The Trampoline handbook

Release 2.0

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CONTENTS

Part I

The Real-Time Operating System

CHAPTER

ONE

Processes

Processes are both Tasks and ISRs category 2. Trampoline category 2 ISRs are like Basic Tasks except the priority level of the interrupt controller is raised to the priority of the ISR while the later is running.

1.1 The States of a Process

A process has a state used by trampoline to perform various actions on the executable when it executes a service. States include those found at page 17 and 18 of the OSEK/VDX specification **??** and 2 extra states used for internal management. The state is coded using 3 bits as shown in table 1.1.

Table 1.1: *States of a process*

Decimal value	bit 2	bit 1	bit 0	Meaning
0	0	0	0	SUSPENDED
1	0	0	1	READY
2	0	1	0	RUNNING
3	0	1	1	WAITING
4	1	0	0	AUTOSTART
5	1	0	1	READY_AND_NEW

Figure 1.1 shows how a process goes from state to state during the lifetime of an application.

AUTOSTART This state is used to indicate what task should be started automatically when StartOS is called. An AUTOSTART task is in this initial state but no task should be in this state when the application code is running.

READY_AND_NEW This state is used to flag a process that is ready but has its context unitialized. This happens when the process has just been activated. The kernel initializes the context of the process the first time it goes to the RUNNING state.

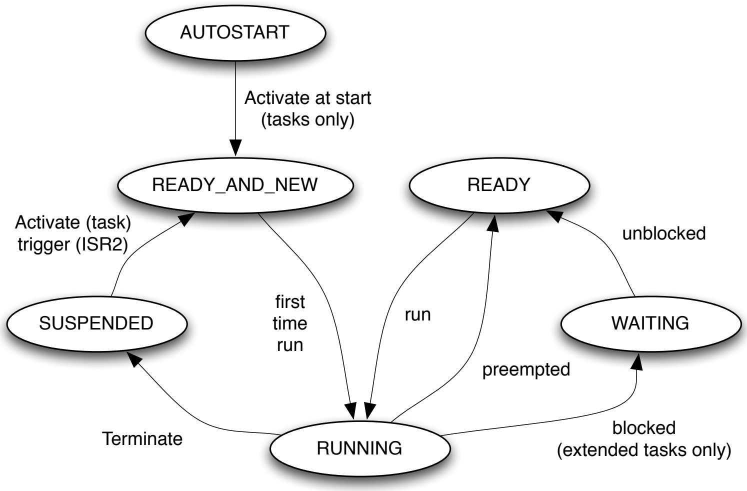


Figure 1.1: *States of a process in Trampoline. AUTOSTART is the initial state of autostart tasks. SUSPENDED is the initial state of both non autostart tasks and ISR category 2.*

1.2 The *idle* task

The ”idle” task is launched when no other task is currently running. It keeps the microprocessor doing nothing.
To be able to use specific platform capabilities (to put the microcontroler in stand by mode for example), this task is hardware specific (in *machine/*). The taks is then able to quantify the microprocessor occupation.
GOIL doesn't produce anything about this idle task (unlike application(s) task(s)). The static part of the idle task descriptor is defined in '`tpl_os_kernel.c`' and we're be able to see that :

- the priority is 0
- it's a basic task

CHAPTER

TWO

OS Applications

OS Applications are a set of objects managed by Trampoline and sharing common data and access rights.

2.1 Execution of the OS Applications startup and shutdown hooks

These hooks are executed from the kernel but with the access right of a task belonging to the OS Application. The system generation tool should choose one of the tasks of the OS Application to be used as context to execute the OS Application startup and shutdown hooks. Execution of an OS Application startup hook is done by the `tpl_call_startup_hook_and_resume` function. The argument of this function is a function pointer to the hook. Similarly execution of an OS Application shutdown hook is done by the `tpl_call_shutdown_hook_and_resume` function. These functions end by a call to `NextStartupHook` and `NextShutdownHook` services respectively to cycle through the hooks.

CHAPTER

THREE

Timing Protection Implementation

The Timing Protection Implementation uses 2 timers. The first one is a *Free Running Timer* (FRT) which is used for *Time Frame*. The second one is a classical timer called *Timing Protection Timer* (TPT) which is used for *Execution Time Budget*, *Resource Locking Budget* and *Interrupt Disabling Budget*.

3.1 Low Level Functions

These functions are provided by the *Board Support Package* and are used to manage the timers needed by the Timing Protection.

3.1.1 FRT related functions

`tpl_status tpl_start_frt(void)` starts the FRT. On a microcontroller having a FRT that starts automatically when the system is powered on, this function does nothing but must be present since it is called by Trampoline in initialization stage. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the FRT could not be started.

`tpl_status tpl_read_frt(tpl_tp_tick *out_value)` write the current value of the FRT in *out_value*. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the FRT could not be read.

`tpl_status tpl_elapsed_frt(tpl_tp_tick last_tick, tpl_tp_tick *out_value)` write the number of ticks elapsed since *last_tick* in *out_value*. If the FRT has overflown/underflown between the time *last_tick* was get and the time `tpl_elapsed_frt` is called, `tpl_elapsed_frt` gives a correct value. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the FRT could not be read.

3.1.2 TPT related functions

`tpl_status tpl_init_tpt(???)` initializes the TPT. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the TPT could not be initialized.

`tpl_status tpl_deinit_tpt(void)` deinitializes the TPT. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the TPT could not be deinitialized.

`tpl_status tpl_start_tpt(tpl_tp_tick delay)` starts the TPT with an expiration delay equal to *delay* ticks. At that time, the `tpl_tpt_handler` function is called. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the TPT could not be started because it is not initialized.

`tpl_status tpl_read_tpt(tpl_tp_tick *out_value)` write the current value of the TPT in *out_value*. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the TPT could not be read.

`tpl_status tpl_elapsed_tpt(tpl_tp_tick last_tick, tpl_tp_tick *out_value)` write the number of ticks elapsed since *last_tick* in *out_value*. An error code is returned: *E_OK* means no error, *E_OS_NOFUNC* means the TPT could not be read.

CHAPTER

FOUR

Schedule Table Implementation

Here is the files list :

- 'tpl_as_schedtable.c' contains the API services.
- 'tpl_as_st_kernel.c' contains the kernel API services, tpl_process_schedtable() and tpl_adjust_next_expiry_point()
- 'tpl_as_action.c' contains tpl_action_finalize_schedule_table()
- 'tpl_as_definitions.h' contains the schedule table's states (SCHEDULETABLE_STOPPED, SCHEDULETABLE_BOOTSTRAP, SCHEDULETABLE_AUTOSTART_ABSOLUTE...)
- 'tpl_os_timeobj_kernel.c' contains tpl_remove_time_obj() which has been modified for the schedule table object.

The schedule table class diagram is shown in Figure 4.1 below.

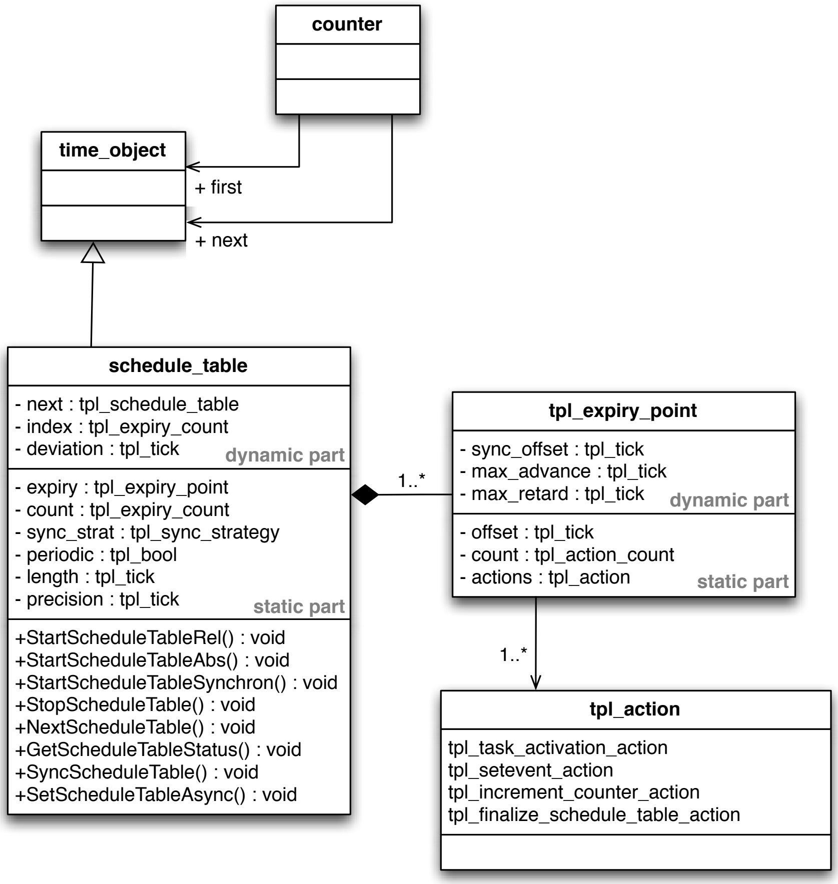


Figure 4.1: *Schedule table class diagram*

4.1 The States of a Schedule Table

A schedule table always has a defined state. States include those found at page 42 of the AUTOSAR specifications 3.1 and others states used for internal management.

