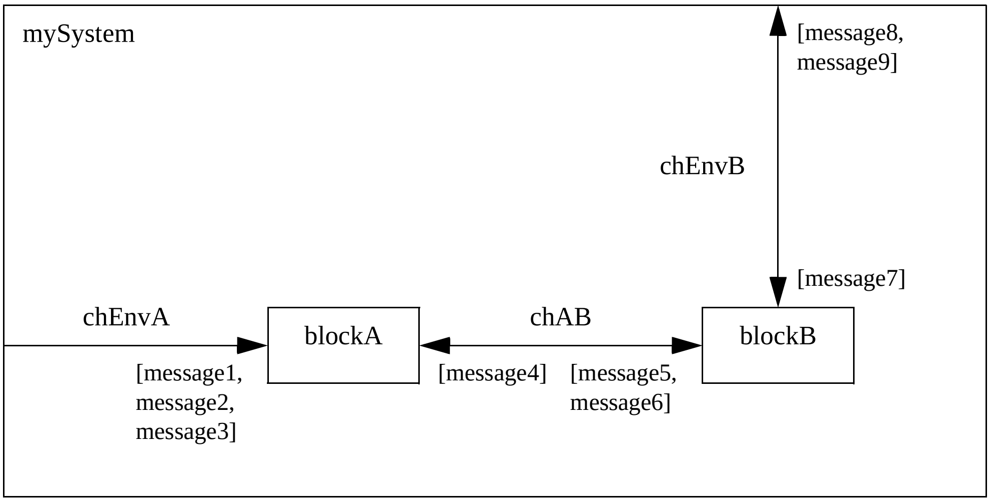


<ins>aTwoWayChannel example:</ins>



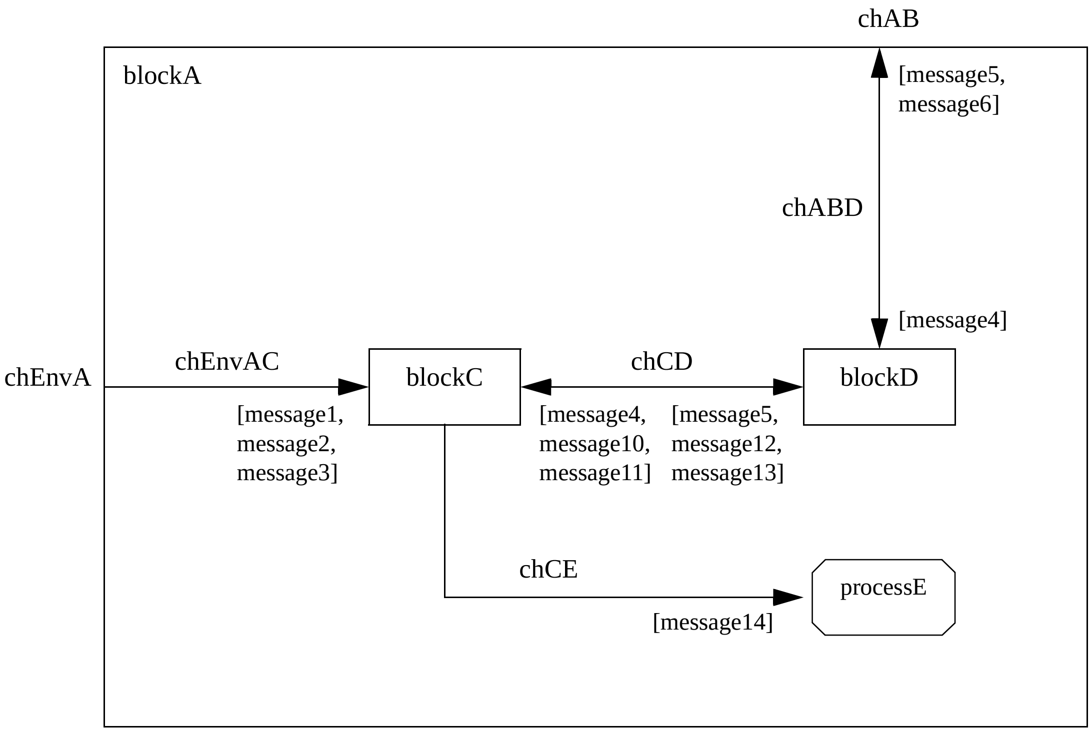
Channels end points can be connected to: the environment, another channel or a process. Graphically a channel can be connected to a block but it is actually connected to another channel inside the block. To represent the outside channels connected to the block at the upper architecture level, a block view is surrounded by a frame representing the edge of the block. The upper level channels connected to the block are then represented outside the frame and channels inside the block can be connected to these upper level channels. Note a channel can be connected to several channels. In any case consistency is kept between levels e.g. all messages in a channel are listed in the upper or lower level channels connected to it.

Example:
Let us consider an SDL-RT system made of two blocks: *blockA* and *blockB*.



An example system view

The channels `chEnvA` and `chEnvB` are connected to the surrounding frame of the system `mySystem`. They define communication with the environment, e.g. the interface of the system. `chEnvA` and `chAB` are connected to `blockA` and define the messages coming in or going out of the block.



An inner block view

The inner view of block *blockA* shows it is made of the blocks *blockC* and *blockD* and of the process *processE*. *chEnvAC* is connected to the upper level channel *chEnvA* and *chABD* is connected to the upper channel *chAB*. The flow of messages is consistent between levels since for example the messages coming in block *blockA* through *chEnvA* (*message1*, *message2*, *message3*) are also listed in *chEnvAC*.

4 - Behavior

First of all a process has an implicit message queue to receive the messages listed in the channels. A process description is based on an extended finite state machine. A process state determines which behavior the process will have when receiving a specific stimulation. A transition is the code between two states. The process can be hanging on its message queue or a semaphore or running e.g. executing code.
SDL-RT processes run concurrently; depending on the underlying RTOS and sometimes on the target hardware the behavior might be slightly different. But messages and semaphores are there to handle process synchronization so the final behavior should be independent of the RTOS and of the hardware. Since SDL-RT is open to any C code it is up to the designer to make sure this statement stays true !
Note that in a state diagram the previous statement is always connected to the symbol upper frame and the next statement is connected to the lower frame or on the side.

4.1 - Start

The start symbol represent the starting point for the execution of the process:

Start symbol

The transition between the Start symbol and the first state of the process is called the start transition. This transition is the first thing the process will do when started. During this initialization phase the process can not receive messages. All other symbols are allowed.

4.2 - State

The name of the process state is written in the state symbol:

State symbol

The state symbol means the process is waiting for some input to go on, the allowed symbols to follow a state symbol are:

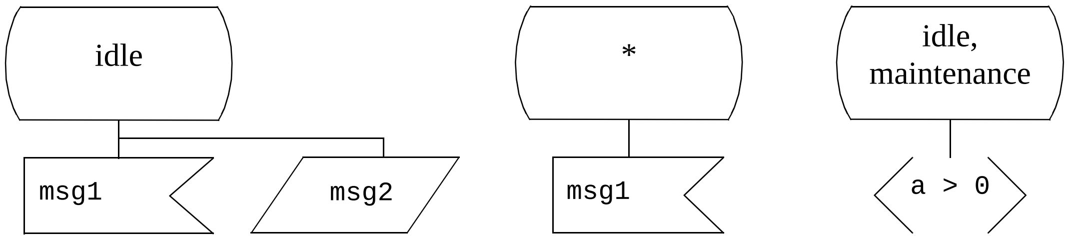
- message input
  the message could be coming from an external channel, or it could be a timer message started by the process itself.
- continuous signal

when reaching a state with continuous signals, the expressions in the continuous signals are evaluated following the defined priorities. All continuous signal expressions are evaluated before the message input !

- save
  the incoming message can not be treated in the current process state. It is saved until the process state changes. When the process state has changed the saved messages are treated first (before any other messages in the queue but after continuous signals).

Some transitions can be valid for several states, the different state names are then listed separated by a comma. A star ('*') means all states.

Examples:



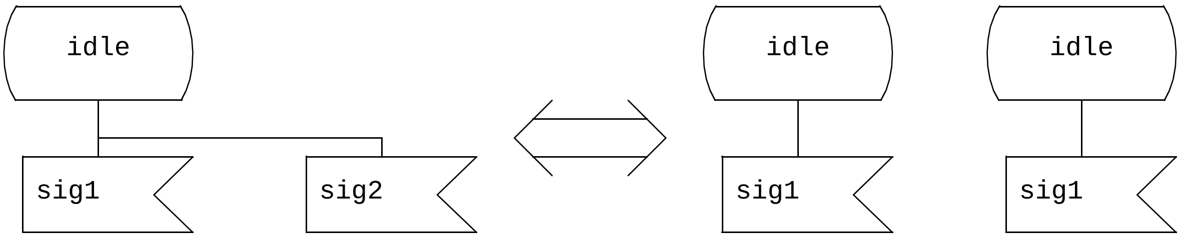
In state `idle` `msg1` can be received and `msg2` is saved.

Message `msg1` can be received in any state

In states `idle` and `maintenance` the expression `a>0` is first evaluated.

A process in a specific state can receive several types of messages or treat several continuous signals. To represent such a situation it is possible to have several message inputs connected to the state or to split the state in several symbols with the same name.

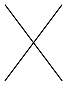
Examples:



Two ways of writing in state `idle`, `sig1` or `sig2` can be received.

4.3 - Stop

A process can terminate itself with the stop symbol.

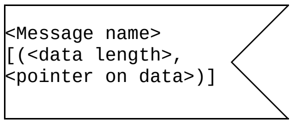


Stop symbol

Note a process can not kill another process, it can only kill itself.
There is no syntax for that symbol.

4.4 - Message input

The message input symbol represent the type of message that is expected in an SDL-RT state. It always follows an SDL-RT state symbol and if received the symbols following the input are executed.



Message input symbol

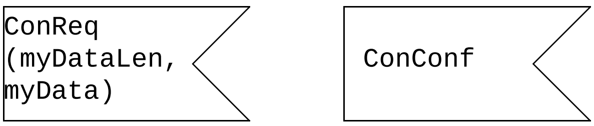
An input has a name and can come with parameters. To receive the parameters it is necessary to declare 2 variables that will be the parameter length and the pointer on the parameters.

The syntax in the message input symbol is the following:

```
<Message name> [(<length of data>, <pointer on data>)]
```

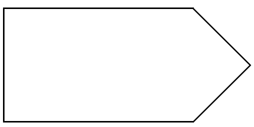
<data length> is a variable that needs to be declared.
<pointer on data> needs to be declared.

Examples:



4.5 - Message output

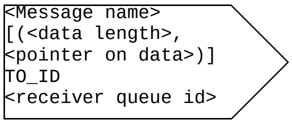
A message output is used to exchange information. It puts data in the receiver’s message queue in an asynchronous way.



Message output symbol

The syntax in the message output symbol can be written in 2 ways depending if the queue Id of the receiver is known or not. A message can be sent to a queue Id or a process name. When communicating with the environment, a special syntax is provided.

4.5.1 Queue Id

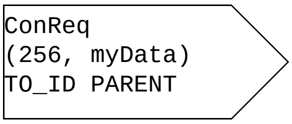


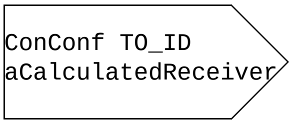
Message output to a queue id

The symbol syntax is:
`<message name>[(<length of data>, <pointer on data>)] TO_ID <receiver queue id>`
It can take the value given by the SDL-RT keywords:

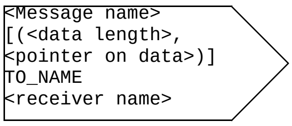
`PARENT`	The queue id of the parent process.
`SELF`	The queue id of the current process.
`OFFSPRING`	The queue id of the last created process if any or NULL if none.
`SENDER`	The queue id of the sender of the last received message.

Examples:





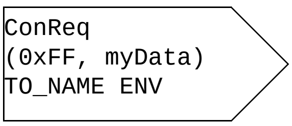
4.5.2 Process name

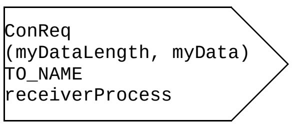


Message output to a process name

The syntax is:
`<message name>[(<length of data>, <pointer on data>)] TO_NAME <receiver name>`
`<receiver name>` is the name of a process if unique or it can be `ENV` when simulating and the message is sent out of the SDL system.

Examples:

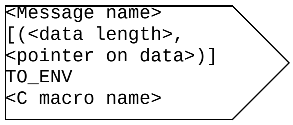




Note:

If several instances have the same process name (several instances of the same process for example), the ’TO_NAME’ will send the message to the first created process with the corresponding name. Therefore this method should no be used when the process name is not unique within the system.

4.5.3 Environment



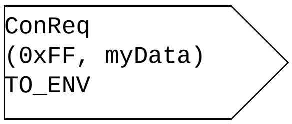
Message output to environment

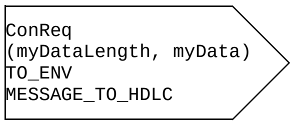
The symbol syntax is:

```
<message name>[(<length of data>, <pointer on data>)] TO_ENV <C macro name>
```

`<C macro name>` is the name of the macro that will be called when this SDL output symbol is hit. If no macro is declared the message will be sent to the environment.

Example:





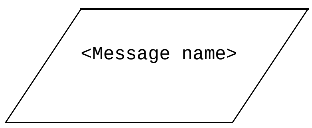
In this second example the generated code will be:

```
MESSAGE_TO_HDLC(ConReq,myDataLength,myData)
```

Note:
When sending data pointed by <pointer on data>, the corresponding memory should be allocated by the sender and should be freed by the receiving process. This is because this memory area is not copied to the receiver; only the pointer value is transmitted. So after being sent the sender should not use it any more.

4.6 - Message save

A process may have intermediate states that can not deal with new request until the on-going job is done. These new requests should not be lost but kept until the process reaches a stable state. Save concept has been made for that matter, it basically holds the message until it can be treated.

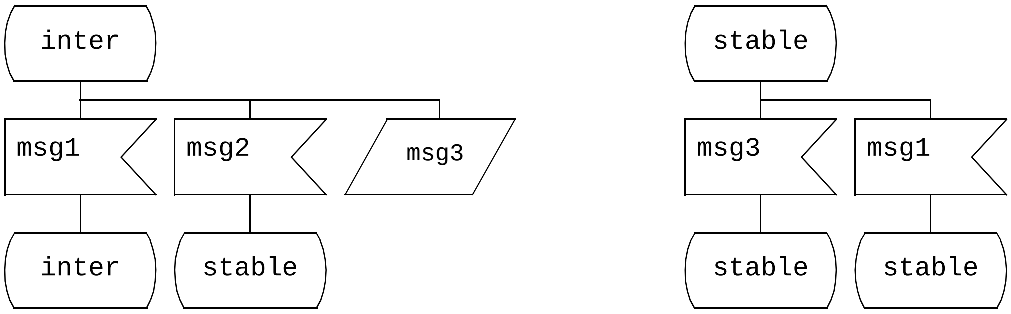


Save symbol

The Save symbol is followed by no symbol. When the process changes to a new state the saved messages will be the first to be treated (after continuous signals if any).

The symbol syntax is:
`<message name>`
Even if the message has parameters.

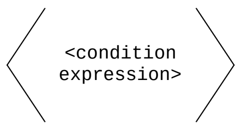
Example:



Let's consider the above process in state `inter` to receive the following messages: `msg3`, `msg2`, `msg1`. `msg3` will be saved, `msg2` will make the process go to state `stable`. Since `msg3` has been saved it will first be treated and finally `msg1`.

4.7 - Continuous signal

A continuous signal is an expression that is evaluated right after a process reaches a new state. It is evaluated before any message input or saved messages.

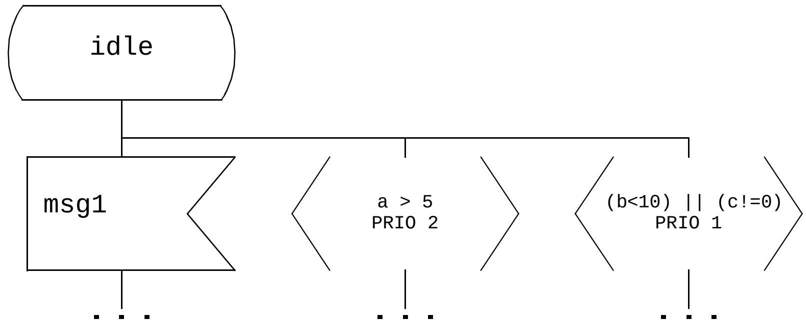


Continuous signal symbol

The continuous signal expression to evaluate can contain any standard C expression that returns a C true/false expression. Since an SDL state can contain several continuous signal a priority level needs to be defined with the `PRIO` keyword. Lower values correspond to higher priorities. A continuous signal symbol can be followed by any other symbol except another continuous signal or a message input. The syntax is:

```
<C condition expression>
PRIO <priority level>
```

Example:



In the above example, when the process gets in state idle it will first evaluate expression `(b<10) || (c!=0)`. If the expression is not true or if the process stayed in the same state it will evaluate expression `a > 5`. If the expression is not true or if the process stayed in the same state it will execute `msg1` transition.

4.8 - Action

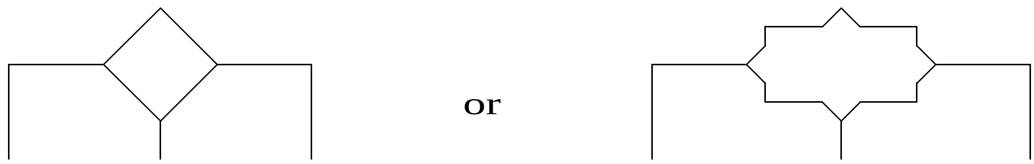
An action symbol contains a set of instructions in C code. The syntax is the one of C language.