Indeed, **bit 1** is the "autostart" bit. It's used when autostarted schedule tables have been declared in the OIL file. Goil generates schedule tables with SCHEDULETABLE_AUTOSTART_X (X can be RELATIVE, ABSOLUTE or SYNCHRON) state. At startup (in `tpl_init_os()`), the system starts autostarted schedule tables and resets the **bit 1**.

bit 4 is the "bootstrap" bit. It's used when the first expiry point of a schedule table is dated in more than **OsCounterMaxAllowedValue** ticks from the current date[1]. It can happen when :

- the schedule table start (<tick_val>) is after the current date and the first expiry point comes be-

[1] As the <offset> parameter of StartScheduleTableRel() cannot be greater than **OsCounterMaxAllowedValue** minus the **InitialOffset** of the schedule table (OS276), the first expiry point cannot be in more than **OsCounterMaxAllowedValue** ticks from the current date. Thus the "bootstrap" bit can set by StartScheduleTableAbs() only.

tween the current date and <tick_val>

- <tick_val> is before the current date and the first expiry point comes after the current date

Figure 4.2 below shows a bootstrap example for the first item.

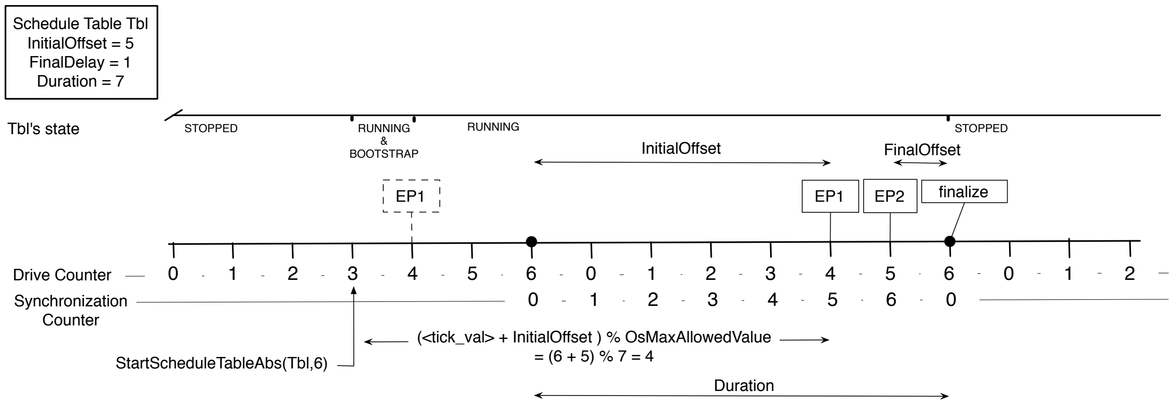


Figure 4.2: *Bootstrap example*

bit 5 is the "asynchronous" bit. It tells the system that the schedule table is in asynchronous mode. Thus, the different states of a schedule table are described in Table ?? below.

Table 4.1: *States of a schedule table*

Decimal Value	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Meaning
0	0	0	0	0	0	0	SCHEDULETABLE_STOPPED
1	0	0	0	0	0	1	SCHEDULETABLE_RUNNING
5	0	0	0	1	0	1	SCHEDULETABLE_NEXT
9	0	0	1	0	0	1	SCHEDULETABLE_WAITING
13	0	0	1	1	0	1	SCHEDULETABLE_RUNNING_-AND_SYNCHRONOUS
6	0	0	0	1	1	0	SCHEDULETABLE_AUTOSTART _ABSOLUTE
10	0	0	1	0	1	0	SCHEDULETABLE_AUTOSTART _RELATIVE
14	0	0	1	1	1	0	SCHEDULETABLE_AUTOSTART _SYNCHRON
16	0	1	0	0	0	0	SCHEDULETABLE_BOOTSTRAP
32	1	0	0	0	0	0	SCHEDULETABLE_ASYNC

Figure 4.3 shows how a schedule table goes from state to state.

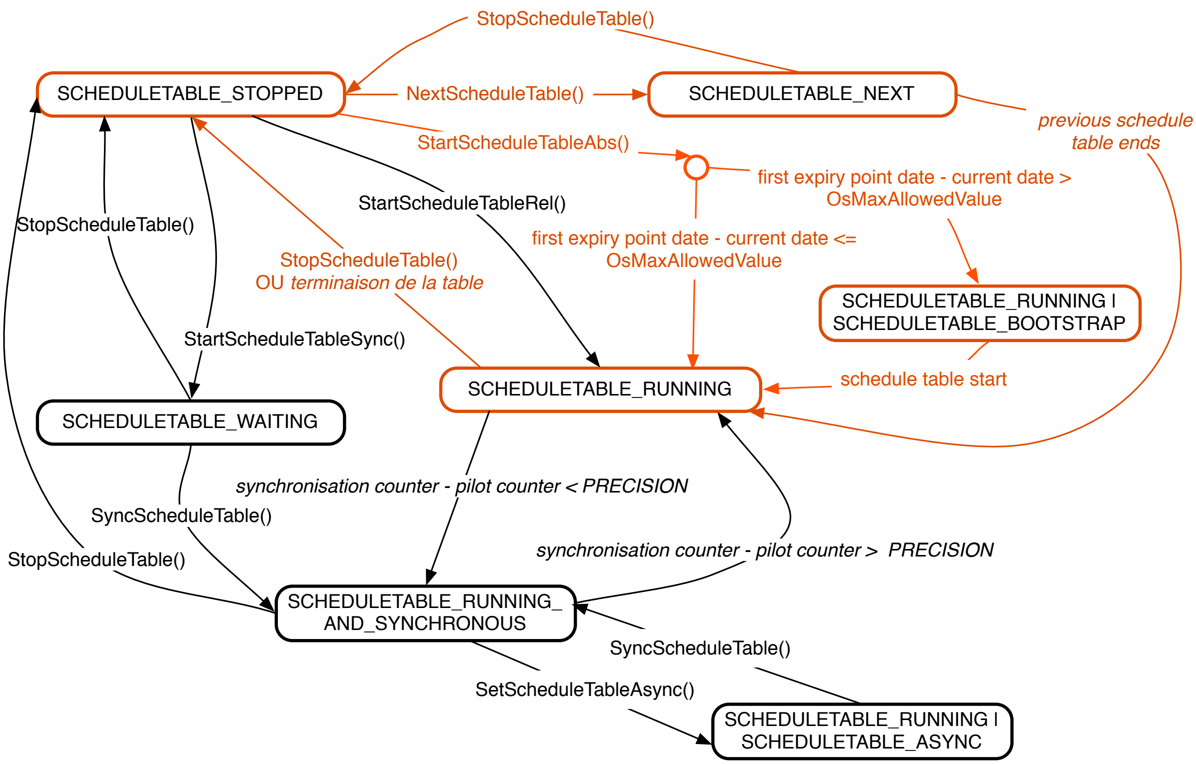


Figure 4.3: *States of a schedule table in Trampoline.*

4.2 Processing a Schedule Table

In the same time of producing the schedule tables expiry points, GOIL adds one expiry point more than the number of expiry point delared in the OIL file : the "finalize" expiry point (see Figure 4.2). Indeed, the RUNNING state of a "nexted" schedule table should be set at the finalize expiry point, thus, this expiry point has to be inserted. Moreover, for a periodic schedule table, the "finalize" expiry point helps to launch the first expiry point of the next period.

To process a **synchronized** schedule table, the schedule table's state has to be updated each expiry point and the next expiry point has to be adjusted according to the schedule table's deviation each epiry point too.

A schedule table is a time object, like an alarm. `tpl_processing_scheduletable()` is called by each expiry point (before activating a task, setting an event or finalizing a schedule table via `tpl_finalize_expiry_point()`. The state machine of this function is shown in the Figure 4.4.