Example:

```
/* Say hi to your friend */
printf("Hello world !\n");
for (i=0;i<MAX;i++)
   {
   newString[i] = oldString[i];
   }
```

4.9 - Decision

A decision symbol can be seen as a C switch / case.



Decision symbols

Since it is graphical and therefore uses quite some space on the diagram it is recommended to use it when its result modifies the resulting process state. The decision symbol is a diamond with branches. Since a diamond is one of the worst shape to put text in it, it can be a "diamonded" rectangle. Each branch can be seen as a case of the switch.
The expression to evaluate in the symbol can contain:

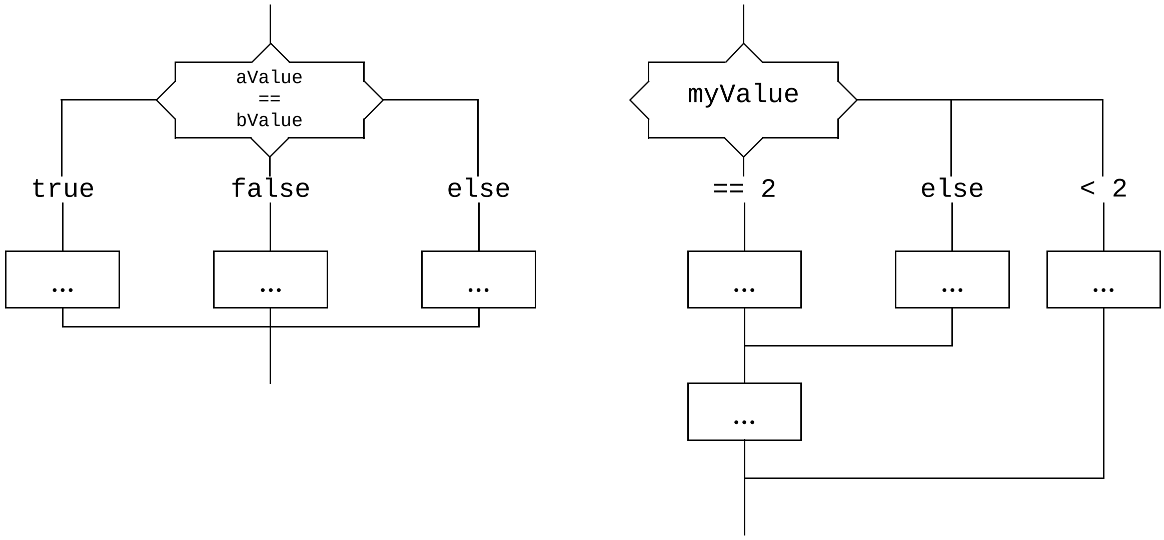
- any standard C expression that returns a C true/false expression,
- an expression that will be evaluated against the values in the decision branches.

The values of the branches have keyword expressions such as:

- >, <, >=, <=, !=, ==
- true, false, else

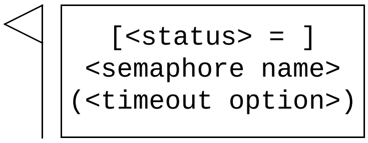
The else branch contains the default branch if no other branch made it.

Examples:



4.10 - Semaphore take

The Semaphore take symbol is used when the process attempts to take a semaphore.



Semaphore take symbol

To take a semaphore, the syntax in the ‘semaphore take SDL-RT graphical symbol’ is:
[<status> =] <semaphore name>(<timeout option>)
where <timeout option> is:

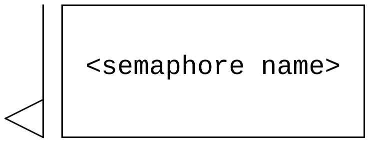
- FOREVER
  Hangs on the semaphore forever if not available.
- NO_WAIT
  Does not hang on the semaphore at all if not available.
- <number of ticks to wait for>
  Hangs on the semaphore the specified number of ticks if not available.

and <status> is:

- OK
  If the semaphore has been successfully taken
- ERROR

If the semaphore was not found or if the take attempt timed out.

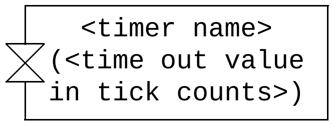
4.11 - Semaphore give



Semaphore give symbol

To give a semaphore, the syntax in the ‘semaphore give SDL-RT graphical symbol’ is:
`<semaphore name>`

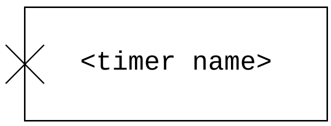
4.12 - Timer start



Timer start symbol

To start a timer the syntax in the ‘start timer SDL-RT graphical symbol’ is :
`<timer name>(<time value in tick counts>)`
`<time value in tick counts>` is usually an ‘int’ but is RTOS and target dependant.

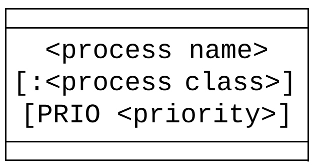
4.13 - Timer stop



Timer stop symbol

To cancel a timer the syntax in the ‘cancel timer SDL-RT graphical symbol’ is :
`<timer name>`

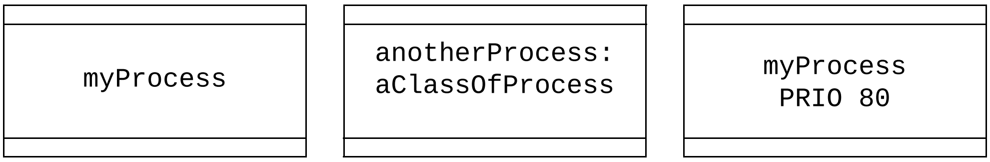
4.14 - Task creation



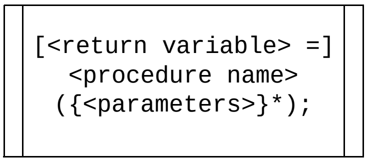
Task creation symbol

To create a process the syntax in the create process symbol is:
`<process name>[:<process class>] [PRIO <priority>]`
to create one instance of `<process class>` named `<process name>` with priority `<priority>`.

Examples:



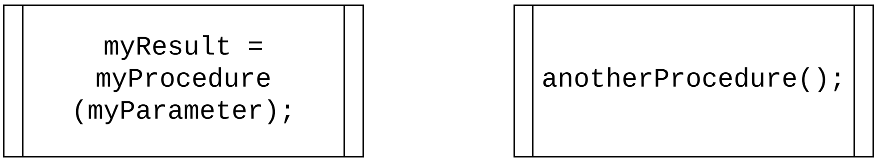
4.15 - Procedure call



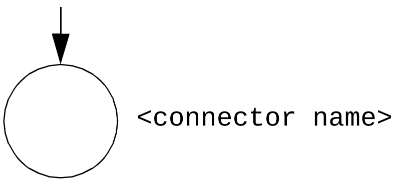
Procedure call symbol

The procedure call symbol is used to call an SDL-RT procedure (Cf. “Procedure declaration” on page 29). Since it is possible to call any C function in an SDL-RT action symbol it is important to note SDL-RT procedures are different because they know the calling process context, e.g. SDL-RT keywords such as SENDER, OFFSPRING, PARENT are the ones of the calling process.
The syntax in the procedure call SDL graphical symbol is the standard C syntax:
`[<return variable> =] <procedure name>({<parameters>}*);`

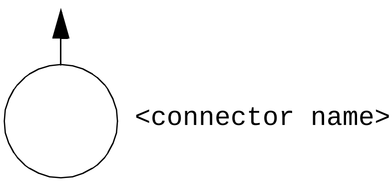
Examples:



4.16 - Connectors



Connector out



Connector in

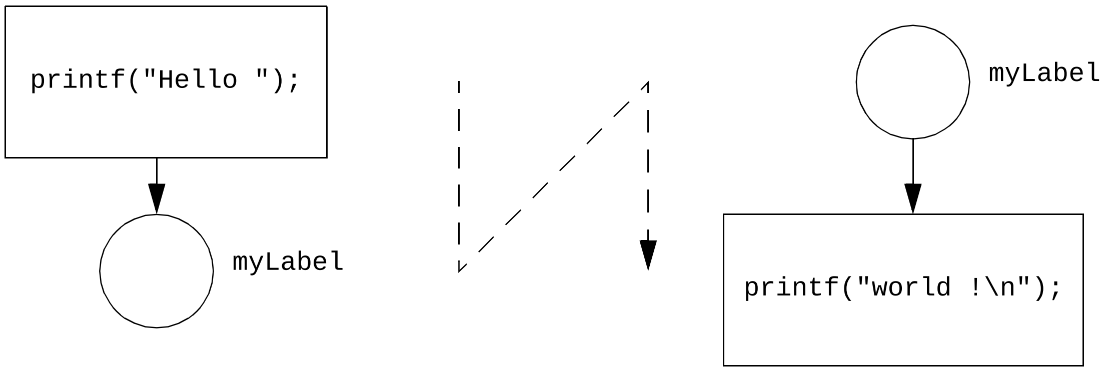
Connectors are used to:

- split a transition into several pieces so that the diagram stays legible and printable,
- to gather different branches to a same point.

A connector-out symbol has a name that relates to a connector-in. The flow of execution goes from the connector out to the connector in symbol.
A connector contains a name that has to be unique in the process. The syntax is:

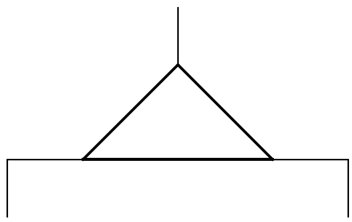
```
<connector name>
```

Examples:



4.17 - Transition option

Transition options are similar to C `#ifdef`.



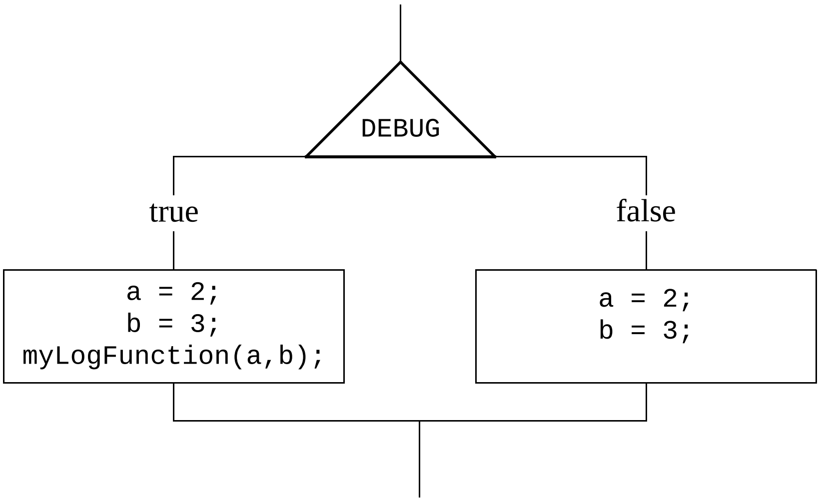
Transition option symbol

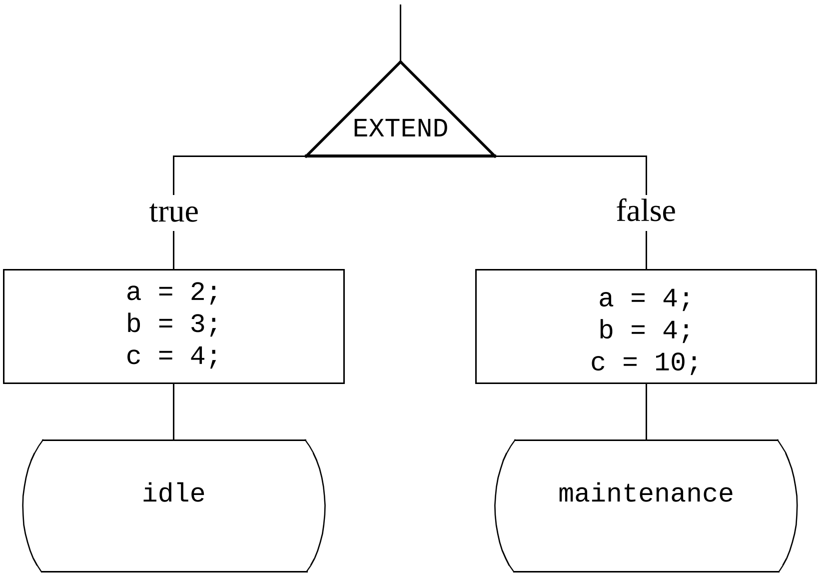
The branches of the symbol have values `true` or `false`. The `true` branch is defined when the expression is defined so the equivalent C code is:

```
#ifdef <expression>
```

The branches can stay separated to the end of the transition or they can meet again and close the option as would do an `#endif`.

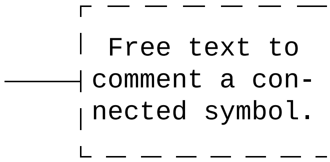
Examples:





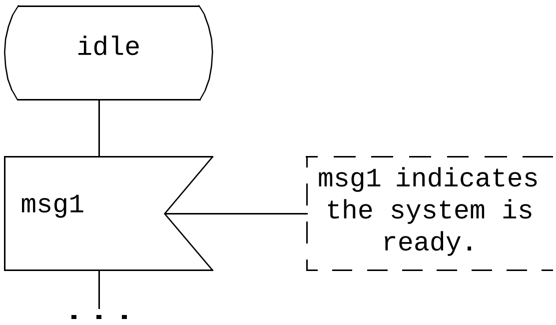
4.18 - Comment

The comment symbol allows to write any type of informal text and connect it to the desired symbol. If needed the comment symbol can be left unconnected.



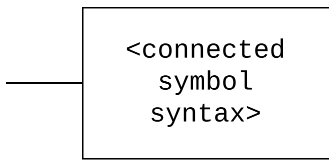
Comment symbol

Example:



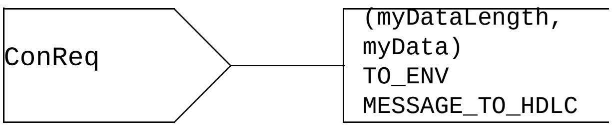
4.19 - Extension

The extension symbol is used to complete an expression in a symbol. The expression in the extension symbol is considered part of the expression in the connected symbol. Therefore the syntax is the one of the connected symbol.

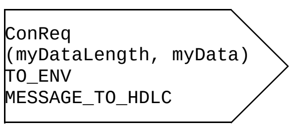


Extension symbol

Example:



is equivalent to:



4.20 - Procedure start

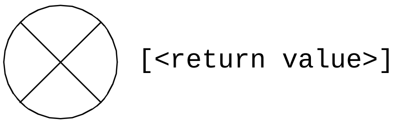
This symbol is specific to a procedure diagram. It indicates the procedure entry point.

Procedure start symbol

There is no syntax associated with this symbol.

4.21 - Procedure return

This symbol is specific to a procedure diagram. It indicates the end of the procedure.

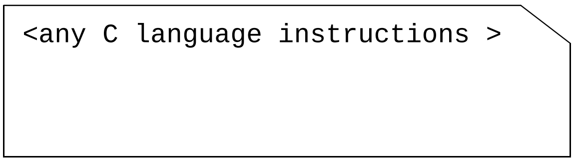


Procedure return symbol

This symbol is specific to a procedure diagram. It indicates the end of the procedure. If the procedure has a return value it should be placed by the symbol.

4.22 - Text symbol

This symbol is used to declare C types variables.

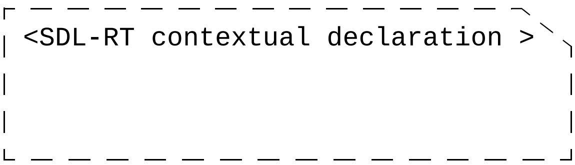


Text symbol

The syntax is C language syntax.

4.23 - Additional heading symbol

This symbol is used to declare SDL-RT specific headings.



Additional heading symbol

It has a specific syntax depending in which diagram it is used.

4.24 - Symbols ordering

The following table shows which symbols can be connected to a specific symbol.

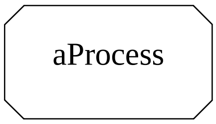
The symbol in this column can be followed by the ticked symbols in its row.	start	state	stop	input	output	save	continuous signal	action	decision	semaphore take	semaphore give	timer start	timer stop	task creation	procedure call	connector in	connector out	transition option	procedure start	procedure return
start	-	X	X	-	X	-	-	X	X	X	X	X	-	X	X	X	X	X	-	-
state	-	-	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
stop	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
input	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
output	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
save	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
continuous	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
action	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
semaphore take	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
semaphore give	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
timer start	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
timer stop	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
task creation	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
procedure call	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	X	X	X	-	X
connector out	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
connector in	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	-	-	X	-	X
transition option	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	-	X	X	-	X
procedure start	-	X	X	-	X	-	-	X	X	X	X	X	X	X	X	-	X	X	-	X
procedure return	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The table above should be read row by row. The symbol in the left column can be followed by the ticked symbols on its row. For example the stop symbol can not be followed by any other symbol. The state symbol can be followed by input, save, or continuous signal symbols.

5 - Declarations

5.1 - Process

A process is implicitly declared in the architecture of the system (Cf. “Architecture” on page 8) since the communication channels need to be connected.