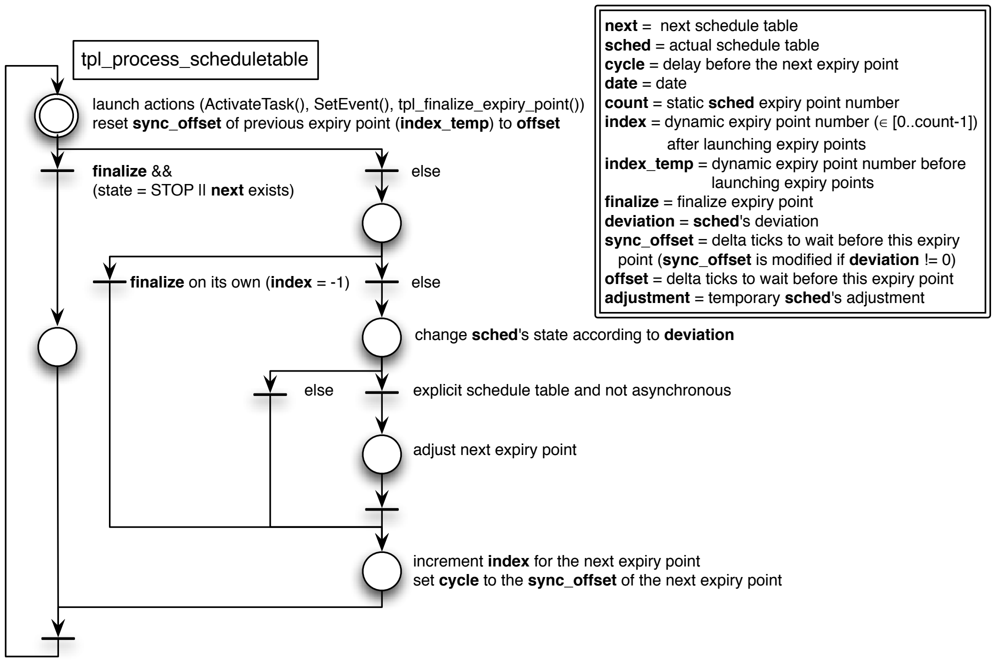
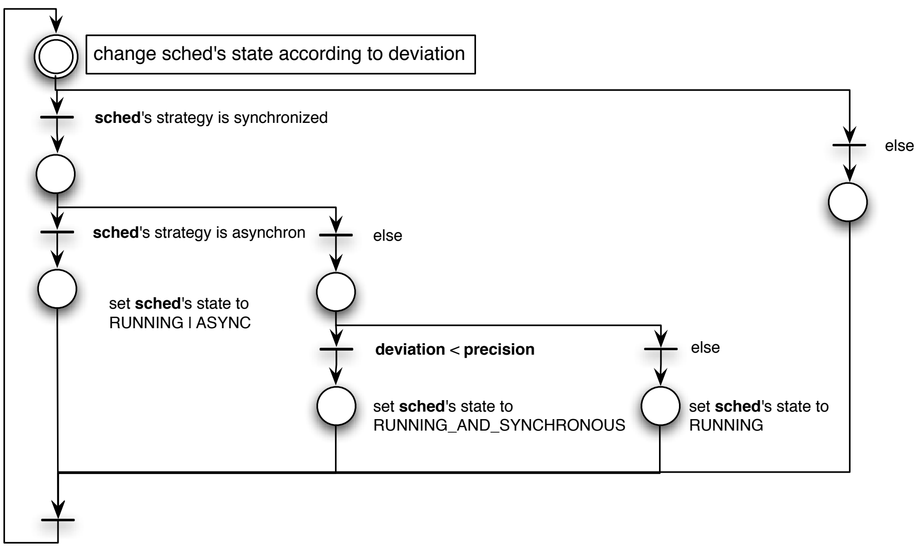
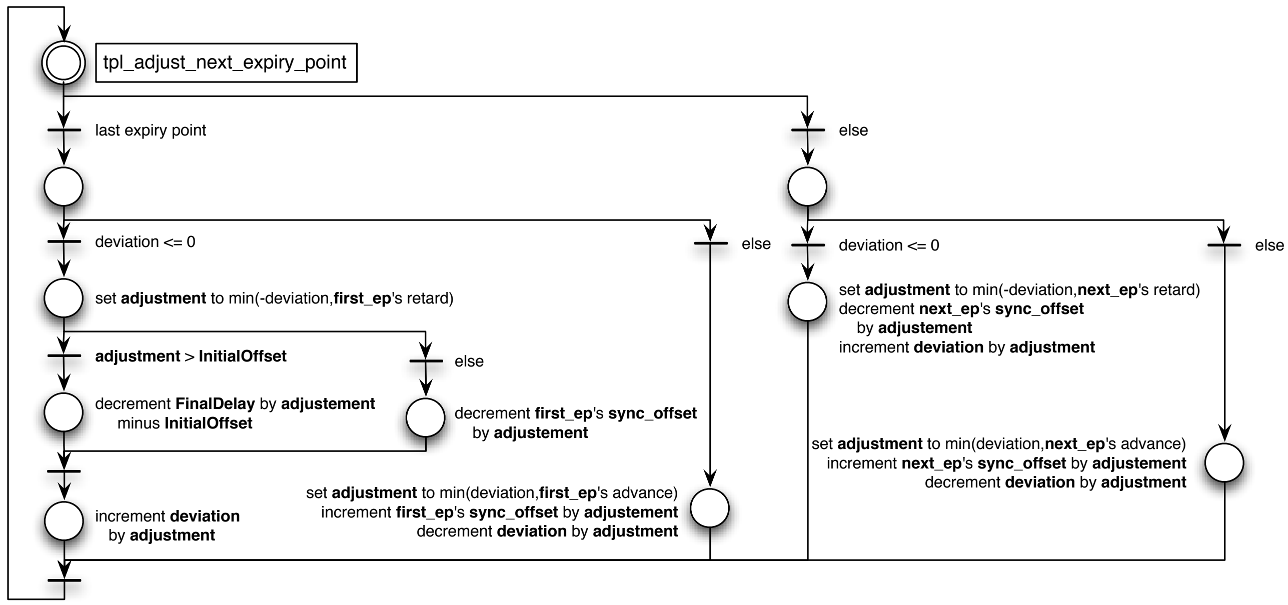


Figure 4.4: *tpl_process_scheduletable's state machine.*





`tpl_finalize_expoiry_point()` state machine is shown in Figure 4.5 below.

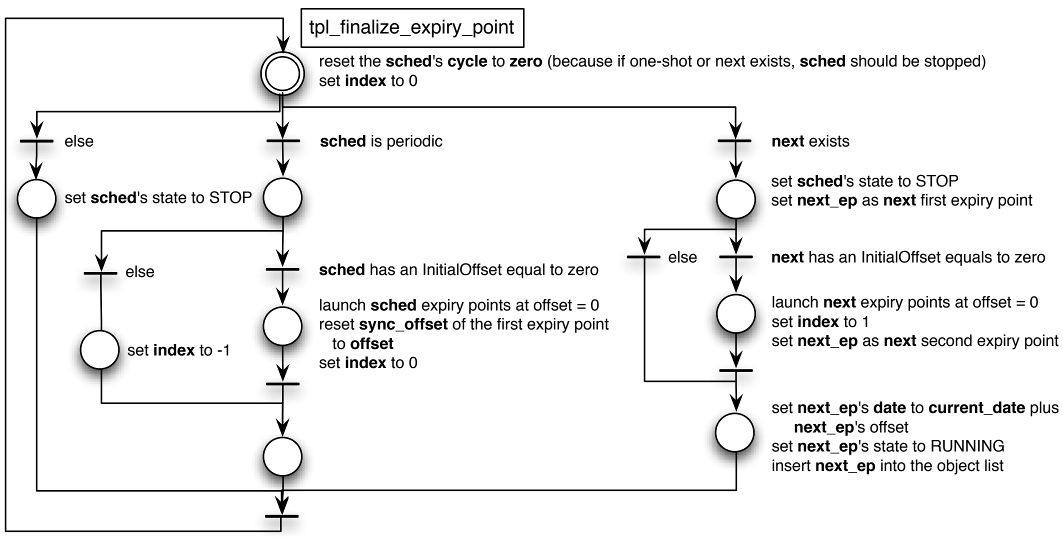


Figure 4.5: *tpl_finalize_expiry_point's state machine.*

CHAPTER

FIVE

The communication library

5.1 Internals

CHAPTER

SIX

System generation and compilation

Trampoline is a static operating system. This means all the objects (tasks, ISR, ...) are known at compile time. This way, an application is made of tasks' code and ISRs' code, application data, and statically initialized descriptor for each object the operating system manages. A system generation tool, like goil, generates these descriptors in C files from an application configuration described in OIL or in XML. After that the Trampoline source code, the generated files and the application source code are compiled and linked together to produce an executable file as shown in figure 6.1.

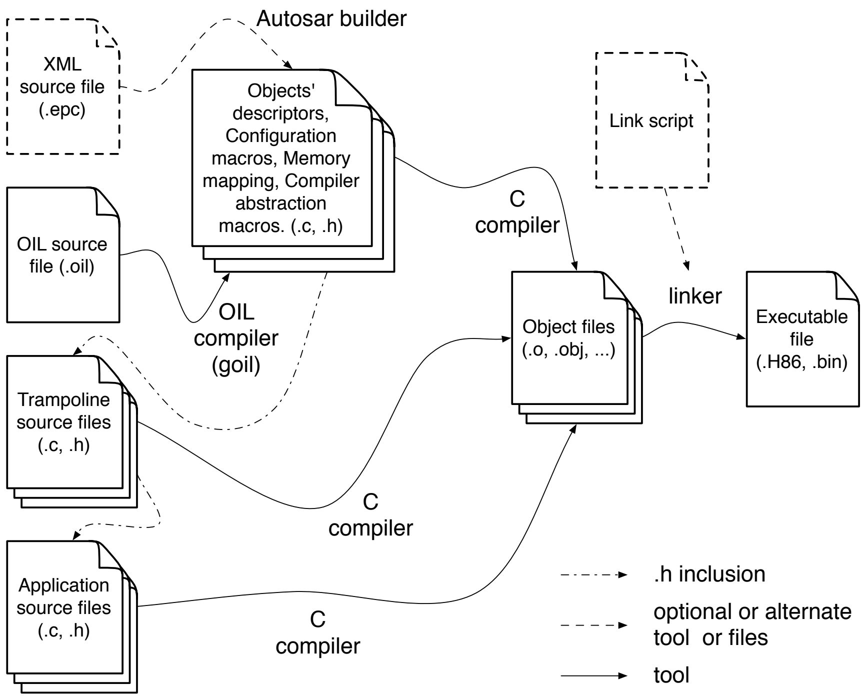


Figure 6.1: ***Build process of an application with Trampoline.*** *Starting from the left, the .c and .h corresponding to the application description given in OIL (or XML) are generated by goil (or another system generation tool, for instance an Autosar compliant one) and compiled using a C compiler. Trampoline source files are compiled too and include .h from the description for configuration purpose (see section 6.2). Application files are compiled and include .h files from Trampoline. All the object files are then linked together using an optional link script generated by goil or provided with the application.*

6.1 The generated files

The following files are generated by goil from the OIL file or should be generated if you use a different system configuration tool. More information may be found in part ??.

File name	Usage
'tpl_app_define.h'	This file contains all the configuration macros (see section 6.2) and is included in all the Trampoline files to trigger conditional compilation. goil generates this file using the 'tpl_app_define_h.goilTemplate' template file.
'tpl_app_config.h'	This file contains the declarations of the constants and functions required by the OSEK and Autosar standard (like OSMAXALLOWEDVALUE_x, OSTICKSPERBASE_x or OSMINCYCLE_x constants for counter x). goil generates this file using the 'tpl_app_config_h.goilTemplate' template file.
'tpl_app_config.c'	This file contains the definitions of the constants and functions required by the OSEK and Autosar standard and the definitions of object descriptors used by Trampoline (see section ??) goil generates this file using the 'tpl_app_config_c.goilTemplate' template file.
'tpl_app_custom_types.h'	Some data types used by Trampoline are not statically defined. They are generated to fit size or performance criterions. For instance, the type used for a TaskType may be a byte if there is less than 256 tasks in the system and a word otherwise. This file defined these data types.
'tpl_service_ids.h'	This file is generated only if Trampoline is compiled with service calls implemented using a system call. It contains all the identifiers of the services used by the application according to the configuration. goil generates this file using the 'tpl_service_ids_h.goilTemplate' template file.
'tpl_dispatch_table.c'	This file is generated only if Trampoline is compiled with service calls implemented using a system call. It contains the dispatch table definition. See section ??. goil generates this file using the 'tpl_dispatch_table_c.goilTemplate' template file.
'tpl_invoque.S'	This file is generated only if Trampoline is compiled with service calls implemented using a system call. It contains the API functions for system services. See section ??. The extension (here .S) may change according to the assembler used. goil generates this file using the 'tpl_invoque.goilTemplate' and 'service_call.goilTemplate' template files.
'MemMap.h'	This file is generated only if memory mapping is enabled. It contains macros for compiler abstraction memory mapping of functions and data as defined in the Autosar standard [3]. goil generates this file using the 'MemMap_h.goilTemplate' template file.

File name	Usage
‘Compiler.h’	This file is generated only if memory mapping is enabled. It contains macros for the compiler abstraction of functions and pointer qualifier as defined in the Autosar standard [2]. goil generates this file using the ‘Compiler_h.goilTemplate’ template file.
‘Compiler_Cfg.h’	This file is generated only if memory mapping is enabled. It contains macros for the compiler abstraction configuration as defined in the Autosar standard [2]. goil generates this file using the ‘Compiler_Cfg_h.goilTemplate’ template file.
‘script.ld’	This file is generated only if memory mapping is enabled. It contains a link script to map the executable in the target memory. goil generates this file using the ‘script.goilTemplate’ template file.

The following sections give details about the content of these files.

6.2 The Configuration Macros

Trampoline can be compiled with various options. These options are controlled by setting the appropriate preprocessor configuration macros. These macros are usually set by goilusing the template found in ‘tpl_app_define_h.goilTemplate’ file to produce the ‘tpl_app_define.h’ file that is included by the files of Trampoline. However, a different generation tool may be used and it should comply to the specification presented in the following tables. When Trampoline is compiled, the coherency and consistency of the configuration macros are checked, by using the preprocessor macros located in the ‘tpl_config_check.h’ file, to ensure they correspond to a supported configuration.

3 kinds of configuration macros are used: boolean macros, numerical macros, symbol macros and string macros. Boolean macros may take 2 values: YES or NO. All macros should be defined, Trampoline does not use the **#ifdef** or \#ifndef scheme to limit the occurrences of unwanted misconfigurations except to prevent multiple inclusions of the same header file.

6.2.1 Number of objects macros

These macros gives the number of objects of each kind (tasks, ISRs, resources, ...) and other values. They are used in Trampoline to check the validity of the various identifiers and to define tables of the corresponding size:

Macro	Kind	Effect
PRIO_LEVEL_COUNT	Integer	The number of priority levels used in the system.
TASK_COUNT	Integer	The number of tasks (basic and extended) used in the system.
EXTENDED_TASK_COUNT	Integer	The number of extended tasks used in the system.
ISR_COUNT	Integer	The number of ISR category 2 used in the system.

Macro	Kind	Effect
ALARM_COUNT	Integer	The number of alarms used in the system.
RESOURCE_COUNT	Integer	The number of resources used in the system.
SEND_MESSAGE_COUNT	Integer	The number of send messages used in the system.
RECEIVE_MESSAGE_COUNT	Integer	The number of receive messages used in the system.
SCHEDTABLE_COUNT	Integer	The number of schedule tables used in the system. This macros is only used when WITH_AUTOSAR is set to YES.
COUNTER_COUNT	Integer	The number of counters used in the system. This macros is only used when WITH_AUTOSAR is set to YES.
APP_COUNT	Integer	The number of OS applications used in the system. This macros is only used when WITH_AUTOSAR is set to YES.
TRUSTED_FCT_COUNT	Integer	The number of trusted functions used in the system. This macros is only used when WITH_AUTOSAR is set to YES.
RES_SCHEDULER_PRIORITY	Integer	The priority of the RES_SCHEDULER resource. This should be equal to the highest priority among the tasks.

6.2.2 Error Handling Macros

Error handling related macros are used to configure what kind of error Trampoline checks and what extra processing is done when an error is encountered. The following macros are available:

Macro	Kind	Effect
WITH_OS_EXTENDED	Boolean	When set to YES, Trampoline system services perform error checking on their arguments. *WITH_OS_EXTENDED* is set to YES with a *STATUS* = EXTENDED and is set to NO with a *STATUS* = BASIC in the oil OS object.
WITH_ERROR_HOOK	Boolean	When set to YES, the `ErrorHook()` function is called if an error occurs. *WITH_ERROR_HOOK* is set to YES/NO with a *ERRORHOOK* = TRUE/FALSE in the oil OS object.
WITH_USEGETSERVICEID	Boolean	When set to YES, Trampoline system services store the id of the current service. This id may be retrieved in the `ErrorHook()` function by using the `OSErrorGetServiceId()` macro. *WITH_USEGETSERVICEID* is set to YES/NO with a *USEGETSERVICEID* = TRUE/FALSE in the oil OS object.

Macro	Kind	Effect
WITH_USEPARAMETERACCESS	Boolean	When set to YES, Trampoline system services store the arguments of the current service. These arguments may be retrieved in the `ErrorHook()` function by using the ad-hoc access macros (see 6.3). *WITH_USEPARAMETERACCESS* is set to YES/NO with a *USEPARAMETERACCESS* = TRUE/FALSE in the oil OS object.
WITH_COM_ERROR_HOOK	Boolean	When set to YES, the communication error hook is called when error occurs in the communication sub-system. This macro is only available when WITH_COM is set to true.
WITH_COM_USEGETSERVICEID	Boolean	When set to YES, Trampoline/COM system services store the id of the current service. This id may be retrieved in the `COMErrorHook()` function by using the `COMErrorGetServiceId()` macro. *WITH_COM_USEGETSERVICEID* is set to YES/NO with a *COMUSEGETSERVICEID* = TRUE/FALSE in the oil COM object.
WITH_COM_USEPARAMETERACCESS	Boolean	When set to YES, Trampoline/COM system services store the arguments of the current service. These arguments may be retrieved in the `COMErrorHook()` function by using the ad-hoc access macros (see **??**). *WITH_COM_USEPARAMETERACCESS* is set to YES/NO with a *COMUSEPARAMETERACCESS* = TRUE/FALSE in the oil COM object.
WITH_COM_EXTENDED	Boolean	When set to YES, Trampoline/COM system services perform error checking on their arguments. *WITH_COM_EXTENDED* is set to YES with a *COMSTATUS* = EXTENDED and is set to NO with a *COMSTATUS* = BASIC in the oil COM object.