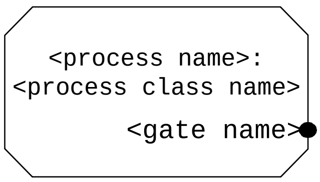


Process symbol

A process has an initial number of instances at startup and a maximum number of instances. A process can also be an instance of a process class (Cf. “Object orientation” on page 52), in that case the name of the class follows the name of the instance after a colon.
The general syntax is:

```
<process instance name>[:<process class>][(<initial number of instances>, <maximum
number of instances>)]
```

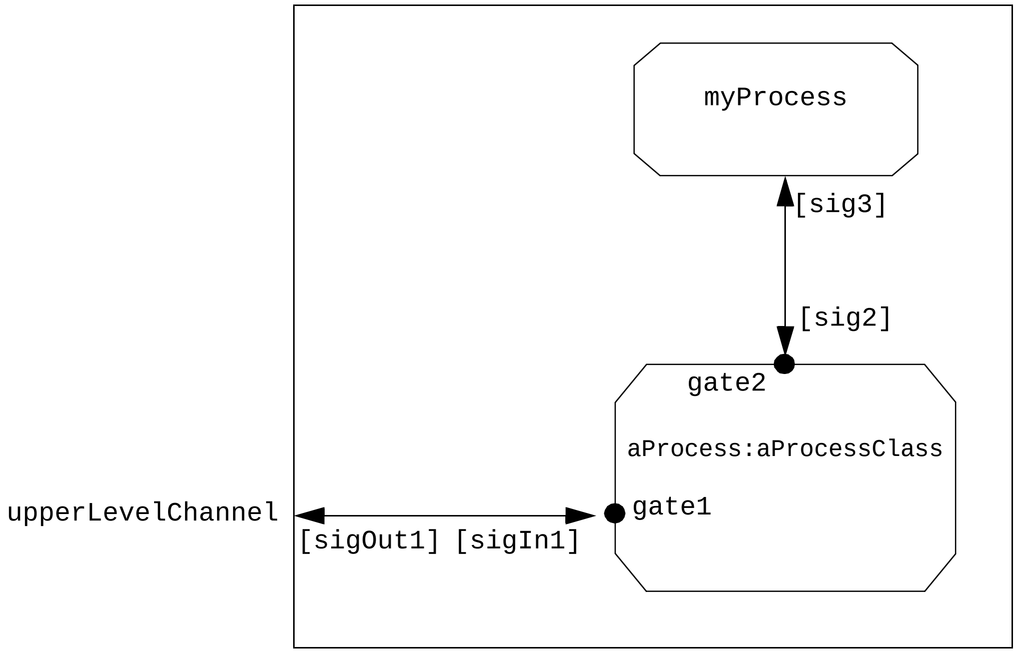
When a process is an instance of a process class the gates of the process class need to be connected in the architecture diagram. The names of the gates appear in the process symbol with a black circle representing the connection point.



Process class instance

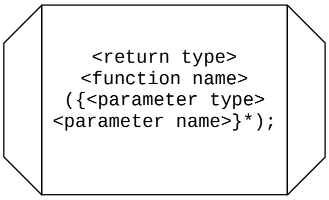
The messages defined in the package going through the gates must be consistent with the messages listed in the architecture diagram where the process instance is defined.

Example:



5.2 - Procedure declaration

An SDL-RT procedure can be defined in any diagram: system, block, or process. It is usually not connected to the architecture but since it can output messages a channel can be connected to it for informational purpose.



Procedure declaration symbol

The declaration syntax is the same as a C function. A procedure definition can be done graphically with SDL-RT or textually in a standard C file.

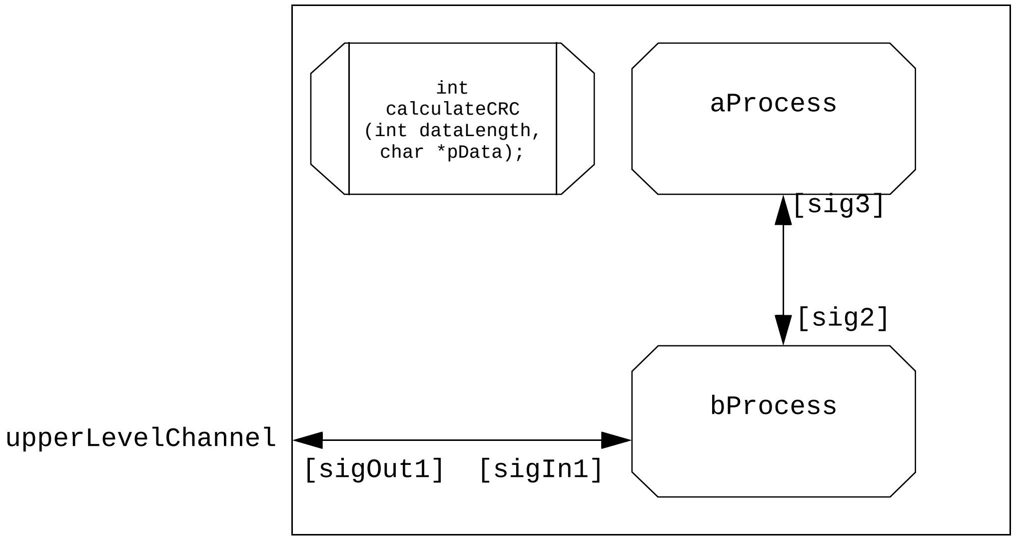
5.2.1 SDL-RT defined procedure

If defined with SDL-RT the calling process context is implicitly given to the procedure. So if a message output is done, the message will be output from the process calling the procedure. That is why the message should be defined in one of the channels connected to the process instead of a channel connected to a procedure. To call such a procedure the procedure call symbol should be used.

5.2.2 C defined procedure

If defined in C language the process context is not present. To call such a procedure a standard C statement should be used in a action symbol.

Example:



5.3 - Messages

Messages do not need any declaration. They are self declared when listed in a channel. It is possible to declare message lists to make the architecture view more synthetic. Such a declaration can be made at any architecture level with the additional heading symbol. The syntax is:
`SDL_RT_MESSAGE_LIST <message list name> = <message name> {,<message name>}*;`
A message list can contain a message list, the included message list name is surrounded by parenthesis.

Example:

```
SDL_RT_MESSAGE_LIST
  myMessageList = msg1, msg2;
SDL_RT_MESSAGE_LIST
  anotherMessageList = (myMessageList), msg3;
```

5.4 - Timers

There is no need to declare timers. They are self declared when used in a diagram.

5.5 - Semaphores

Semaphores can be declared at any architecture level. Since each RTOS has its own type of semaphores with specific options there will be no detailed description of the syntax. The general syntax in the declaration symbol is:

```
<semaphore type>
  <semaphore name>({<list of options>[,]}*);
```

Semaphore declaration

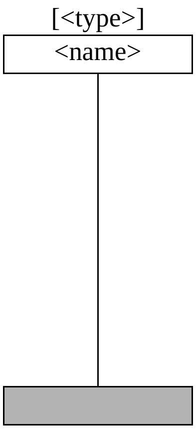
It is important to note the semaphore is identified by its name.

6 - MSC

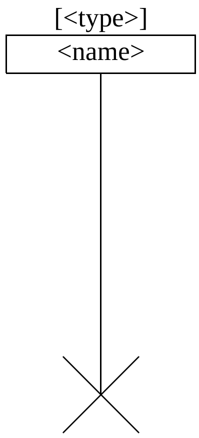
SDL-RT integrates the Message Sequence Chart dynamic view. On such a diagram, time flows from top to bottom. Lifelines represent SDL-RT agents or semaphores and key SDL-RT events are represented. The diagram put up front the sequence in which the events occur.
In the case of embedded C++ it is possible to use a lifeline to represent an object. In that case the type is `object` and the name should be `<object name>:<class name>`

6.1 - Agent instance

An agent instance starts with an agent instance head followed by an instance axis and ends with an instance tail or an instance stop as shown in the diagrams below.



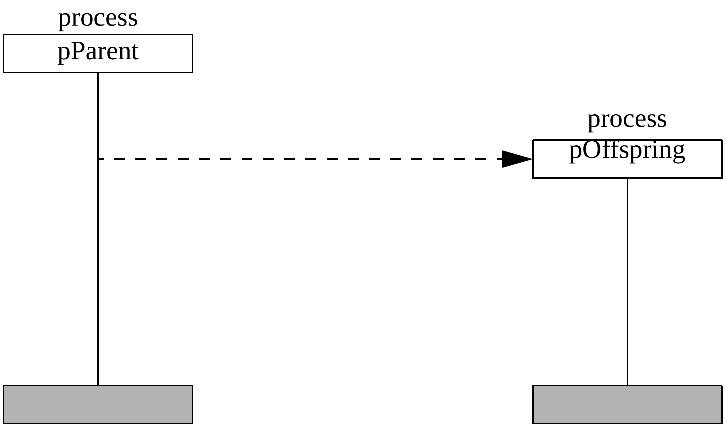
Lifeline with an instance tail symbol



Lifeline with an instance stop symbol

The type of the agent can be specified on top of the head symbol and the name of the agent is written in the instance head symbol. The instance tail symbol means the agent lives after the diagram. The instance stop symbol means the agent no longer exist after the symbol.
When an agent creates another agent a dashed arrow goes from the parent agent to the child agent.

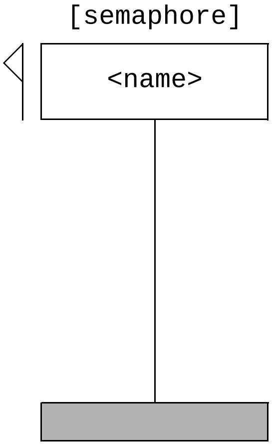
Example:



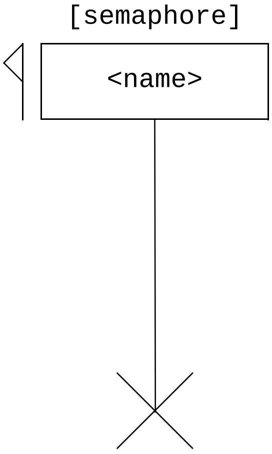
Process pParent creates process pOffspring

6.2 - Semaphore representation

A semaphore representation is made of a semaphore head, a lifeline, and a semaphore end or tail. The symbols are the same as for a process except for the head of the semaphore.



Semaphore with an instance tail symbol

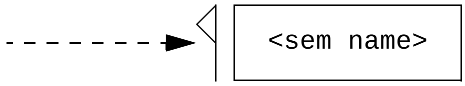


Semaphore with an instance stop symbol

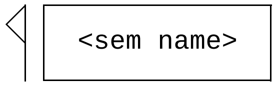
6.3 - Semaphore manipulations

Several cases are to be considered with semaphore manipulations. A process makes an attempt to take a semaphore, its attempt can be successful or unsuccessful, if successful the semaphore might still be available (counting semaphore) or become unavailable. During the time the semaphore is unavailable, its lifeline gets thicker until it is released.

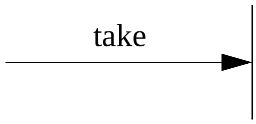
The manipulation symbols are the following:



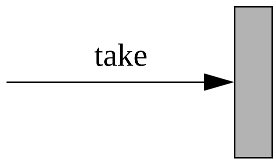
Semaphore creation from a known process.



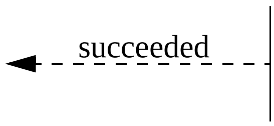
Semaphore creation from an unknown process.



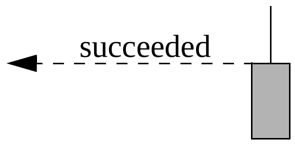
Semaphore take attempt.



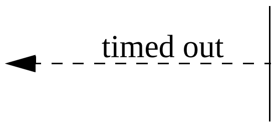
Semaphore take attempt on a locked semaphore.



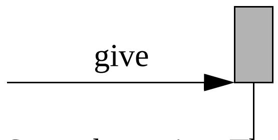
Semaphore take successfull but semaphore is still available.



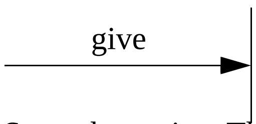
Semaphore take successfull and the semaphore is not available any more.



Semaphore take timed out.

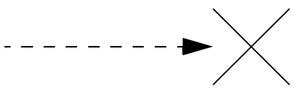


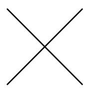
Semaphore give. The semaphore was unavailable before the give.



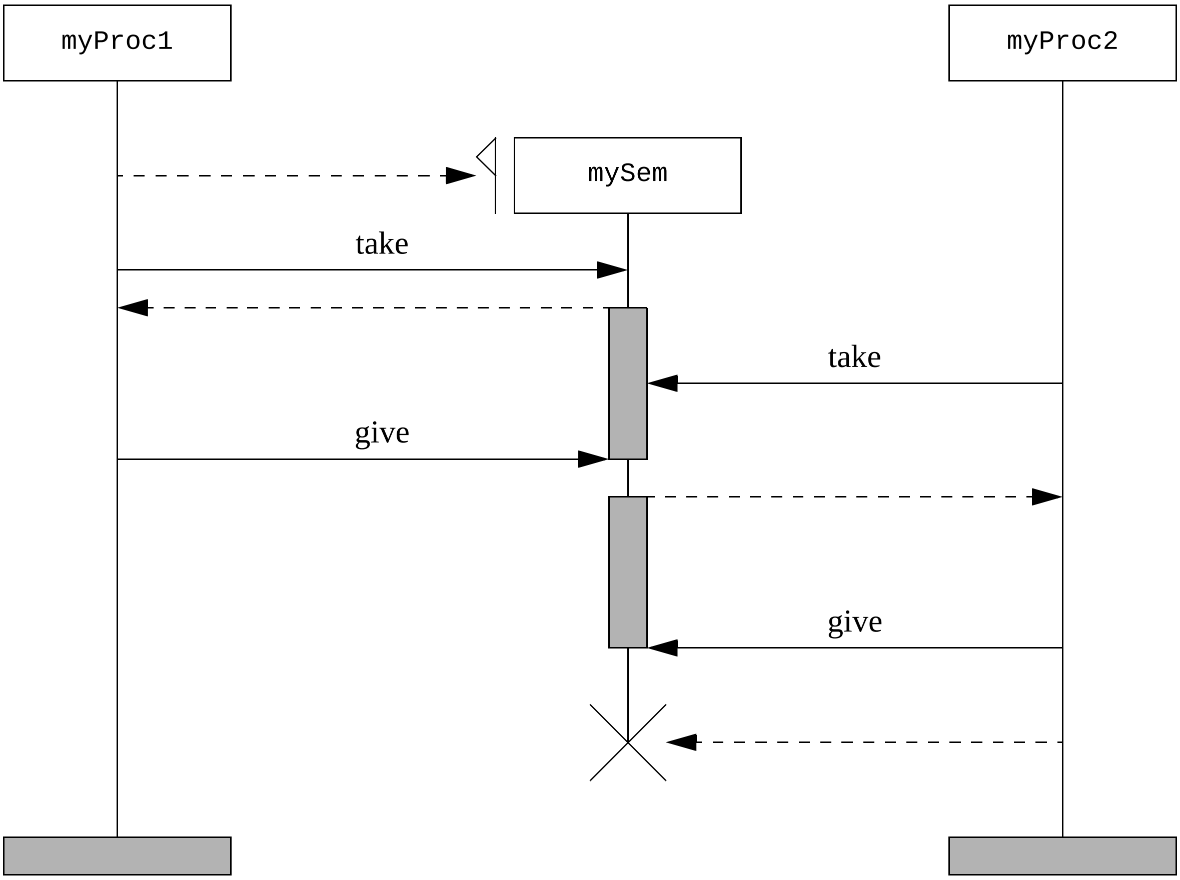
Semaphore give. The semaphore was available before the give.


Semaphore continues.


Semaphore is killed by a known process.


Semaphore is killed by an unknown process.

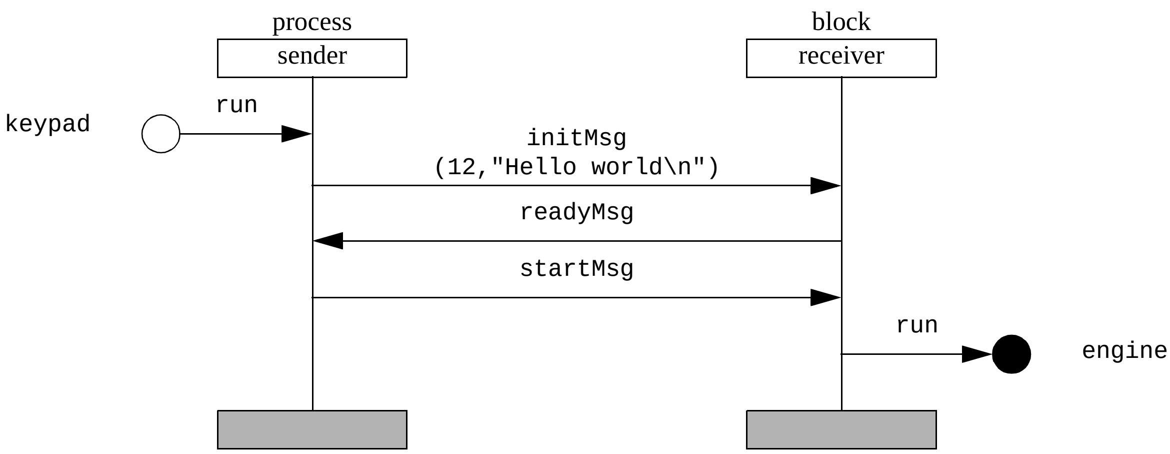
Example:



Process `myProc1` first creates semaphore `mySem`, then takes it successfully. Process `myProc2` makes an attempt to take semaphore `mySem` but gets blocked on it. Process `myProc1` releases the semaphore so `myProc2` successfully gets the semaphore. Process `myProc2` gives it back, and kills it.

6.4 - Message exchange

A message symbol is a simple arrow with its name and optional parameters next to it. The arrow can be horizontal meaning the message arrived instantly to the receiver or the arrow can go down to show the message arrived after a certain time or after another event. A message can not go up ! When the sender and the receiver are represented on the diagram the arrow is connected to their instances. If the sender is missing it is replaced by a white circle, if the receiver is missing it is replaced by a black circle.The name of the sender or the receiver can optionally be written next to the circle.

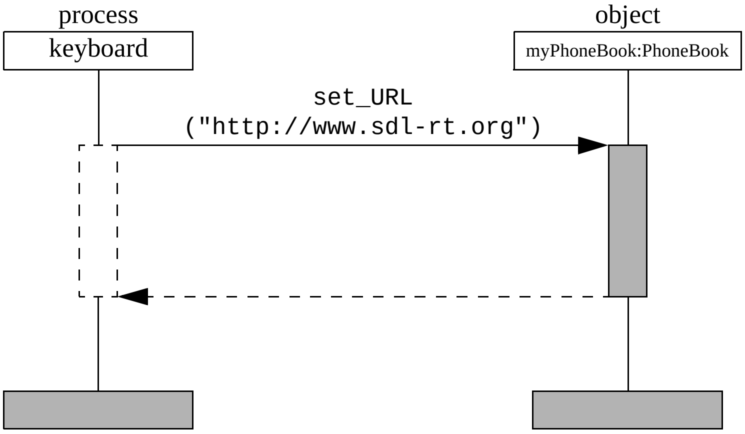


An external agent called `keypad` sends `run` message to process `sender`. Process `sender` sends `initMsg` that is considered to be received immediatly to block `receiver`. Block `receiver` replies `readyMsg`, process `sender` sends `startMsg`, and block `receiver` sends `run` to an external agent.

A message is considered received by an agent when it is read from the agent's message queue; not when it arrives in the message queue !

6.5 - Synchronous calls

This representation is used when using embedded C++ to show method calls on an object. Object can be represented by lifelines. Synchronous calls are shown with an arrow to the instance representing the object. While the object has the focus its lifeline becomes a black rectangle and the agent lifeline becomes a white rectangle. That means the execution flow has been transferred to the object. When the method returns a dashed arrow return to the method caller.



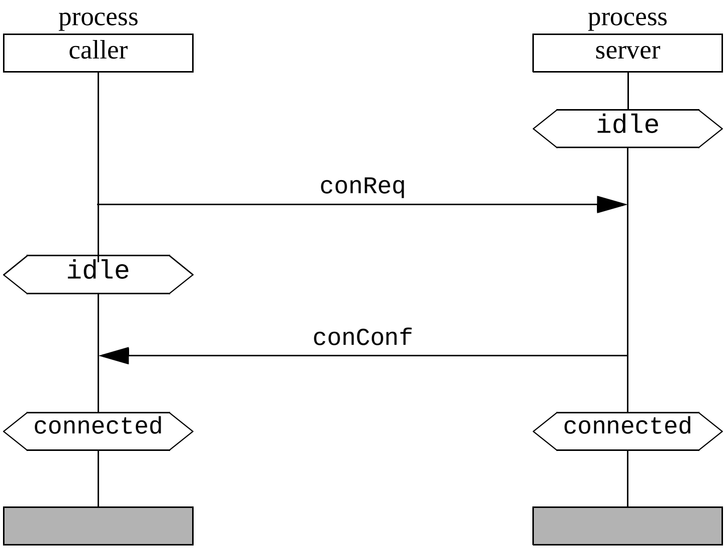
Process `keyboard` calls method `set_URL` from `myPhoneBook` object that is an instance of `PhoneBook` class.

6.6 - State

A lifeline represents a process and depending on its internal state a process reacts differently to the same message. It is interesting to represent a process state on its lifeline. It is also interesting to represent a global state for information. In that case the state symbol covers the concerned instances. In both cases the same symbol is used.

State symbol

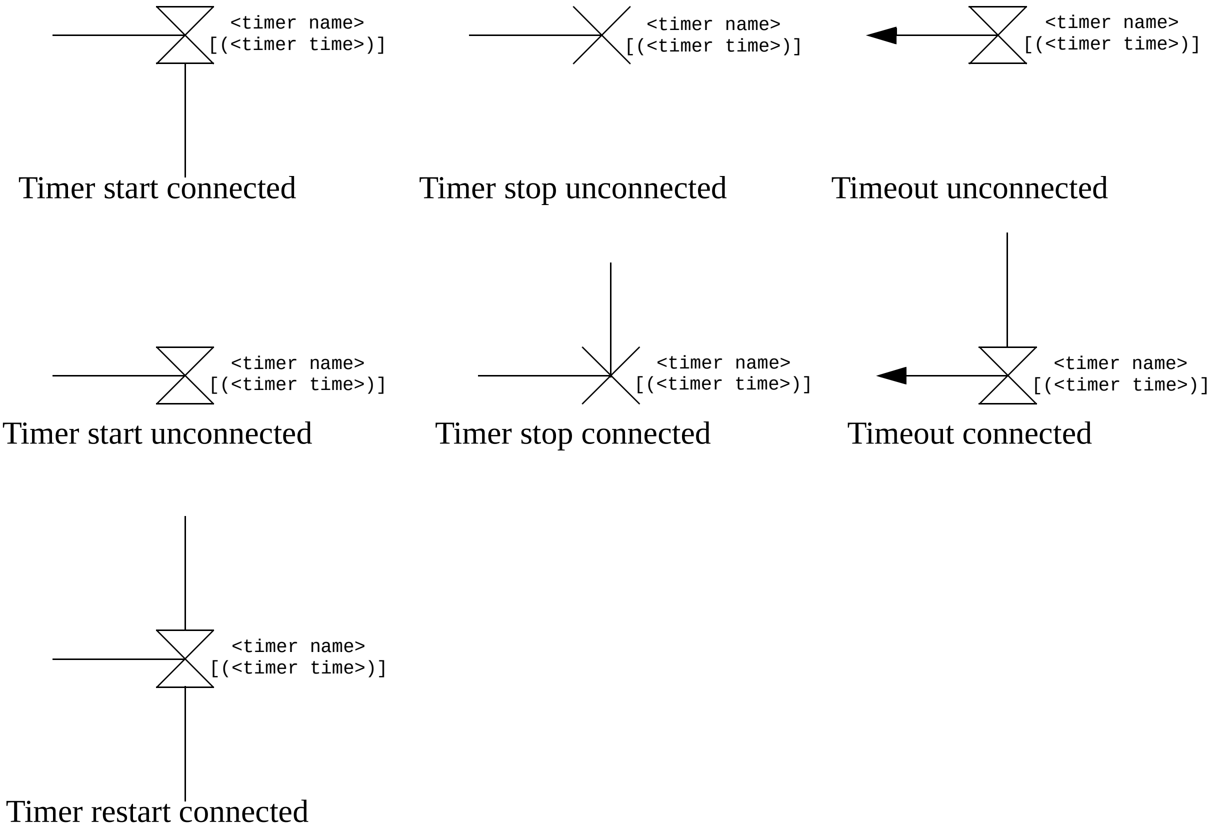
Example:



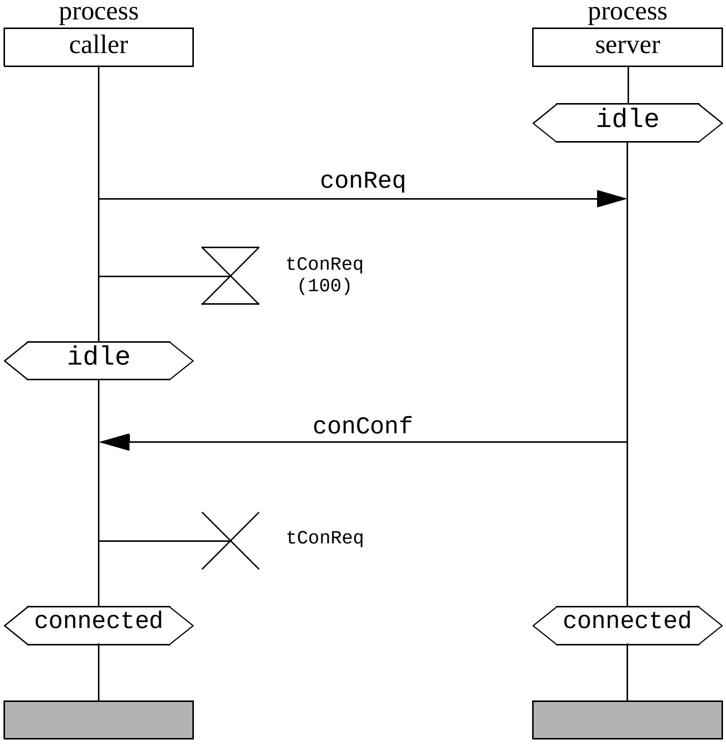
Process `server` goes to `idle` state. Process `caller` in its start transition sends a `conReq` to `server` and goes to state `idle`. Process `server` returns an `conConf` message and goes to `connected` state. When `conConf` message is received by process `caller` it also moves to `connected` state.

6.7 - Timers

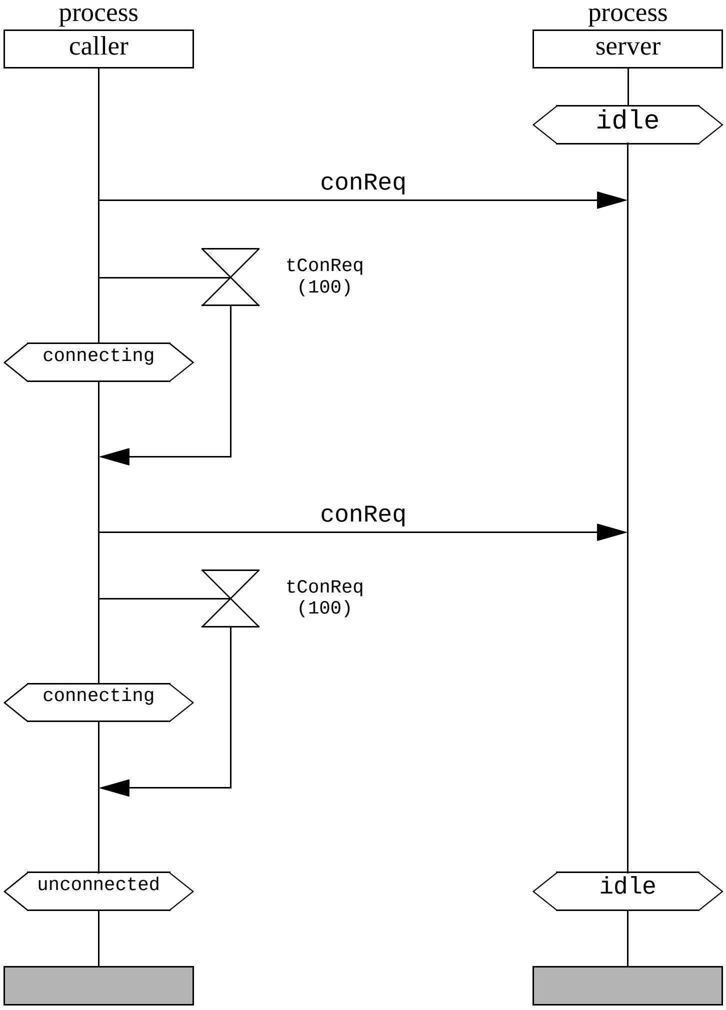
Two symbols are available for each timer action depending if the beginning and the end of the timer are connected or not. The timer name is by the cross and timeout value is optional. When specified the timeout value unit is not specified; it is usually RTOS tick counts.



Examples:



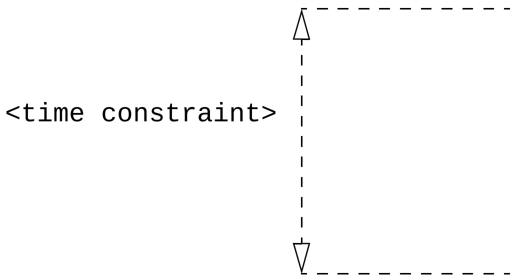
Process `caller` tries to initiate connection with `conReq` message. At the same time it starts timer `tConReq` so that if no answer is received it will retry connecting. If an answer is received the timer is cancelled and process `caller` goes to state `connected`.



Process `caller` tries to initiate connection with `conReq` message. Since it receives no answer after two tries it gives up and goes to unconnected state.

6.8 - Time interval

To specify a time interval between two events the following symbol is used.



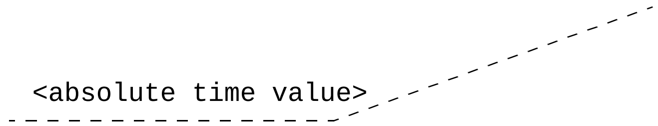
Time constraint syntax is the following:

- absolute time is expressed with an @ up front the time value,

- relative time is expressed with nothing up front its value,
- time interval is expressed between square brackets,
- time unit is RTOS specific -usually tick counts- unless specified (s, ms, µs).

Note it is possible to use time constraint on a single MSC reference.

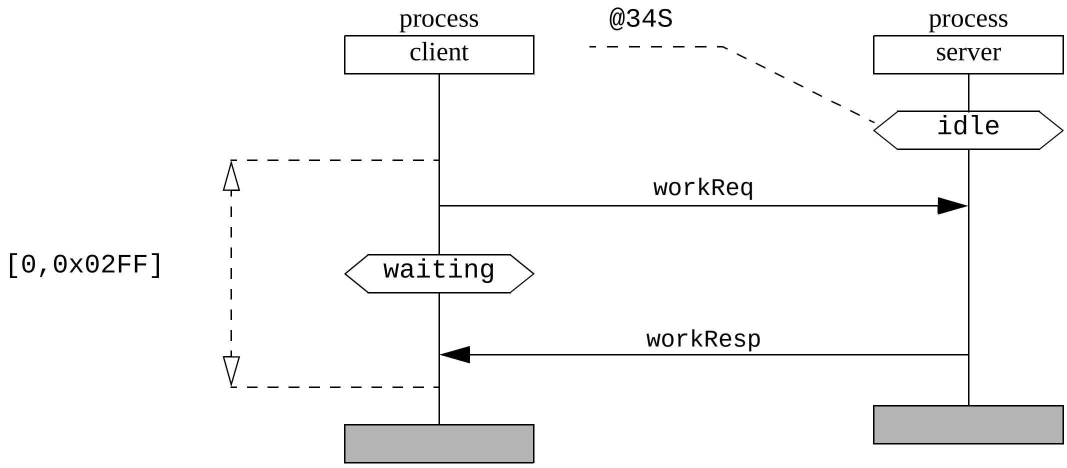
Absolute time can also be specified with the following symbol:



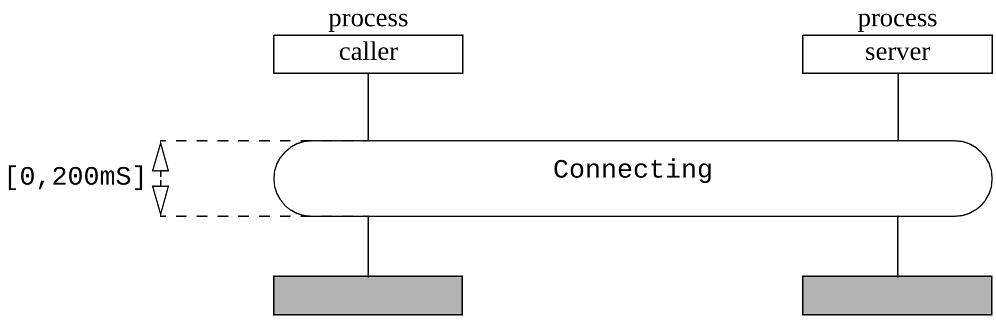
<u>Examples:</u>

Table 1: Examples of time constraint expressions

Expression	Meaning
1.3ms	takes 1.3 ms to do
[1,3]	takes a minimum of 1 to a maximum of 3 time units
@[12.4s,14.7s]	should not occur before absolute time 12.4 s and should not finish after absolute time 14.7 s.
<5	takes less than 5 time units



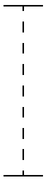
Process `server` reaches state `idle` at absolute time 34 Sec.
Process `client` request process server to compute some work in less than 0x02FF time units.



`Connecting` MSC should take less than 200mS.

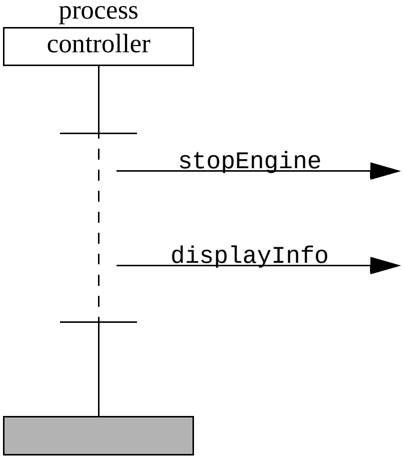
6.9 - Coregion

Coregion is used whenever the sequence of events does not matter. Events in a coregion can happen in any order. The coregion symbol replaces the lifeline instance.



Coregion symbol

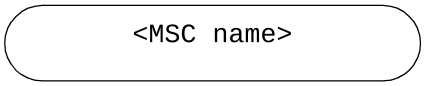
Example:



Process `controller`
sends `stopEngine` and `displayInfo` or
sends `displayInfo` and `stopEngine`.