6.2.3 Protection Macros

Protection macros deal with protection facility provided by the Autosar standard. The following Macros are available:

Macro	Kind	Effect
WITH_MEMORY_PROTECTION	Boolean	When set to YES, Trampoline enables the memory protection facility. This is only supported on some ports (MPC5510 and ARM9 at time of writing). Memory protection requires the memory mapping and the use of system call. *WITH_MEMORY_PROTECTION* is set to YES/NO with the MEMORY_PROTECTION attribute of MEMMAP object (see **??**) set to TRUE/FALSE.
WITH_TIMING_PROTECTION	Boolean	When set to YES, Trampoline enables the timing protection facility. *WITH_TIMING_PROTECTION* is set to YES if the *AUTOSAR_SC* is 2 or 4 (see **??**) and a least one of the objects specifies a timing protection related attribute in the oil file.
WITH_PROTECTION_HOOK	Boolean	When set to YES, Trampoline calls the ProtectionHook() with the appropriate argument when a protection fault occurs. *WITH_PROTECTION_HOOK* is set to YES with a *PROTECTIONHOOK* = TRUE in the oil OS object.
WITH_STACK_MONITORING	Boolean	When set to YES, Trampoline enables the stack monitoring. Each time a context switch occurs, the stack pointer is checked. If the stack pointer is outside the stack zone of the process, a fault occurs. *WITH_STACK_MONITORING* is set to YES with a *STACKMONITORING* = TRUE in the oil OS object.

6.2.4 Hook call macros

Hook call macros control whether a hook is called or not. The following Macros are available:

Macro	Kind	Effect
WITH_ERROR_HOOK	Boolean	see 6.3
WITH_PRE_TASK_HOOK	Boolean	When set to YES, each time a task is scheduled, the function PreTaskHook() is called. *WITH_PRE_TASK_HOOK* is set to YES/NO with a *PRETASKHOOK* = TRUE/FALSE in the oil OS object.
WITH_POST_TASK_HOOK	Boolean	When set to YES, each time a task is descheduled, the function PostTaskHook() is called. *WITH_POST_TASK_HOOK* is set to YES/NO with a *POSTTASKHOOK* = TRUE/FALSE in the oil OS object.
WITH_STARTUP_HOOK	Boolean	When set to YES, the function StartupHook() is called within the StartOS service. *WITH_STARTUP_HOOK* is set to YES/NO with a *STARTUPHOOK* = TRUE/FALSE in the oil OS object.

Macro	Kind	Effect
WITH_SHUTDOWN_HOOK	Boolean	When set to YES, the function ShutdownHook() is called within the ShutdownOS service. *WITH_SHUTDOWN_HOOK* is set to YES/NO with a *SHUTDOWNHOOK* = TRUE/FALSE in the oil OS object.
WITH_PROTECTION_HOOK	Boolean	see 6.4

6.2.5 Miscellaneous macros

Here are the other available macros:

Macro	Kind	Effect
WITH_USERESSCHEDULER	Boolean	When set to YES, the RES_SCHEDULER resource is used by at least one process. *WITH_USERESSCHEDULER* is set to YES/NO with a *USERESSCHEDULER* = TRUE/FALSE in the oil OS object.
WITH_SYSTEM_CALL	Boolean	When set to YES, services are called by the mean of a system call, also known as a software interrupt (see section **??**). *WITH_SYSTEM_CALL* is set to YES/NO according to the target architecture and requires a memory mapping
WITH_MEMMAP	Boolean	When set to YES, a memory mapping is used: A '`MemMap.h`' files giving the available memory segments is included and should be generated or provided by the user. goil generates such a file. *WITH_MEMMAP* is set to YES/NO with a *MEMMAP* = TRUE/FALSE in the oil OS object.
WITH_COMPILER_SETTINGS	Boolean	When set to YES, the compiler dependent Autosar macros are used: '`Compiler.h`' and '`Compiler_Cfg.h`' files are includes and should generated or provided by the user. goil generates these files if *MEMMAP* is TRUE and the *COMPILER* sub-attribute is set.
WITH_AUTOSAR	Boolean	When set to YES, Trampoline contains additional system services, code and declarations related to the Autosar standard. For instance, the counter descriptor includes the counter type (hardware or software). *WITH_AUTOSAR* is set to YES/NO when at least an Autosar object is present in the system configuration (oil file for instance).
TRAMPOLINE_BASE_PATH	String	The path to Trampoline root directory.

Macro	Kind	Effect
AUTOSAR_SC	Integer	The Autosar scalability class ranging from 0 to 4. 0 means OSEK
WITH_OSAPPLICATION	Boolean	When set to YES, OS Application are used.
WITH_TRACE	Boolean	When set to YES, the tracing of the operating system is enabled. Only available if WITH_-TRACE is set to YES.
TRACE_TASK	Boolean	When set to YES, task (de)scheduling events are traced. Only available if WITH_TRACE is set to YES.
TRACE_ISR	Boolean	When set to YES, ISR category 2 (de)scheduling events are traced. Only available if WITH_TRACE is set to YES.
TRACE_RES	Boolean	When set to YES, resources get and release are traced. Only available if WITH_TRACE is set to YES.
TRACE_ALARM	Boolean	When set to YES, alarm activities are traced. Only available if WITH_TRACE is set to YES.
TRACE_U_EVENT	Boolean	When set to YES, user events are traced. Only available if WITH_TRACE is set to YES.
TRACE_FORMAT	Symbol	Trace format. A function named tpl_trace_for-mat_<trace_format> is expected. Only available if WITH_TRACE is set to YES.
TRACE_FILE	String	File name where the trace is stored. Usable on Posix target only. Only available if WITH_-TRACE is set to YES.
WITH_IT_TABLE	Boolean	When set to YES, the external interrupts are dispatched using a table of fonction pointers.
WITH_COM	Boolean	When set to YES, internal communication is used.
TPL_COMTIMEBASE	Integer	The COMTIMEBASE expresses in nanosec-onds.
WITH_COM_STARTCOMEXTENSION	Boolean	When set to YES, the communication exten-sion function is called.

6.3 Application configuration

The application configuration is generated by goil using the template found in ‘`tpl_app_config_-h.goilTemplate`’ file and ‘`tpl_app_config_c.goilTemplate`’ file to produce the ‘`tpl_app_-define.h`’ and ‘`tpl_app_define.c`’ files.

6.3.1 Counter related constants declaration

The 'tpl_app_config.h' files contains the counters related constants: those of the SystemCounter[1] and those of the counters defined by the user. The SystemCounter constants are located in the generated files because the SystemCounter default attributes may be modified by the user in the OIL or XML file. The constants of a user defined counter are declared as follow:

```
extern CONST(tpl_tick, OS_CONST) OSTICKSPERBASE_<counter name>;
extern CONST(tpl_tick, OS_CONST) OSMAXALLOWEDVALUE_<counter name>;
extern CONST(tpl_tick, OS_CONST) OSMINCYCLE_<counter name>;
```

Where <counter name> is obviously the name given to the counter in the confguration. For the System-Counter, the following constants are declared:

```
extern CONST(tpl_tick, OS_CONST) OSTICKSPERBASE;
extern CONST(tpl_tick, OS_CONST) OSMAXALLOWEDVALUE;
extern CONST(tpl_tick, OS_CONST) OSMINCYCLE;
```

6.3.2 Events definition

The 'tpl_app_config.c' file should contain the event mask definitions. For each event defined in the configuration, the following lines should appear:

```
#define API_START_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"

#define <event name>_mask <mask value>
CONST(EventMaskType, AUTOMATIC) <event name> = <event name>_mask;

#define API_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
```

Where <event name> is the name given to the event in the configuration and <mask value> is the value set by the user in the configuration or, when set to AUTO, the value computed by the generation tool.

6.3.3 Standard resources definition

Standard resources need the definition of an identifier used to reference the resource in a system service (GetResource() and ReleaseResource()) and an instance of a tpl_resource structure (see **??**). This is done with the following definitions:

```
#define API_START_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"

#define <resource name>_id <resource id>
CONST(ResourceType, AUTOMATIC) <resource name> = <resource name>_id;

#define API_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
```

[1] the default counter of an OSEK operating system

```
#define OS_START_SEC_VAR_UNSPECIFIED
#include "tpl_memmap.h"

VAR(tpl_resource, OS_VAR) <resource name>_rez_desc = {
  /* ceiling priority of the resource */  <resource priority>,
  /* owner previous priority          */  0,
  /* owner of the resource            */  INVALID_PROC_ID,
#if WITH_OSAPPLICATION == YES
  /* OS Application id                */  <resource application id>,
#endif
  /* next resource in the list        */  NULL
};

#define OS_STOP_SEC_VAR_UNSPECIFIED
#include "tpl_memmap.h"
```

Where <resource name> is the name given to the resource in the configuration, <resource priority> is the priority of the resource that is computed by the generation tool and is the maximum priority of the processes that use the resource and <resource application id> is the identifier of the OS Application the resource belongs to. Since this field is protected by *WITH_OSAPPLICATION*, it may be leaved empty when no OS Application is used.

<resource id> ranges from 0 to the number of standard resources minus 1. Once every standard resource descriptor is defined, a table gathering pointers to the resource descriptors and indexed by the resource id has to be defined. This table is used by system services to get the resource descriptor from the resource id. Suppose 3 standard resource, *motor1*, *motor2* and *dac* has been defined and RES_SCHEDULER is used, the table should be as follow:

```
#define OS_START_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
CONSTP2VAR(tpl_resource, AUTOMATIC, OS_APPL_DATA)
tpl_resource_table[RESOURCE_COUNT] = {
  &motor1_rez_desc,
  &motor2_rez_desc,
  &dac_rez_desc,
  &res_sched_rez_desc
};
#define OS_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
```

&res_sched_rez_desc, the pointer to the resource descriptor of RES_SCHEDULER should always be the last element of the table. If RES_SCHEDULER is not used, simply remove it from the table.

6.3.4 Tasks definition

Each task needs an identifier to reference a task un a system service (`ActivateTask()`, `ChainTask()`, `GetTaskState()`, `SetEvent()` and `GetEvent()`) and the declaration of the task function. The following definitions should appear for each task:

```
#define API_START_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
```

```
#define <task name>_id <task id>
CONST(TaskType, AUTOMATIC) <task name> = <task name>_id;

#define API_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"

#define APP_Task_<task name>_START_SEC_CODE
#include "tpl_memmap.h"

FUNC(void, OS_APPL_CODE) <task name>_function(void);

#define APP_Task_<task name>_STOP_SEC_CODE
#include "tpl_memmap.h"
```

Where <task name> is the name given to the task in the configuration and <task id> is the identifier of the task computed by the system generation tool. Task ids should range from 0 to the number of tasks minus 1. In addition, id allocation must start with extended tasks first and basic task after. In addition an instance of the static task descriptor must be provided:

```
#define OS_START_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
CONST(tpl_proc_static, OS_CONST) <task name>_task_stat_desc = {
  /* context                  */  <task name>_CONTEXT,
  /* stack                    */  <task name>_STACK,
  /* entry point (function)   */  <task name>_function,
  /* internal ressource       */  <internal resource>,
  /* task id                  */  <task name>_id,
#if WITH_OSAPPLICATION == YES
  /* OS application id        */  <application>,
#endif
  /* task base priority       */  <task priority>,
  /* max activation count     */  <task activation>,
  /* task type                */  <task type>
#if WITH_AUTOSAR_TIMING_PROTECTION == YES
  /* pointer to the timing
     protection descriptor    */  ,<timing protection>
#endif
};
#define OS_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
```

Where <task name> is the name given to the task in the configuration. <internal resource> mays be one of the following:

- a pointer to the internal resource descriptor (see **??**) if an internal resource has been defined in the configuration;
- a pointer to the scheduler internal resource if the task has been defined as non-preemptable in the configuration;
- NULL if none of the above cases apply.

<application> is the id of the OS Application the task belongs to when OS Application are used or, when they are not used, nothing at all. <task priority> is the priority of the task as computed by the system generation tool. <task activation> is the maximum number of task activation allowed as defined in the configuration. <task type> may be EXTENDED or BASIC. <timing protection> is a pointer to the timing protection descriptor or NULL if no timing protection is defined for the task.

Also an instance of the dynamic task descriptor must be provided:

```
#define OS_START_SEC_VAR_UNSPECIFIED
#include "tpl_memmap.h"

VAR(tpl_proc, OS_VAR) <task name>_task_desc = {
  /* resources                       */  NULL,
#if WITH_MEMORY_PROTECTION == YES
  /* if > 0 the process is trusted  */  <trusted count>,
#endif /* WITH_MEMORY_PROTECTION */
  /* activate count                  */  0,
  /* task priority                   */  <task priority>,
  /* task state                      */  <task state>
#if WITH_AUTOSAR_TIMING_PROTECTION == YES
  /* activation allowed              */  ,TRUE
#endif
};

#define OS_STOP_SEC_VAR_UNSPECIFIED
#include "tpl_memmap.h"
```

Where <task name> is the name given to the task in the configuration. <trusted count> is 0 if the task belongs to a non trusted OS Application and 1 if the tasks belongs to a trusted OS Application. <task priority> is the priority of the task as computed by the system generation tool. <task state> is the initial state of the task and must be set to AUTOSTART or SUSPENDED.

If the task is an EXTENDED one, an event mask descriptor is added:

```
VAR(tpl_task_events, OS_VAR) <task name>_task_evts = {
  /* event set  */ 0,
  /* event wait */ 0
};
```

Where <task name> is the name given to the task in the configuration.

CHAPTER

SEVEN

Ports details

7.1 PowerPC

7.1.1 System services

The PowerPC port uses the `sc` software interrupt to call system services [1]. `sc` stands for System Call. It saves the current *PC* in *SRR0* register and the current *MSR* in *SRR1* register and jump to the System Call handler.

The id of the system service to call is given in the *r0* register and *r0* save and restore are added around. For instance, the following listing gives the `ActivateTask` service code. These function are generated from templates by goil (see 6.1) and are part of the *invoque* layer (see **??**):

```
  .global ActivateTask
ActivateTask:
  subi r1,r1,4                    /* make room on stack    */
  stw  r0,0(r1)                   /* save r0               */
  li   r0,OSServiceId_ActivateTask   /* load r0 with the id   */
  sc                              /* system call           */
  lwz  r0,0(r1)                   /* restore r0            */
  addi r1,r1,4                    /* restore stack         */
  blr                             /* return                */

  .type ActivateTask,@function
  .size ActivateTask,$$-ActivateTask
```

When the System Call begin execution, the process stack has the mapping depicted in figure 7.1.

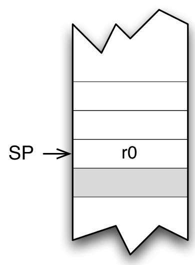


Figure 7.1: *Process stack mapping at the beginning of the System Call handler. The grayed zone represents an unknown content depending on from where the service was called.*

7.1.2 Dispatching the service call

The System Call handler is usually located in the $\texttt{0C00}_H$ exception handler but, depending on the CPU kind, it may be located elsewhere. Since the available memory for the interrupt or exception handler may vary, a jump is made to the `tpl_sc_handler`.

`tpl_sc_handler` performs the following tasks:

1. saves additional registers to be able to work
2. disables memory protection
3. switches to kernel stack if needed
4. calls the service
5. performs a context switch if needed and programs the MPU.
6. switches back to the process stack if needed
7. enable memory protection
8. restore registers
9. get back to the process

Note: Currently the PowerPC port does not support tasks that use floating point registers

Saving additional registers

The following registers are saved: *lr*, *cr*, *r11* and *r12*. In fact, it should be not necessary to save *r11* and *r12* because these registers are volatile as defined in the PowerPC EABI [4] but we prefer a conservative approach. Register saving is done by the following code at start of the `tpl_sc_handler` and the mapping of the process stack is depicted at figure 7.2:

```
subi  r1,r1,PS_FOOTPRINT  /* Make room on stack */

stw   r11,PS_R11(r1)      /* Save r11           */
stw   r12,PS_R12(r1)      /* Save r12           */
mflr  r11
stw   r11,PS_LR(r1)       /* Save lr            */
mfcr  r11
stw   r11,PS_CR(r1)       /* Save cr            */
```

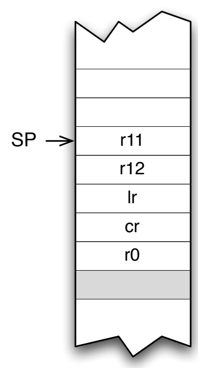


Figure 7.2: *Process stack mapping after additional registers have been saved by the beginning of the System Call handler.*

Disabling memory protection

This part of the dispatch layer is done in the `tpl_enter_kernel` function and is assembled only if *WITH_MEMORY_PROTECTION* is set to YES. After saving the *lr*, the `tpl_kernel_mp` function is called and does the actual job. At last *lr* is restored.

```
#if WITH_MEMORY_PROTECTION == YES
  /*
   * Switch to kernel mem protection scheme
   */
  subi  r1,r1,4
  mflr  r11
  stw   r11,0(r1)       /* save lr on the current stack */
  bl    tpl_kernel_mp   /* disable memory protection    */
  lwz   r11,0(r1)       /* restore lr                   */
  mtlr  r11
  addi  r1,r1,4
#endif
```