6.10 - MSC reference

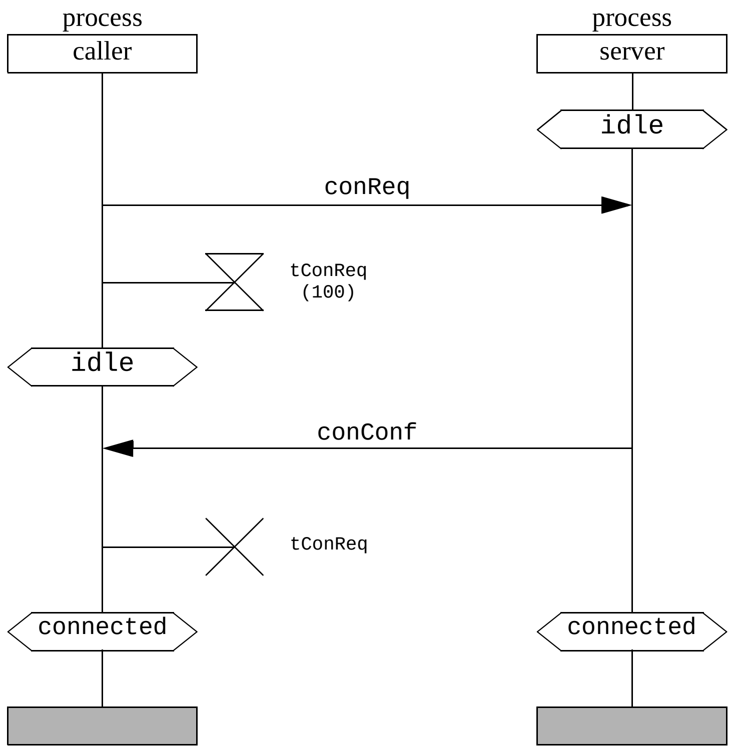
MSC reference allows to refer to another MSC. The resulting MSC is smaller and more legible.



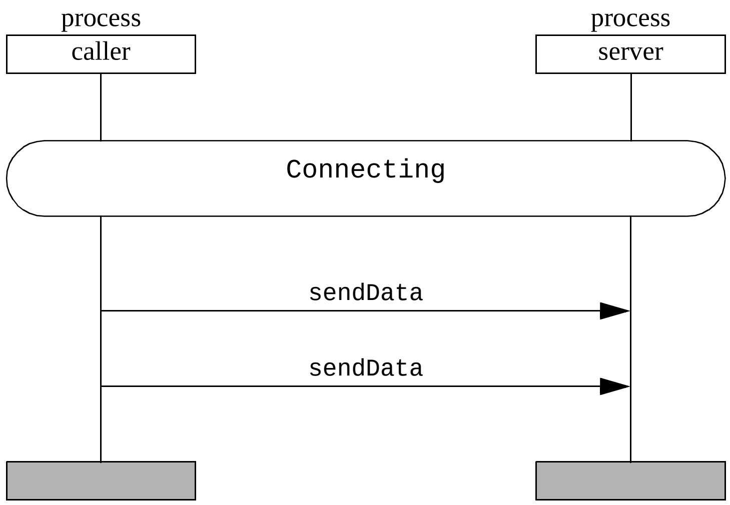
MSC reference symbol

A reference concerns the connected instances. An instance is connected if its lifeline disappears in the symbol. An instance is not connected if it goes over the reference symbol.

Example:



Connecting MSC

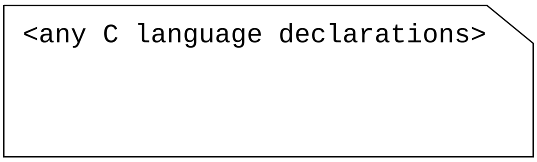


DataTransfer MSC

The DataTransfer MSC starts with a reference to Connecting MSC. That means the scenario described in Connecting MSC is to be done before the rest of the DataTransfer MSC occur.

6.11 - Text symbol

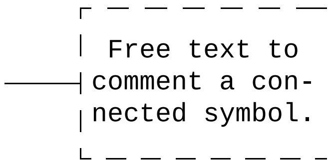
The text symbol contains data or variable declarations if needed in the MSC.



Text symbol

6.12 - Comment

As its name states...



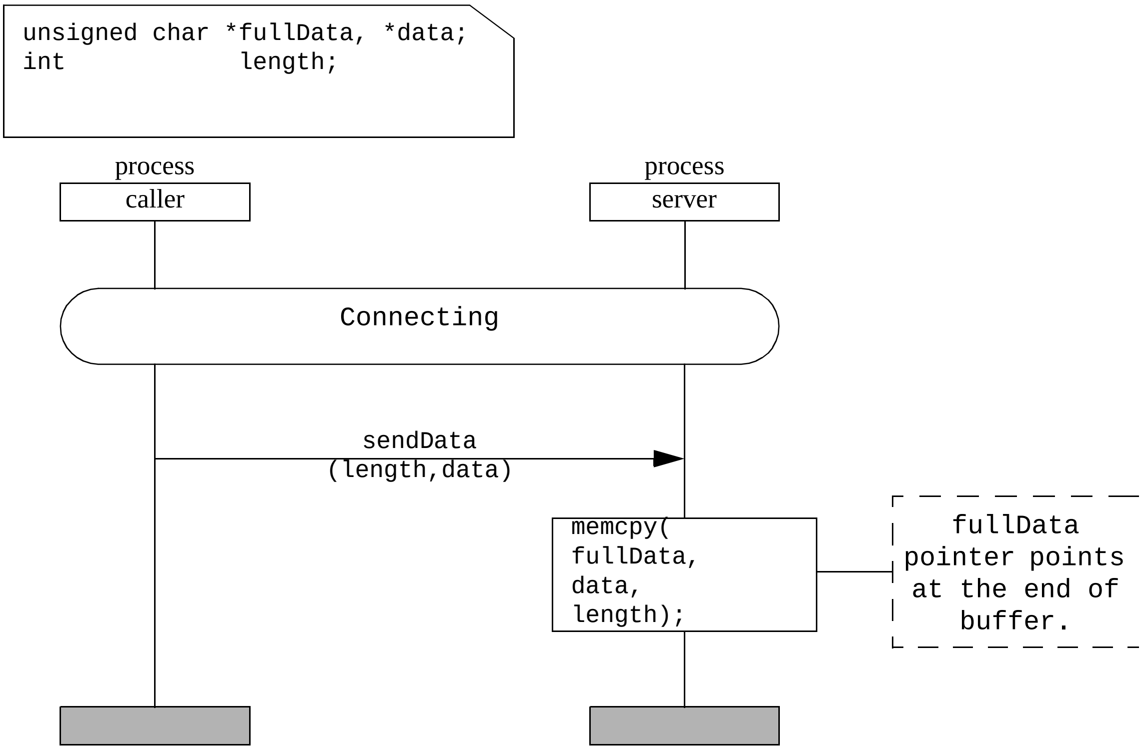
Comment symbol

6.13 - Action

An action symbol contains a set of instructions in C code. The syntax is the one of C language.

Examples:

```
/* Say hi to your friend */
printf("Hello world !\n");
for (i=0;i<MAX;i++)
   {
   newString[i] = oldString[i];
   }
```

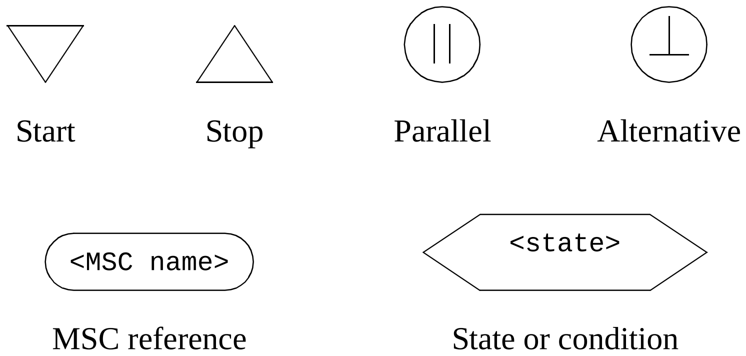


DataTransfer MSC

The action symbol contains standard C instructions related to data declarations.

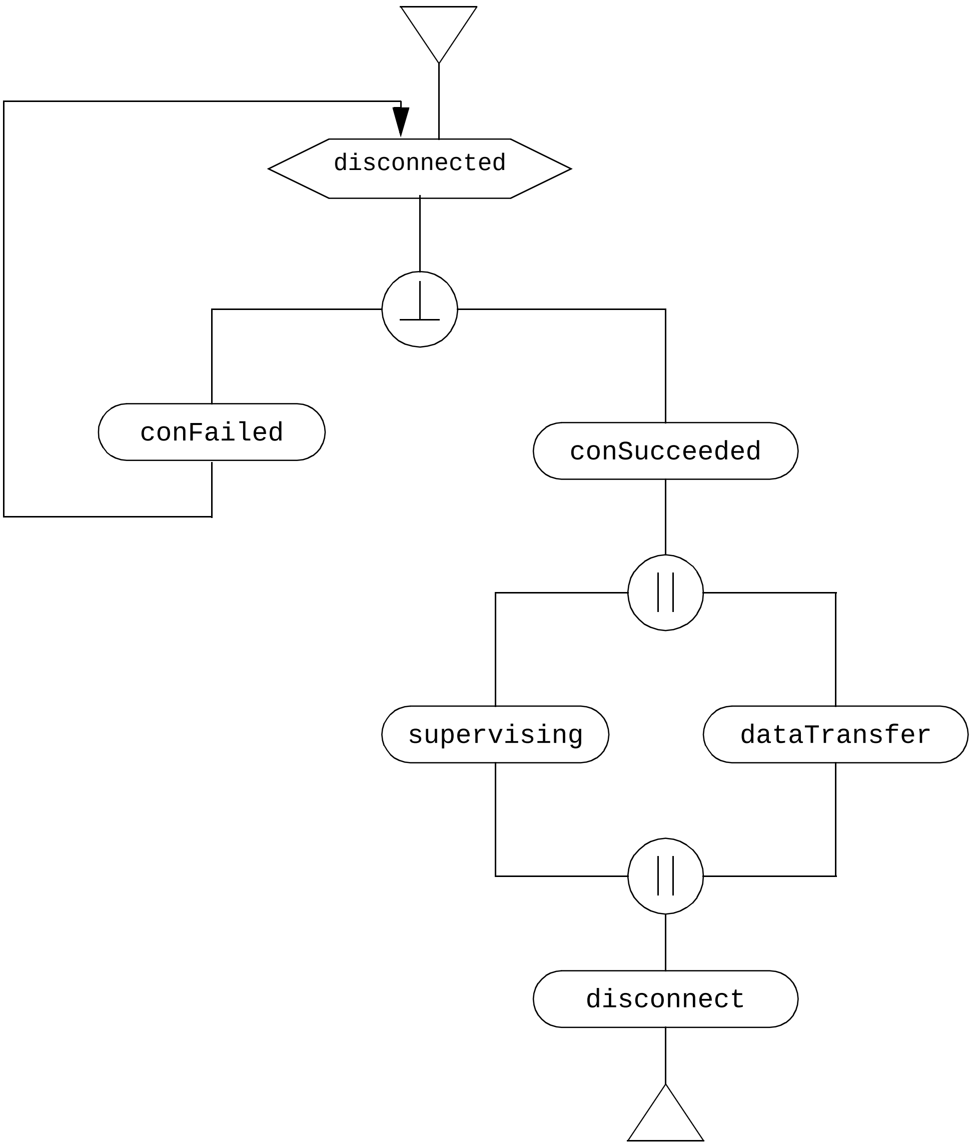
6.14 - High-level MSC (HMSC)

High level MSC diagram is a synthetic view of how MSCs relate to each other. It is only a few symbols: start, stop, alternative, parallel, state or condition, and MSC reference.



The SDL-RT HMSC starts with the start symbol and ends with the stop symbol. The parallel symbol means the following connected path will be executed in parallel. The Alternative symbol means one and only one of the connected path is executed. Whenever two paths meet again the path separator symbol is to be repeated. That means if a parallel symbol is used that creates two different paths, the parallel symbol should be used when the path merge back.
Symbols are connected with lines or arrows if clearer. A symbol is entered by its upper level edge and leaved by any other edge.

Example:



The system starts in `disconnected` state. Connection attempts are made, either the `conFailed` scenario or the `conSucceeded` scenario is executed. If `conSucceeded` is executed `supervising` and `dataTransfer` are executing in parallel. They merge back to `disconnect` and end the HMSC scenario.

7 - Data types

The data types, the syntax and semantic are the ones of ANSI C language. There is no SDL-RT predefined data types at all but just some keywords that should not be used in the C code. Considering the SDL-RT architecture and concepts surrounding the C code some important aspects need to be described.

7.1 - Type definitions and headers

Types are declared in the text symbol:

```
<Any C type declaration >
```

Types declared in an agent are only visible in the architecture below the agent.

7.2 - Variables

Variables are declared after the type definitions in the same text symbol.

```
<Any C type definition >
<Any C global variable definition >
```

Variables declared in an agent are only visible in the architecture below the agent. For example global variables are to be declared at system level. A variable declared in a block level is not seen by an upper level block. Variables declared in an SDL-RT process in a text symbol are local to the process. They can not be seen or manipulated by any other process.

7.3 - C functions

SDL-RT internal C functions are to be defined through the SDL-RT procedure symbol. An SDL-RT procedure can be defined graphically in SDL-RT or textually in C. When defined in C the procedure call symbol should not be used. A standard C statement in an action symbol should be used.

7.4 - External functions

External C functions can be called from the SDL-RT system. These should be prototyped in the system or in an external C header. It is up to an SDL-RT tool to gather the right files when compiling and linking.

8 - Memory management

Real time systems need to exchange information. The best way to do so is to have a reserved chunk of shared memory that several tasks can access. SDL-RT implicitly runs on such an underlying architecture since it supports global variables and exchanges message parameters through pointers. That raises memory management rules to follow to ensure a proper design.

8.1 - Global variables

SDL-RT processes can share global variables. This is very powerful but also very dangerous since the data can be corrupted if manipulated without caution. It is strongly recommended to use semaphores to access global variables to be sure data is consistent. An example of such a design is given later in this document.

8.2 - Message parameters

Parameters of a message are passed through a pointer. This implies the data pointed by the sending process will be accessible by the receiving process. Therefore a good design should meet the following rules:

- Sending processes allocate specific memory areas to store parameters,
- Once the message is sent the parameter memory area should never be manipulated again by the sending process,
- Receiver processes are responsible for freeing memory containing message parameters.

9 - Syntax

All SDL-RT names must be a combination of alphabetical characters, numerical characters, and underscores. No other symbols are allowed.

Examples:

```
myProcessName
my_procedure_name
block_1
_semaphoreName
```

10 - Semantic

Since some SDL-RT concepts can be reached through their names (processes, semaphores) each name in the system must be unique. This will make the design more legible and ease the support of SDL-RT in a tool.

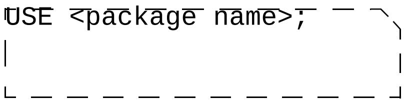
It is suggested to use the following convention for names:

- block names should start with ’b’,
- process names should start with ’p’,
- timer names should start with ’t’,
- semaphore names should start with ’s’,
- global variables should start with ’g’.

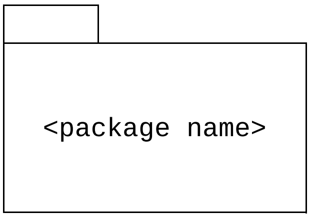
11 - Object orientation

11.1 - Package

Object orientation in SDL-RT allows to define classes of processes and blocks. Classes definitions are gathered in an SDL-RT package. To be able to use classes defined in a package, an SDL-RT system should explicitly import the package with USE keyword in an additional heading symbol at system level.



A package is a separated entity that contains agents or classes of agents. It is referenced by its name.

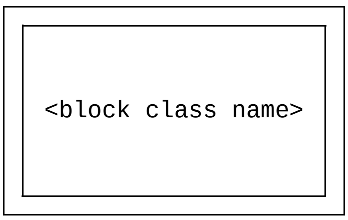


It can contain:

- blocks,
- classes of blocks,
- processes,
- classes of processes,
- procedures,
- data definitions.

11.2 - Block class

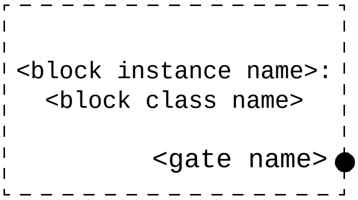
Defining a block class allows to use the same block several times in the SDL-RT system. The SDL-RT block does not support any other object oriented features. A block class symbol is a block symbol with a double frame. It has no channels connected to it.



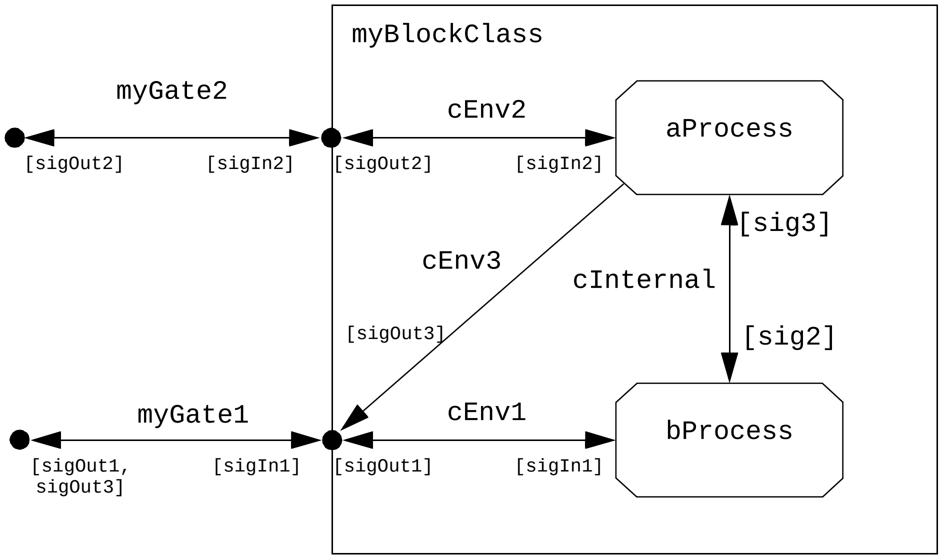
A block class can be instantiated in a block or system. The syntax in the block symbol is:

```
<block instance name>:<block class name>
```

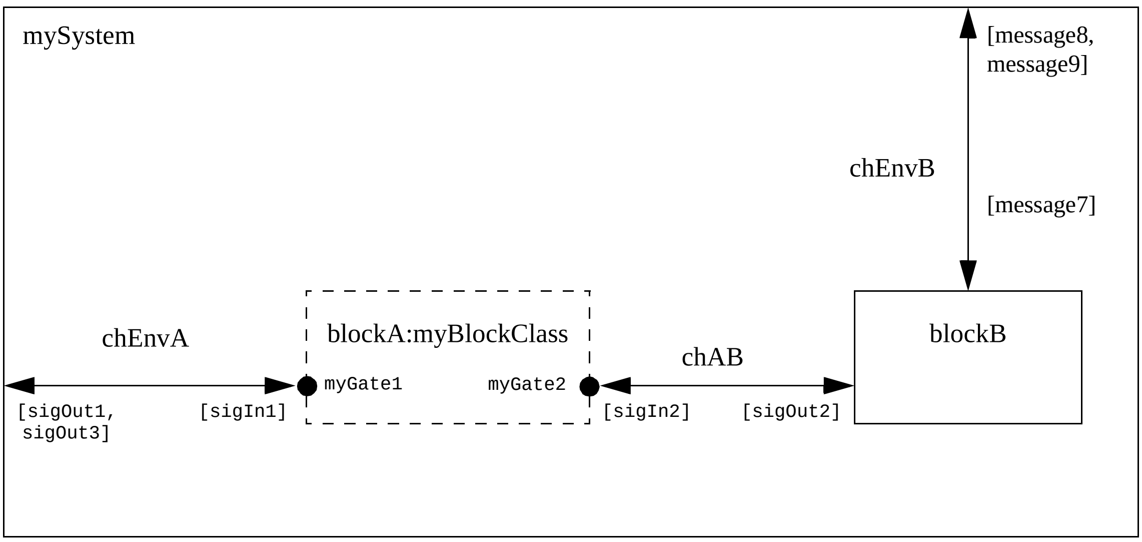
Messages come in and go out of a block class through gates. In the block class diagram gates are represented out of the block class frame. When a block class is instantiated the gates are connected to the surrounding SDL-RT architecture. The messages listed in the gates are to be consistent with the messages listed in the connected channels.



Example:



Definition diagram of myBlockClass block class



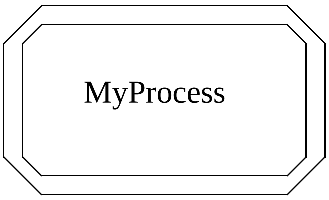
blockA is an instance of myBlockClass

11.3 - Process class

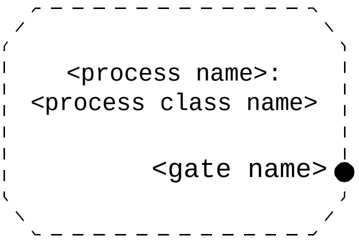
Defining a process class allows to:

- have several instances of the same process in different places of the SDL-RT architecture,
- inherit from a process super-class,
- specialize transitions and states.

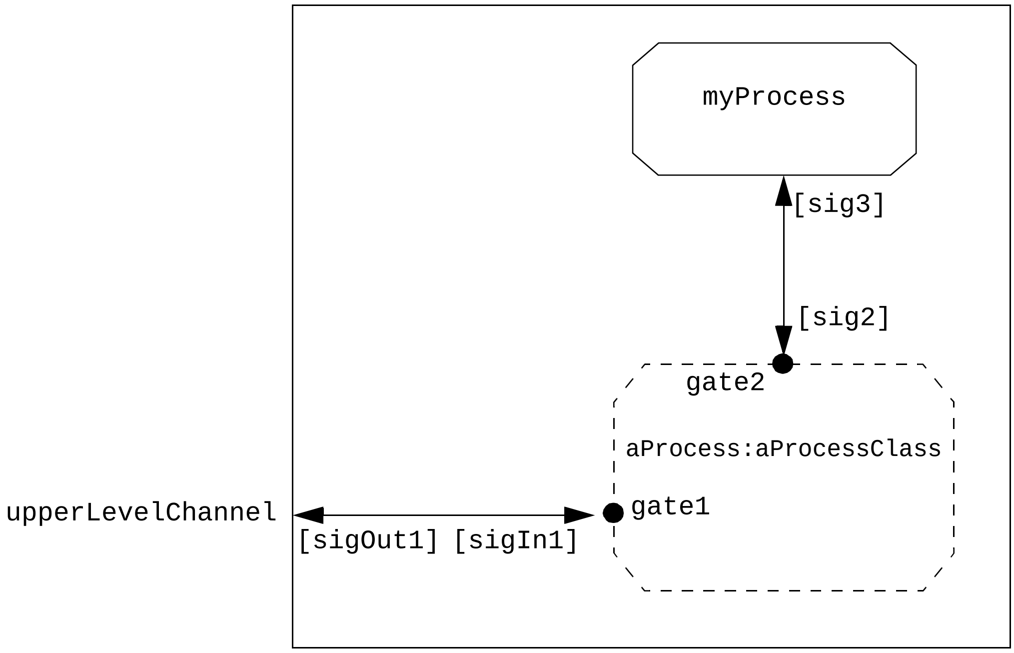
A process class symbol is a process symbol with a double frame. It is has no channels connected to it.



A process class can be instantiated in a block or a system. The syntax in the process symbol is:
`<process instance name>:<process class name>`
Messages come in and go out of a process class through gates. In the process class diagram, gates are represented out of the process class frame. When a process class is instantiated the gates are connected to the surrounding SDL-RT architecture. The messages listed in the gates are to be consistent with the messages listed in the connected channels. The names of the gates appear in the process symbol with a black circle representing the connection point.

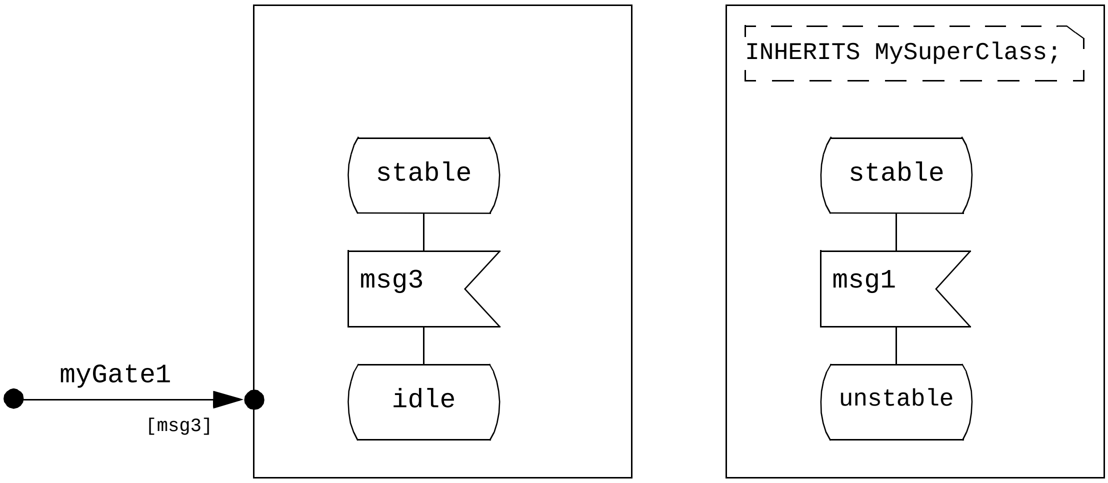


<u>Example:</u>

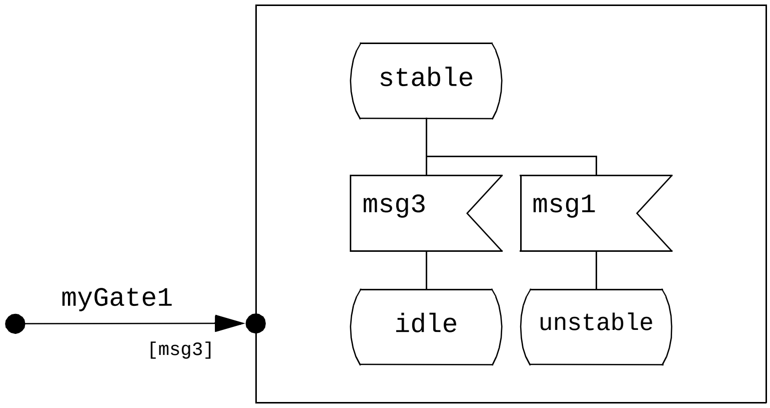


SDL-RT transitions, gates and data are the elements that can be redefined when specializing. In the sub class the super class to inherit from is defined with the `INHERITS` keyword in an **additional heading symbol**. There are several ways to specialize a process class depending on what is defined in the super class.

- If the element is new in the sub class, it is simply added to the super class definition,

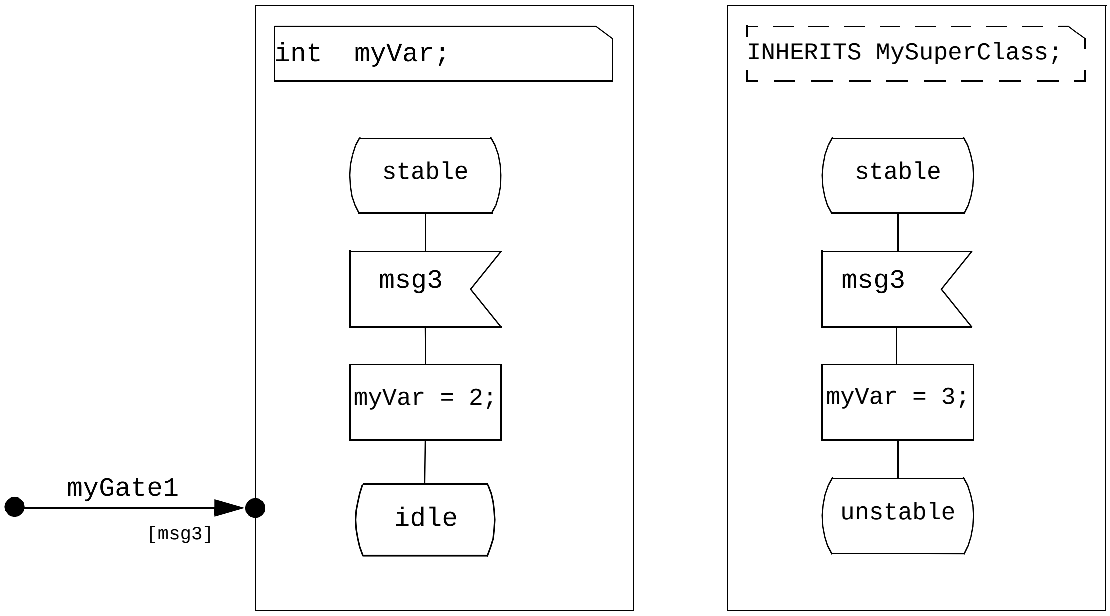


MySuperClass   MyClass

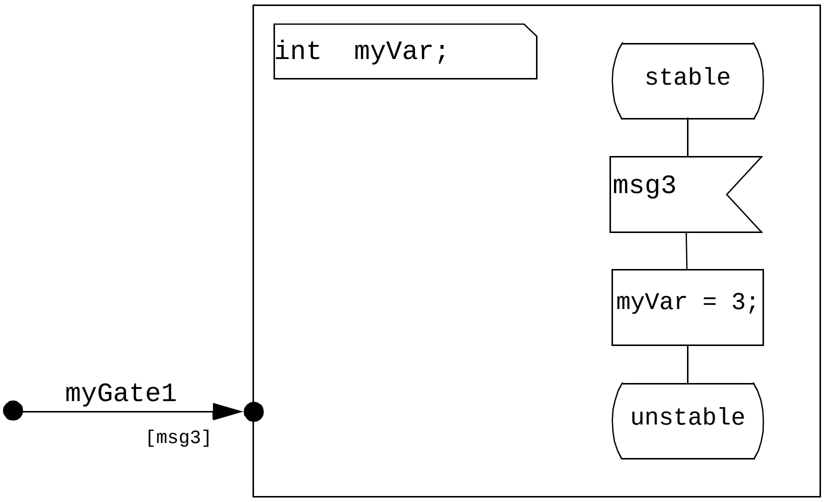


An instance of MyClass

- If the element exists in the super class, the new element definition overwrites the one of the super class,

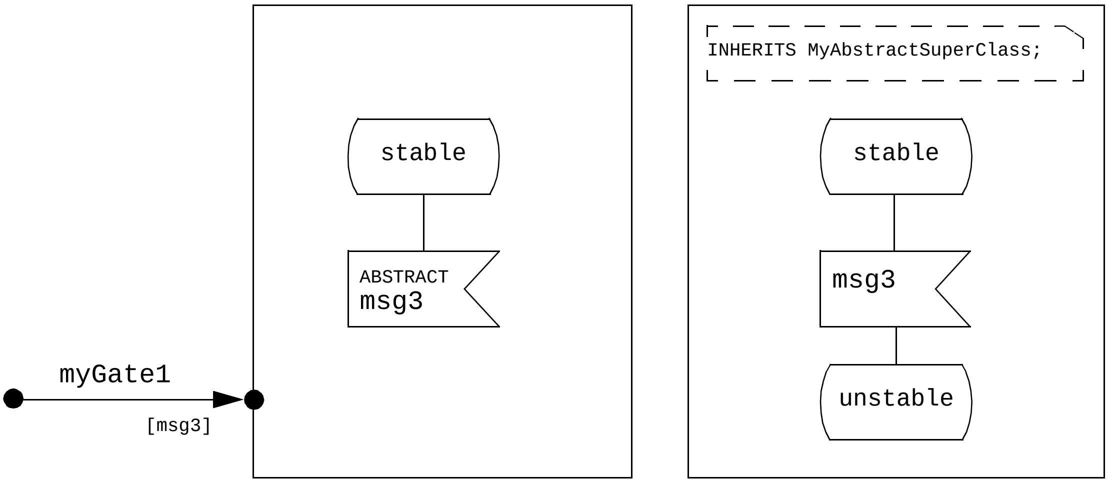


MySuperClass MyClass

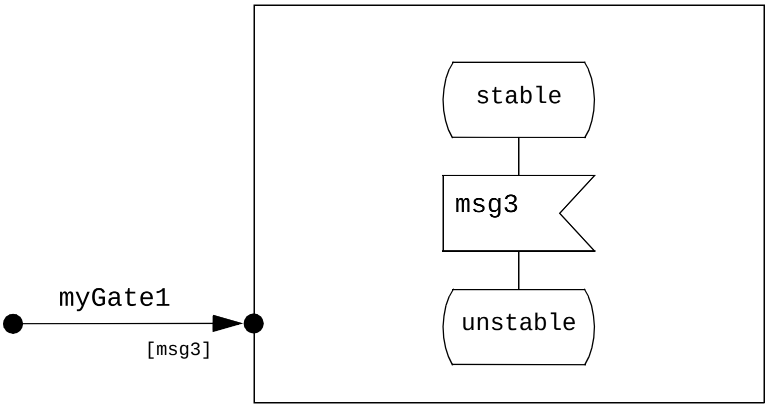


An instance of MyClass

- A class can be defined as abstract with the ABSTRACT keyword. It means the class can not be instantiated as is; it needs to be specialized. A class can define abstract transitions or abstract gates. It means the abstract transition or gate exists but that it is not defined. Such a class is obviously abstract and needs to be defined as such.