Switching to the kernel stack

Once the dispatch layer has saved the registers it uses and has switched to the kernel memory protection scheme, it switches to the kernel stack. However the kernel stack could used already because a call to a `PreTaskHook` or a `PostTaskHook` is done on the kernel stack and such a hook may call a service. So the dispatch layer is reentrant. The number of reentrant calls is counted by the *tpl_reentrancy_counter*. In addition the process stack pointer (*r1*), *SRR0* and *SRR1* are saved in the kernel stack. The kernel stack mapping is shown in figure 7.3. For a reentrant call, the same frame is build over the current one. The switch to the kernel stack is done as follow:

```
  /*
   * Check the reentrancy counter value and increment it
   * if the value is 0 before the inc, then we switch to
   * the system stack.
   */
  lis   r11,TPL_HIG(tpl_reentrancy_counter)
  ori   r11,r11,TPL_LOW(tpl_reentrancy_counter)
  lwz   r12,0(r11)    /* get the value of the counter */
  cmpwi r12,0
  addi  r12,r12,1
  stw   r12,0(r11)
  bne   no_stack_change

  /*
   * Switch to the kernel stack
   *
   * Get the pointer to the bottom of the stack
   */
  lis   r11,TPL_HIG(tpl_kernel_stack_bottom)
  ori   r11,r11,TPL_LOW(tpl_kernel_stack_bottom)
  stw   r1,KS_SP-KS_FOOTPRINT(r11)  /* save the sp of the caller */
  mr    r1,r11                      /* set the kernel stack      */
```

```
no_stack_change:
  /*
   * make space on the stack to call C functions
   */
  subi  r1,r1,KS_FOOTPRINT
```

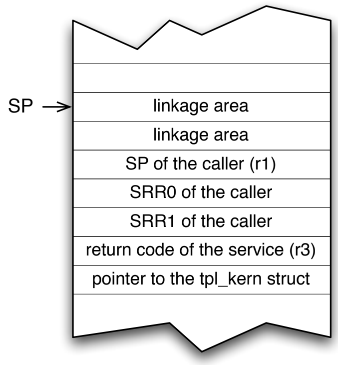


Figure 7.3: *Kernel stack mapping after allocation.*

Calling the service

Since the registers used to pass parameters to a function, that is *r3* to *r10* as documented in [4], have not been changed until now, calling the function that implements the service respects the register usage conventions.

The first thing to do is to get the function pointer corresponding to the service id. The service id is in *r0* as explained in 7.1.1 and is used as an index to the *tpl_dispatch_table*.

```
  slwi  r0,r0,2                          /* compute the offset    */
  /*
   * load the ptr to the dispatch table
   */
  lis   r11,TPL_HIG(tpl_dispatch_table)
  ori   r11,r11,TPL_LOW(tpl_dispatch_table)
  lwzx  r11,r11,r0                 /* get the ptr to the service  */
  mtlr  r11                        /* put it in lr for future use */
```

The second thing to do is to reset the *tpl_need_switch* flag that triggers a context switch. This flag (a byte) is located in the *tpl_kern* kernel struct. This is done as follow:

```
  lis   r11,TPL_HIG(tpl_kern)
  ori   r11,r11,TPL_LOW(tpl_kern)
  stw   r11,KS_KERN_PTR(r1)       /* save the ptr for future use  */
  li    r0,NO_NEED_SWITCH
  stb   r0,20(r11)
```

In the future *tpl_kern* will be reused, so its address is saved in the kernel stack.

Then, to allow reentrancy for a service call in a hook, the *RI* bit of the *MSR* is set to 1. Without that, a `sc` cannot be properly executed.

```
  mfmsr r11
  ori   r11,r11,RI_BIT_1
  mtmsr r11
```

At last, the service is called:

```
  blrl
```

Context switch

The *tpl_need_switch* flag that as been possibly modified by the service is now checked to do a context switch if needed.

```
  lwz   r11,KS_KERN_PTR(r1) /* get back the tpl_kern address */
  lbz   r12,20(r11)         /* get the tpl_need_switch flag  */
  andi. r0,r12,NEED_SWITCH  /* check if a switch is needed   */
  beq   no_context_switch
```

A context switch is performed in 3 steps. The first one is the context save of the process that loses the CPU. This step is optional because if the service was a `TerminateTask` or a `ChainTask`, the context needs not to be saved. This information is in the *tpl_need_switch* flag. Before doing the actual context save, the return value of the service must be saved in the proper location of the kernel stack. The `tpl_save_context` function will read it from this location and expects a pointer to the context saving area or the process in *r3*. *s_old*, the address of the context saving area, is in another member of *tpl_kern*. At the end, the *tpl_kern* address is reread because *r11* has been destroyed in `tpl_save_context`.

```
  stw   r3,KS_RETURN_CODE(r1) /* save the return value           */
  andi. r0,r12,NEED_SAVE      /* r12 contains tpl_need_switch      */
  beq   no_save
  lwz   r3,0(r11)             /* r11 contains the tpl_kern address */
  bl    tpl_save_context      /* and s_old is put into r3          */
  lwz   r11,KS_KERN_PTR(r1)   /* get back tpl_kern address         */
```

The second step consists in loading the configuration of memory protection for the process that get the CPU by calling the `tpl_set_process_mp` function. This function expects the id of the process in *r3*. Again this id is located in member *proc_id* of *tpl_kern*. This is done only if *WITH_MEMORY_PROTECTION* is *YES*.

```
#if WITH_MEMORY_PROTECTION == YES
  lwz   r3,16(r11) /* get the id of the process which get the cpu  */
  bl    tpl_set_process_mp     /* set the memory protection scheme */
#endif
```

The third step loads the context of the process that get the CPU. The address of *tpl_kern* is loaded into *r11* because it has been destroyed in `tpl_set_process_mp`, *s_running*, the address of the context saving area of the current process is loaded into *r3* and `tpl_load_context` is called. At last, *r3* is restored.

```
  lwz   r11,KS_KERN_PTR(r1)
  lwz   r3,4(r11)                   /* get s_running               */
  bl    tpl_load_context
  lwz   r3,KS_RETURN_CODE(r1)
```

Switching back to the process stack

At this stage, the *SRR0* and *SRR1* registers saved in the kernel stack are restored. The space reserved in the kernel stack is freed. The reentrancy counter is decremented and the stack switches to the process stack if the reentrancy counter is 0.

```
  lwz   r11,KS_SRR0(r1)
  mtspr spr_SRR0,r11
  lwz   r11,KS_SRR1(r1)
  mtspr spr_SRR1,r11

  addi  r1,r1,KS_FOOTPRINT       /*  free back space on the stack  */

  /*
   * The reentrancy counter is decremented. If it reaches
   * 0, the process stack is restored
   */
  lis   r11,TPL_HIG(tpl_reentrancy_counter)
  ori   r11,r11,TPL_LOW(tpl_reentrancy_counter)
  lwz   r12,0(r11)    /*  get the value of the counter */
  subi  r12,r12,1
  stw   r12,0(r11)
  cmpwi r12,0
  bne   no_stack_restore

  /*  Restore the execution context of the caller
      (or the context of the task/isr which just got the CPU)      */
  lwz   r1,KS_SP-KS_FOOTPRINT(r1)   /*  Restore the SP and switch
                                        back to the process stack  */
```

Enabling memory protection

Then, if memory protection is used, the user scheme is reenabled. The actual works depends on the kind of MPU and is done in `tpl_user_mp`.

```
#if WITH_MEMORY_PROTECTION == YES
  subi  r1,r1,4
  mflr  r11
  stw   r11,0(r1)    /* save lr on the current stack  */
  bl    tpl_user_mp /* Enable the memory protection  */
  lwz   r11,0(r1)    /* restore lr                    */
  mtlr  r11
  addi  r1,r1,4
#endif
```

Restoring registers

Registers saved at stage 1 on the process stack are restored an the stack is freed.

```
  lwz   r11,PS_CR(r1)
  mtcr  r11
```

```
lwz   r11,PS_LR(r1)
mtlr  r11
lwz   r12,PS_R12(r1)
lwz   r11,PS_R11(r1)

addi  r1,r1,PS_FOOTPRINT
```

Getting back to the process

At last, the dispatch layer is exited using a `rfi`.

```
rfi                                  /* return from interrupt */
```

7.1.3 Interrupt handler

7.1.4 The CallTrustedFunction service

The `CallTrustedFunction` service is implemented by the `tpl_call_trusted_function_-service` function. This function is a special case of service because the kernel stack and the process stack have to be modified. In addition, an `ExitTrustedFunction` service is implemented to restore the process stack when the trusted function exits. Both services have to be written in assembly language since C does not allow to explicitely modify the stack.