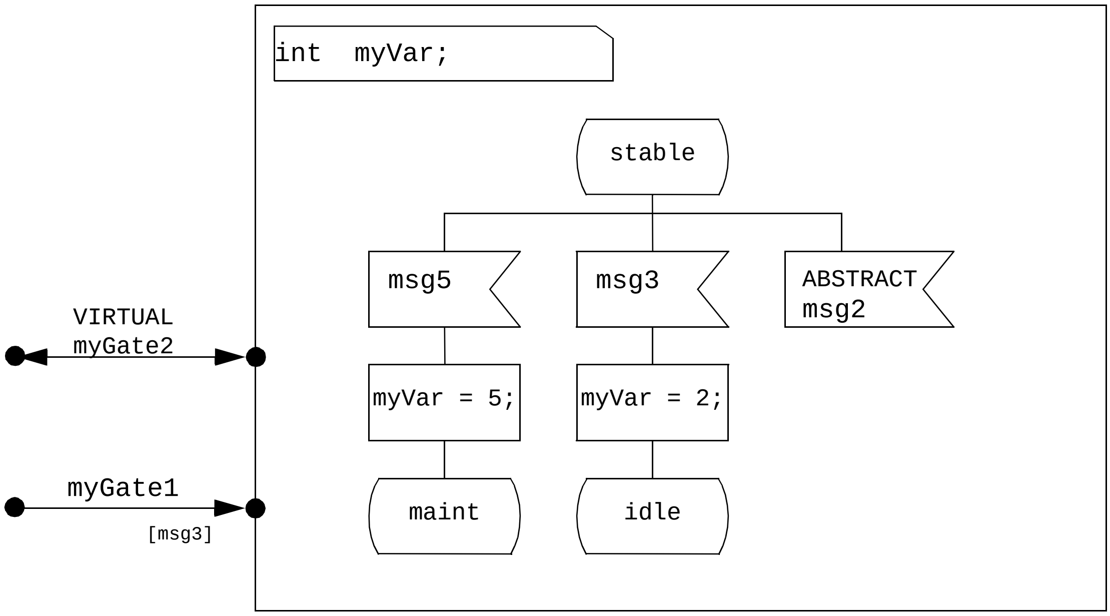


MyAbstractSuperClass   MyClass

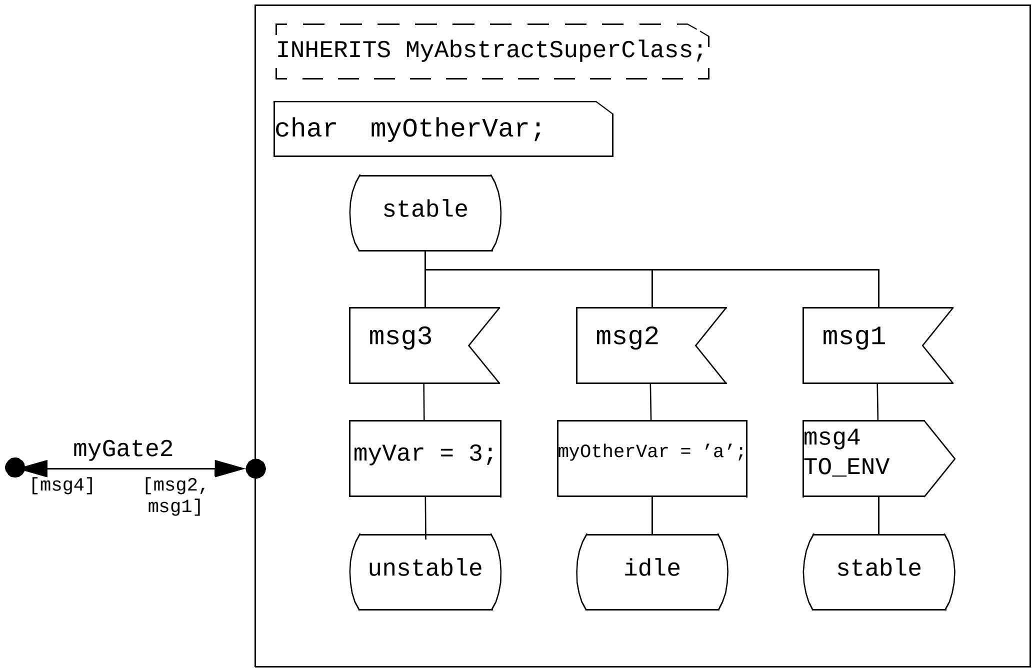


An instance of MyClass

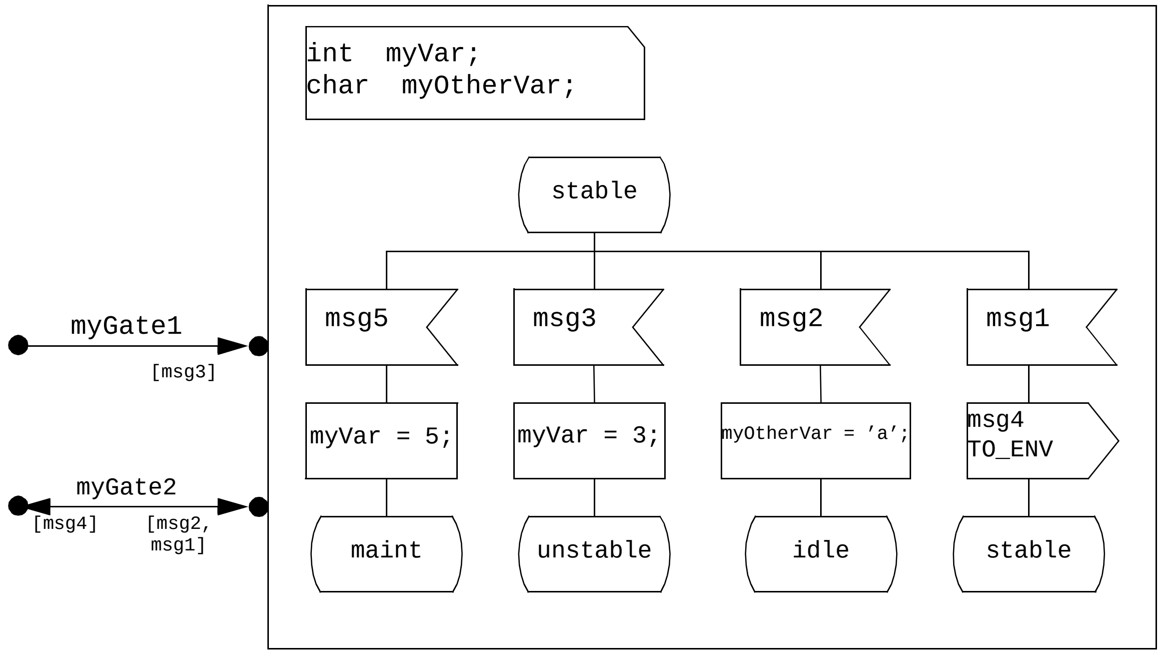
Here comes an example mixing all object oriented concepts and the resulting object:



MyAbstractSuperClass



MyClass



An instance of MyClass

12 - Symbols contained in diagrams

The table below shows what symbols can be contained in a specific diagram type.

In the diagrams listed in this column the ticked symbols on the right can be used.	package	block class	process class	block	process	procedure declaration	semaphore declaration	channel	additional heading	text	gate definition	gate usage	behavior symbols
package	X	X	X	X	X	X	X	X	X	X	X	-	-
block class	-	X	X	X	X	X	X	X	X	X	X	X	-
process class	-	-	-	-	-	-	-	-	X	X	X	-	X
block	-	-	-	X	X	X	X	X	X	X	-	X	-
process	-	-	-	-	-	-	-	-	X	X	-	-	X
procedure	-	-	-	-	-	-	-	-	-	X	-	-	X

A diagram listed in the first column can contain the ticked symbols in the other columns. For example the process symbol can contain the additional heading symbol, the text symbol and all the behavior symbols. The behavior symbols are all symbols described in “Behavior” on page 13.

13 - Textual representation

Storage format follows XML (eXtensible Markup Language standard from W3C available at http://www.w3c.org) standard with the following DTD (Document Type Definition):

```
<!-- Entity for booleans -->
<!-- ================== -->

<!ENTITY % boolean "(TRUE|FALSE)">


<!-- Entities for symbol types -->
<!-- ========================= -->

<!ENTITY % sdlSymbolTypes1
"sdlSysDgmFrm|sdlSysTypeDgmFrm|sdlBlkDgmFrm|sdlBlkTypeDgmFrm|sdlBlkType|sdlBlk|sdlBlkT
ypeInst|sdlPrcsType|sdlPrcs|sdlPrcsTypeInst">
<!ENTITY % sdlSymbolTypes2 "sdlInherits|sdlPrcsTypeDgmFrm|sdlPrcsDgmFrm|sdlPrcdDgm-
Frm|sdlStart|sdlState|sdlInputSig|sdlSendSig|sdlSaveSig|sdlContSig">
<!ENTITY % sdlSymbolTypes3 "sdlTask|sdlDecision|sdlTransOpt|sdlJoin|sdlText|sdlCom-
ment|sdlTextExt|sdlCnctrOut|sdlCnctrIn|sdlPrcsCreation|sdlStop">
<!ENTITY % sdlSymbolTypes4 "sdlInitTimer|sdlResetTimer|sdlSemDecl|sdlSemTake|sdlSem-
Give|sdlPrcdProto|sdlPrcdDecl|sdlPrcdCall|sdlPrcdStart|sdlPrcdReturn">
<!ENTITY % mscSymbolTypes
"mscExternalFrm|mscInlineExpr|mscLifeline|mscLostMsg|mscFoundMsg|mscComment|mscGenName
Area|mscText|mscAbsTimeConstr|mscCondition|mscMscRef|mscInlineExprZone">
<!ENTITY % hmscSymbolTypes "hmscDgmFrm|hmscParallelFrm|hmscStart|hmscEnd|hmscCondi-
tion|hmscMscRef|hmscCnctnPoint">
<!ENTITY % mscdocSymbolTypes "mscdocDgmFrm|mscdocMscRef|mscdocHeader">
<!ENTITY % SymbolType
"(%sdlSymbolTypes1;|%sdlSymbolTypes2;|%sdlSymbolTypes3;|%sdlSymbolTypes4;|%mscSymbolTy
pes;|%hmscSymbolTypes;|%mscdocSymbolTypes;)">


<!-- Entity for lifeline component type -->
<!-- ================================== -->

<!ENTITY % LifelineComponentType "(norm|susp|meth|coreg|act)">


<!-- Entity for time interval type -->
<!-- ============================= -->

<!ENTITY % TimeIntervalType "(start|end|timeout|constraint)">


<!-- Entity for connector types -->
<!-- ========================== -->

<!ENTITY % ConnectorType "(void|chnl|chnlgate|sdlarrow|mscvoid|mscgate|mscarrow-
gate|hmscarrow)">


<!-- Entity for side for connectors -->
<!-- ============================== -->
```

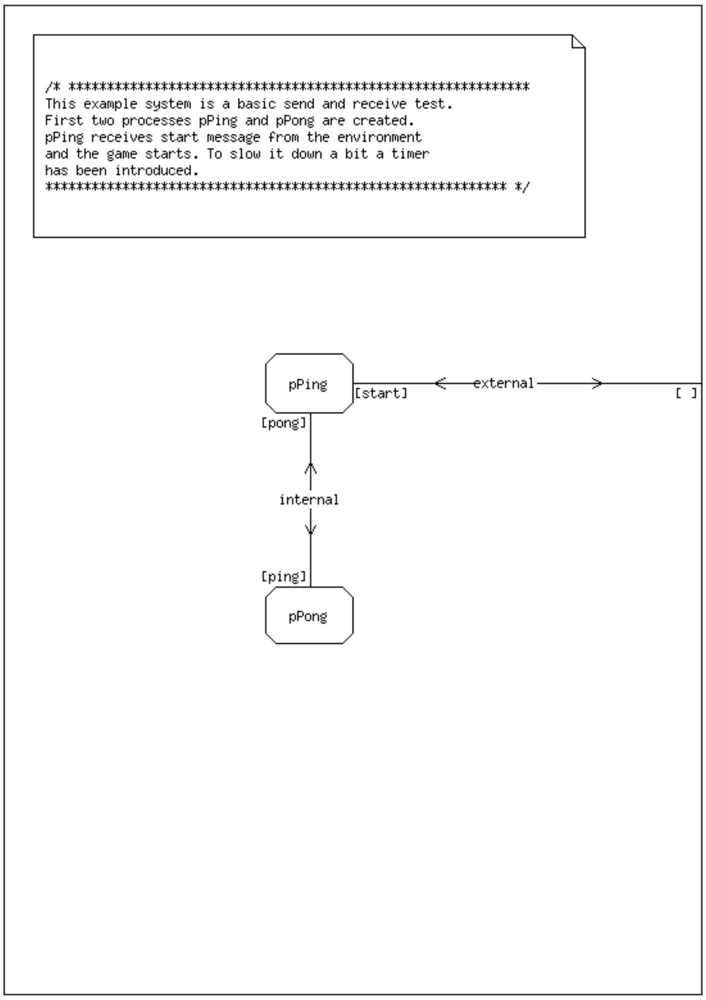
```
<!ENTITY % Side "(n|s|w|e|x|y)">


<!-- Entity for end types for connectors -->
<!-- =================================== -->

<!ENTITY % ConnectorEndType "(voidend|arrow|midarrow)">


<!-- Entity for link segment orientation -->
<!-- =================================== -->

<!ENTITY % Orientation "(h|v)">


<!-- Entity for link types -->
<!-- ===================== -->

<!ENTITY % LinkType "(sbvoid|dbvoid|ssvoid|dsvoid|chnl|dec|transopt|msg|rtn)">


<!-- Entity for diagram types -->
<!-- ======================== -->

<!ENTITY % DiagramType "(sys|systype|blk|blktype|prcs|prcstype|prcd|msc|hmsc|msc-
doc|class|usec|act|state|comp|seq|coll|depl)">



<!-- Element for text in symbols/links/... -->
<!-- ===================================== -->

<!ELEMENT Text (#PCDATA)>
<!ATTLIST Text
  id  CDATA "0"
>


<!-- Element for lifeline symbol components (MSC specific) -->
<!-- ===================================================== -->
<!-- The "Text" component and "width" attribute are only for action symbols -->

<!ELEMENT LifelineComponent (Text?)>
<!ATTLIST LifelineComponent
  type    %LifelineComponentType;   #REQUIRED
  height  CDATA                     #REQUIRED
  width   CDATA                     "-1"
>


<!-- Element for lifeline symbol time intervals (MSC specific) -->
<!-- ========================================================= -->

<!ELEMENT TimeInterval (Text)>
<!ATTLIST TimeInterval
  type      %TimeIntervalType;  #REQUIRED
  startpos  CDATA               #REQUIRED
  endpos    CDATA               "-1"
  offset    CDATA               #REQUIRED
```

```
>


<!-- Element for spanned lifelines for spanning symbols (MSC specific) -->
<!-- ================================================================= -->

<!ELEMENT SpannedLifeline EMPTY>
<!ATTLIST SpannedLifeline
  lifelineId  IDREF   #REQUIRED
>


<!-- Element for inline expression zones (MSC specific) -->
<!-- ================================================== -->

<!ELEMENT Zone EMPTY>
<!ATTLIST Zone
  zoneSymbolId  IDREF   #REQUIRED
>


<!-- Element for symbols -->
<!-- =================== -->
<!-- The "LifelineComponent" and "TimeInterval" components and the "dies" attribute are
only for lifelines symbols -->
<!-- The "Zone" component is only for inline expression symbols -->
<!-- The "SpannedLifeline" component is only for spanning symbols in MSC diagrams -->

<!ELEMENT Symbol (Text, (((LifelineComponent*), (TimeInterval*)) | ((SpannedLifeline*),
(Zone*)) | (Symbol*)))>
<!ATTLIST Symbol
  symbolId        ID            #REQUIRED
  type            %SymbolType;  #REQUIRED
  xCenter         CDATA         #REQUIRED
  yCenter         CDATA         #REQUIRED
  fixedDimensions %boolean;     "FALSE"
  width           CDATA         "10"
  height          CDATA         "10"
  dies            %boolean;     "FALSE"
>


<!-- Element for connectors -->
<!-- ====================== -->

<!ELEMENT Connector (Text, Text)>
<!ATTLIST Connector
  attachedSymbolId  IDREF               #REQUIRED
  type              %ConnectorType;     #REQUIRED
  isOutside         %boolean;           #REQUIRED
  side              %Side;              #REQUIRED
  position          CDATA               #REQUIRED
  endType           %ConnectorEndType;  #REQUIRED
>


<!-- Element for link segments -->
<!-- ========================= -->
```

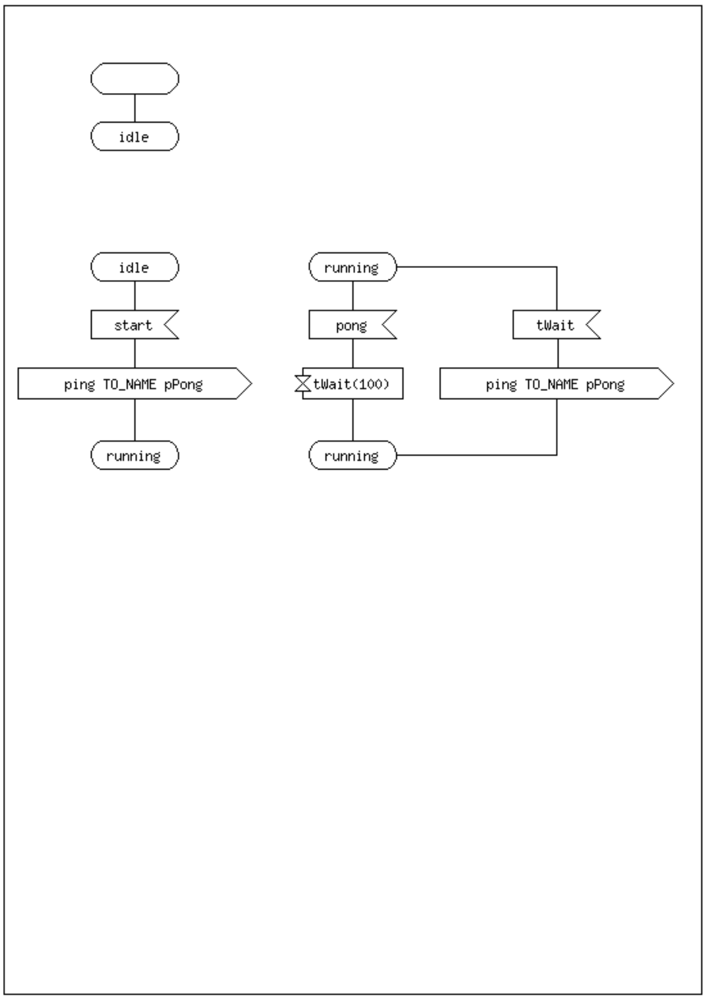
```
<!ELEMENT LinkSegment EMPTY>
<!ATTLIST LinkSegment
  orientation %Orientation; #REQUIRED
  length      CDATA         #REQUIRED
>


<!-- Element for links -->
<!-- ================= -->

<!ELEMENT Link (Text, Connector, Connector, LinkSegment*)>
<!ATTLIST Link
  type            %LinkType;  #REQUIRED
  textSegmentNum  CDATA       #REQUIRED
>


<!-- Element for diagrams -->
<!-- ==================== -->

<!ELEMENT Diagram (Symbol, Link*)>
<!ATTLIST Diagram
  type        %DiagramType; #REQUIRED
  pageWidth   CDATA         "21"
  pageHeight  CDATA         "29.7"
  nbPagesH    CDATA         "1"
  nbPagesV    CDATA         "1"
  cellWidthMm CDATA         "5"
>
```

14 - Example systems

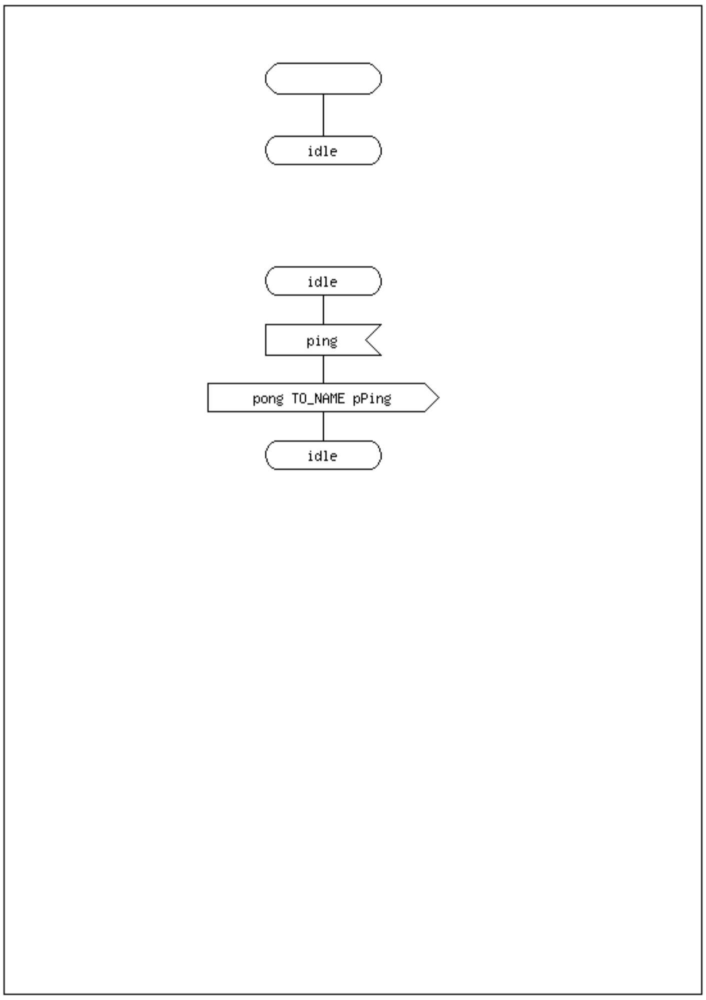
14.1 - Ping Pong



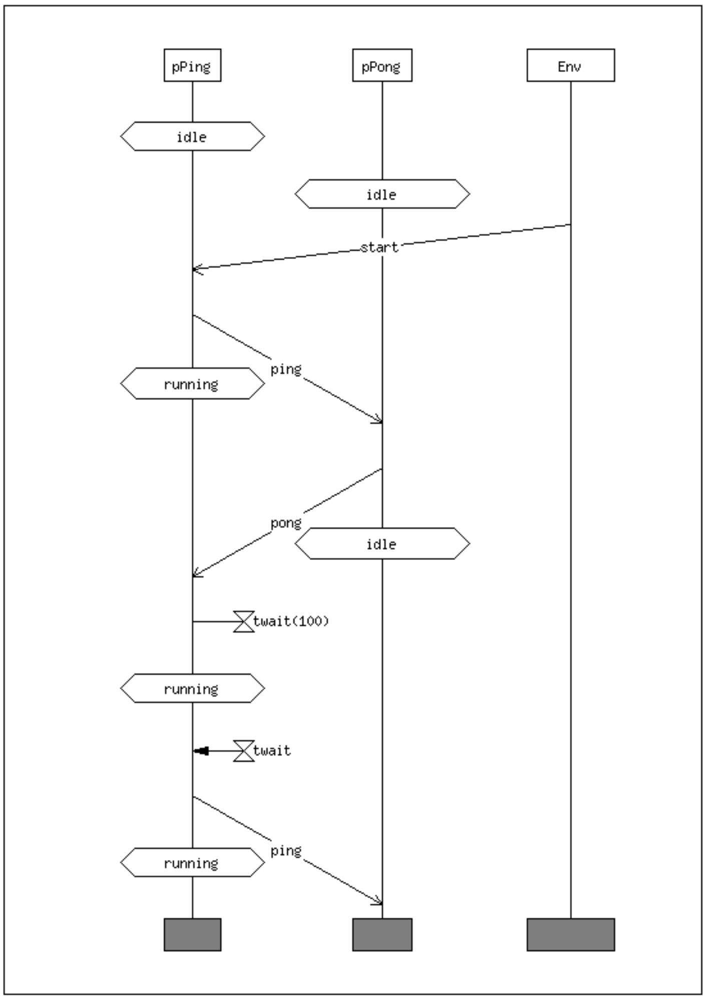
Ping pong system view



Ping process

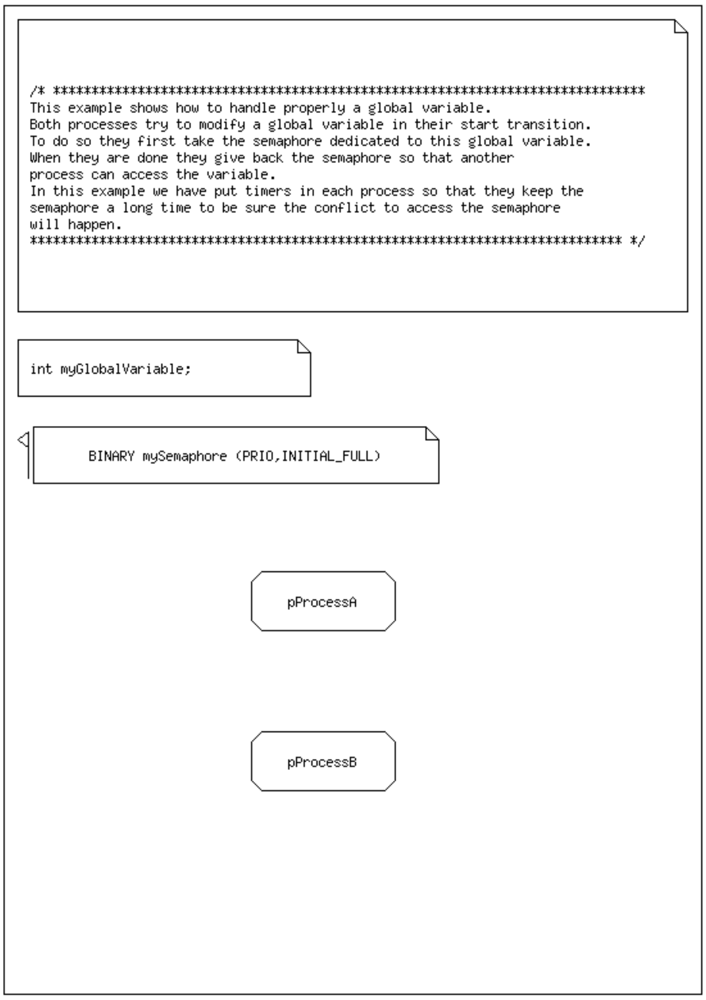


Pong process

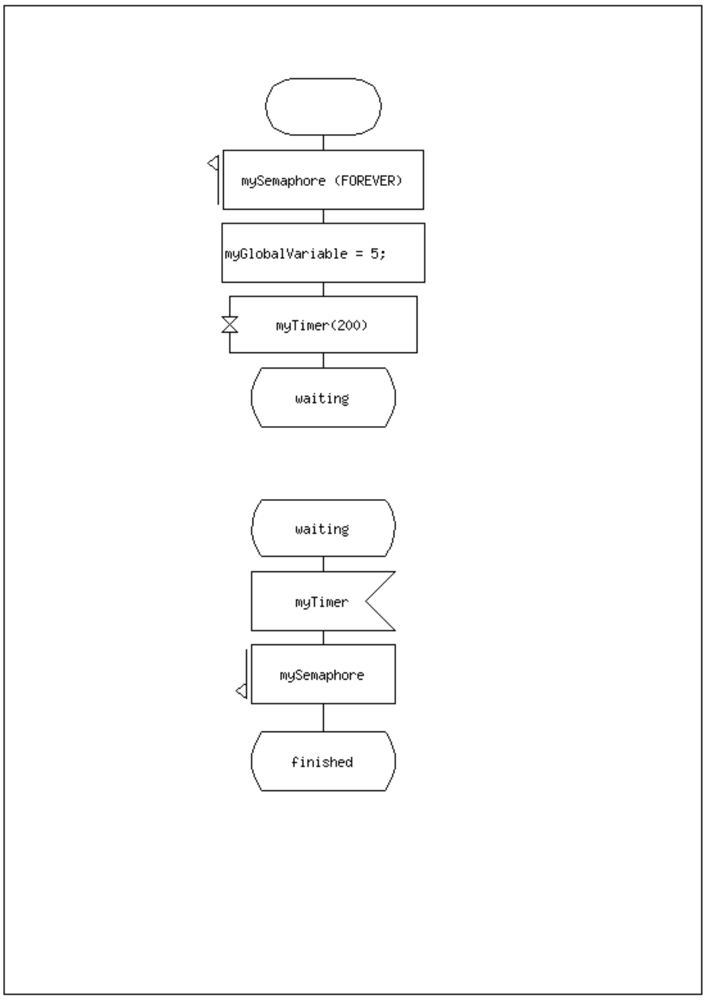


MSC trace of the ping pong system

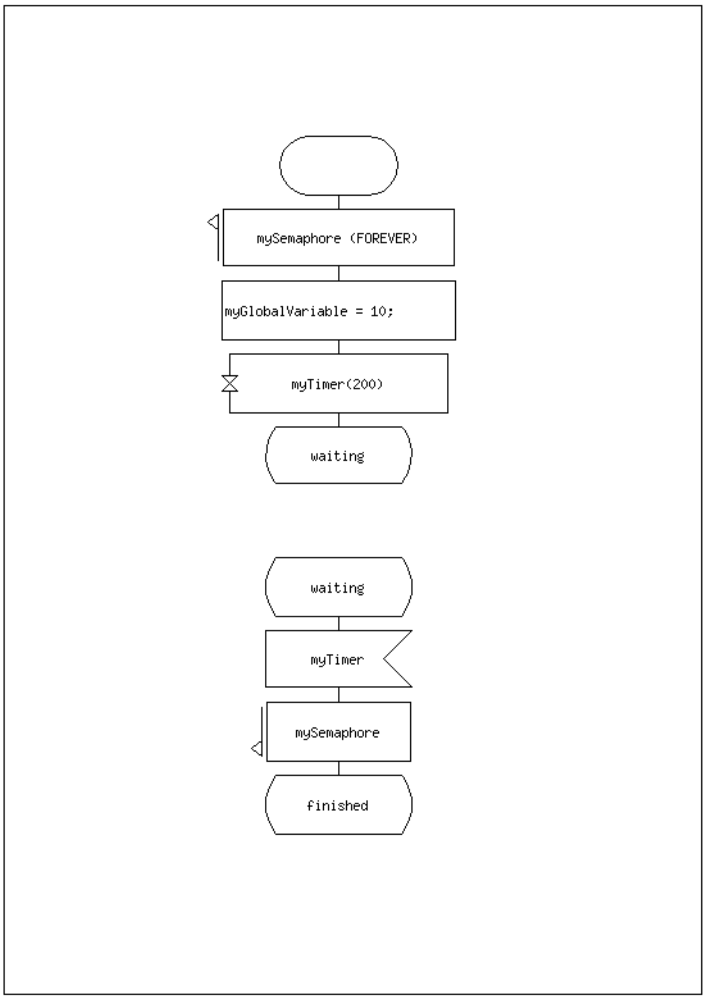
14.2 - A global variable manipulation



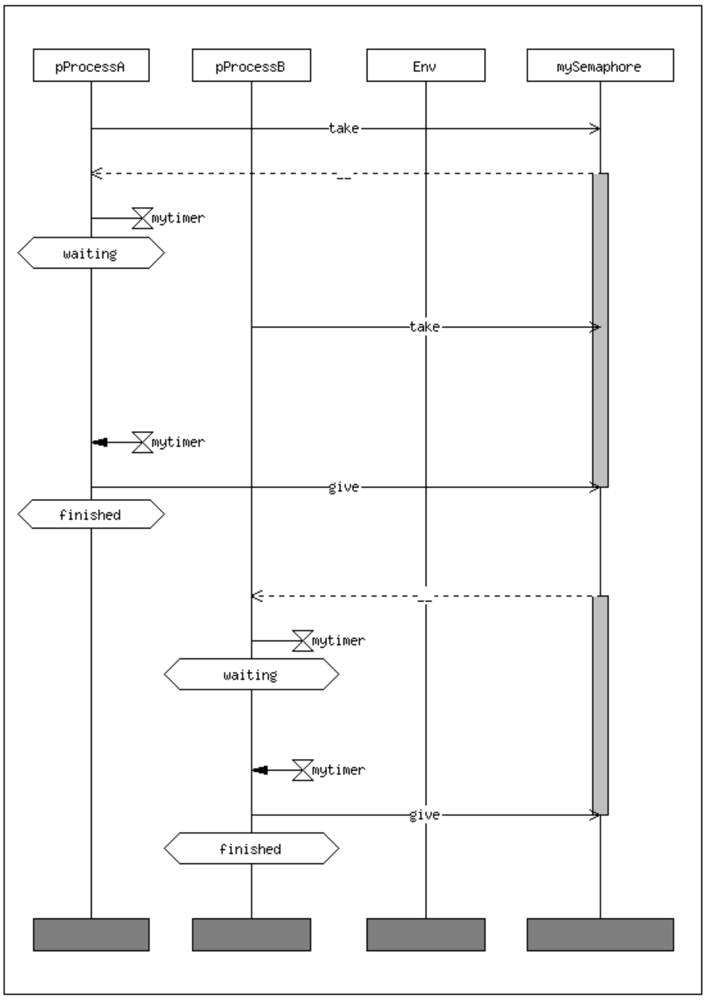
Global variable manipulation example system


mySemaphore (FOREVER)
myGlobalVariable = 5;
myTimer(200)
waiting
waiting
myTimer
mySemaphore
finished

Process A


mySemaphore (FOREVER)
myGlobalVariable = 10;
myTimer(200)
waiting
waiting
myTimer
mySemaphore
finished

Process B



MSC trace of the global variable manipulation

15 - Keywords

The following keyword have a meaning at in some specific SDL-RT symbols listed below:

keywords	concerned symbols
PRIO	Task definition Task creation Continuous signal
TO_NAME TO_ID TO_ENV	Message output
FOREVER NO_WAIT	semaphore manipulation
>, <, >=, <=, !=, == true, false, else	decision branches
USE SDL_MESSAGE_LIST	text symbol

Table 2: Keywords in symbols

16 - Differences with classical SDL

It is difficult to list all the differences between SDL-RT and SDL even though an SDL developer would understand SDL-RT and vice versa. Still to be able to clearly state the differences between these languages we will pinpoint the main differences in the paragraphs below.

16.1 - Data types

This is the most significant difference between SDL and SDL-RT. Classical SDL has its own data types and syntax where SDL-RT basically uses ANSI C language. Some symbols have a specific syntax with SDL-RT since there is no C equivalent instruction such as output, input, save, or semaphore manipulations.
The advantages are obvious:

- the syntax is known by all real time developers,
- it implicitly introduces the concept of pointers that does not exist in SDL,
- it eases integration of legacy code where it is quite tricky to do from classical SDL,
- and last but not least it makes code generation out of SDL-RT quite straightforward.

16.2 - Semaphores

Semaphore is a key concept in real time systems that classical SDL misses. Specific semaphore symbols have been introduced in SDL-RT to answer the real time developer needs.

16.3 - Inputs

Classical SDL has nice concepts when it comes to dealing with message exchanges. But these concepts are not so interesting in real time development and are quite tricky to implement on a real target or operating system. That is why SDL-RT has removed the following concepts: enabling conditions when receiving a message, internal messages, two levels priority messages.

16.4 - Names

Classical SDL uses exotic names for some well known concepts such as "signal" where it is basically related to a "message". Since "message" is the usual name in Real Time Operating Systems SDL-RT uses the same term.
When it comes to object orientation classical SDL talks about "type" instead of the usual "class" term. SDL-RT uses the common developer word "class".

16.5 - Object orientation

Classical SDL uses "virtual", "redefined", and "finalized" when it comes to object oriented concepts. For example a super class should specify a transition is "virtual" so that the sub class is allowed "redefine" or "finalize" it. This is C++ like but actually quite painful when it comes to write and does not make things any clearer. SDL-RT takes the Java notation instead where there is no need to specify anything to be able to redefine it in a sub class.

17 - Modifications from previous releases

17.1 - Semaphore manipulation

17.1.1 V1.0 to V1.1

The semaphore take now returns a status that indicates if the take attempt timed out or was successfull. The semaphore lifeline gets grayed when the semaphore is unavailable.

18 - Lexical rules

A subset of the BNF (Backus-Naur Form) is used in these pages :

<traditional English expression>	as it says…
[<stuff>]	stuff is optional
{<stuff>}+	stuff is present at least one or more times
{<stuff>}*	stuff is present 0 or more times

19 - Glossary

ANSI	American National Standards Institute
BNF	Backus-Naur Form
MSC	Message Sequence Chart
RTOS	Real Time Operating System
SDL	Specification and Description Language
SDL-RT	Specification and Description Language - Real Time

20 - Index

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