`tpl_call_trusted_function_service` performs the following steps:

1. check the trusted function id is within the allowed range
2. increment the trusted counter of the calling process
3. build a frame on the process stack to store the registers pushed by a service call except for *r0* and for *SRR0* and *SRR1*; put the address of `ExitTrustedFunction` in the *lr* location in the process stack; save *SRR0* and *SRR1* in the process stack
4. get the trusted function address and put it in *SRR0*
5. go back to the dispatch layer

Checking the trusted function id

The id of the trusted function is checked to avoid to call a function at an arbitrary address.

```
mov   r11,r3               /* save r3 in r11 b/c it will be destroyed    */
cmpw  r3,TRUSTED_FCT_COUNT /* check the id of the trusted function       */
ori   r3,r0,E_OS_SERVICEID /* E_OS_SERVICEID return code                 */
bge   invalid_trusted_fct_id
mov   r3,r11               /* restore r3 if the trusted function id ok   */
```

Incrementing the trusted counter

The trusted counter of the process is incremented each time a trusted function is called. When the trusted counter is > 0, the process is trusted. In such a case, the dispatch layer does not enable memory protection when scheduling the process so it has an unlimited access to the whole addressing space.

```
lwz   r11,KS_KERN_PTR(r1)   /* get the ptr to tpl_kern                  */
lwz   r11,12(r11)           /* get the ptr to the runnning process desc */
lwz   r12,4(r11)            /* get trusted_count member                 */
addi  r12,r12,1             /* increment it                             */
stw   r12,4(r11)            /* put it back in the process desc          */
```

Building the frame

The frame is used to store the calling context of the trusted function and is shown in figure 7.4. The following code builds this frame:

```
/*
 * First get back the process stack pointer
 */
lwz   r11,KS_SP(r1)
/*
 * Make room to prepare the call of the trusted function
 */
subi  r11,r11,PS_TRUSTED_FOOTPRINT_IN
/*
 * store ExitTrustedFunction as the return address
 */
lis   r12,TPL_HIG(ExitTrustedFunction)
ori   r12,r12,TPL_LOW(ExitTrustedFunction)
stw   r12,PS_LR(r11)
/*
 * Update the stack pointer
 */
stw   r11,KS_SP(r1)
/*
 * second get back SRR0 and SRR1 and save them to the process stack
 */
lwz   r12,KS_SRR0(r1)
stw   r12,PS_SRR0_IN(r11)
lwz   r12,KS_SRR1_IN(r1)
stw   r12,PS_SRR1(r11)
```

Setting the trusted function address

The *SRR0* saved by the dispatch layer after the `CallTrustedFunction` is changed to the address of the trusted function. This way, instead of returning to the caller, the trusted function will be executed.

```
lis   r11,TPL_HIG(tpl_trusted_fct_table)
ori   r11,r11,TPL_LOW(tpl_trusted_fct_table)
slwi  r0,r3,2
lwzx  r12,r11,r0
stw   r12,KS_SRR0(r1)
```

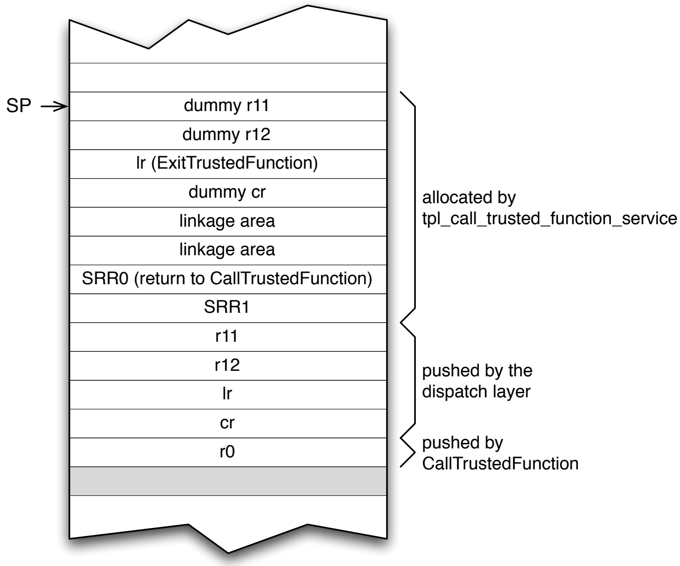


Figure 7.4: *Process stack mapping at the end of* `tpl_call_trusted_function_service`*. r0, at the bottom of the stack has been pushed by CallTrustedFunction. cr to r11 has been pushed by the dispatch layer. SRR0 and SRR1 are saved here by* `tpl_call_trusted_function_service` *to be able to go back to the calling process. Above, the linkage area allows the trusted function to call functions. Above, a frame that will be used by the dispatch layer to restore an execution context for the trusted function is built.*

Going back to the dispatch layer

A simple `blr` goes back to the dispatch layer. The latter cleans up the process stack. Once the trusted function starts execution, the process stack is like that:

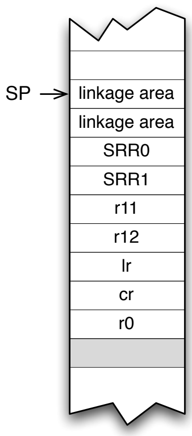


Figure 7.5: *Process stack mapping when the trusted function starts its execution.*

7.1.5 The ExitTrustedFunction service

When a trusted function finishes, the context of the `CallTrustedFunction` must be restored to return to the caller. `ExitTrustedFunction` does not need to be called explicitly because its address has been set as the return address of the trusted function by `tpl_call_trusted_function_service`. Calling `ExitTrustedFunction` explicitly may result in an undefined behavior or in the crash of the calling process but see below. The mapping of the process stack at start of `tpl_exit_trusted_function_service` is shown in figure 7.6.

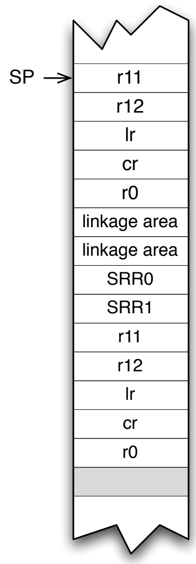


Figure 7.6: *Process stack mapping when the `tpl_exit_trusted_function_service` function starts its execution.*

First, `tpl_exit_trusted_function_service` decrements the trusted counter of the calling process. A particular attention must be given to this point because by building a fake stack frame and calling Explicitly `ExitTrustedFunction` to underflow this counter, a process could get a full access to the memory. So the counter is tested before to avoid to go under 0.

```
lwz   r11,KS_KERN_PTR(r1)   /* get the ptr to tpl_kern */
lwz   r11,12(r11)           /* get the ptr to the runnning process desc */
lwz   r12,4(r11)            /* get trusted_count member */
/*
 * Warning, the trusted counter has to be check (compared to 0) to
 * avoid to decrement it if it is already 0. Without that a process
 * could build an had-hoc stack an call explicitly ExitTrustedFunction
 * to get access to all the memory.
 */
cmpwi r12,0                 /* check it is not already at 0 */
beq   cracker_in_action     /* uh uh */
subi  r12,r12,1             /* decrement it */
stw   r12,4(r11)            /* put it back in the process desc */
```

`tpl_exit_trusted_function_service` has to remove from the process stack the frame that was built by `tpl_call_trusted_function_service`, restore *SRR0* and *SRR1* before returning to the dispatch layer.

```
cracker_in_action:

  /*
   * get the process stack pointer
   */
  lwz   r11,KS_SP(r1)

  /*
   * get back the SRR0 and SRR1
```

```
  */
lwz   r12,PS_SRR0_OUT(r11)
stw   r12,KS_SRR0(r1)
lwz   r12,PS_SRR1_OUT(r11)
stw   r12,KS_SRR1(r1)

/*
 * free the process stack and update it in the kernel stack
 */
addi  r11,r11,PS_TRUSTED_FOOTPRINT_OUT
stw   r11,KS_SP(r1)

/*
 * that's all
 */
blr
```

7.1.6 Execution of the OS Applications startup and shutdown hooks

These hooks are executed from the kernel but with the access right of a task belonging to the OS Application. The system generation tool should choose one of the tasks of the OS Application to be used as context to execute the OS Application startup and shutdown hooks. Execution of an OS Application startup hook is done by the `tpl_call_startup_hook_and_resume` function. The argument of this function is a function pointer to the hook. Similarly execution of an OS Application shutdown hook is done by the `tpl_call_shutdown_hook_and_resume` function. These functions end by a call to `NextStartupHook` and `NextShutdownHook` services respectively to cycle through the hooks.

7.1.7 The MPC5510 Memory Protection Unit

The access control rights of the memory region descriptor rules the access of 5 bus masters (labeled from 4 to 0). Unused bus masters are set to the same access right for all the regions. Bus master 4 is used for factory testing only, so the access rights should be set to no access. Bus master 3 is the Flexray controller. Since it is not used in the current version of Trampoline, it is set to no access too. Bus master 2 is the DMA controller and for the same reason it is set to no access. Bus master 1 is the Z0 core. Again it is set to no access.

The access control rights register has the following bit usage:

Bus master 4 is a special case. The 2 bits have the following meaning:

Bit	Meaning
M4RE	If set to 1, bus master 4 may **read** memory in the region. If 0, no read is allowed
M4WE	If set to 1, bus master 4 may **write** memory in the region. If 0, no write is allowed

So in our case, these bits are set to 0.

Of course, other bus masters have more sophisticated access right:

Bit	Meaning
MxPE	The PID Enable bit. Set to 0 in our case
MxSM	These 2 bits rules the supervisor mode access control with the following meaning: $00 = rwx$, $01 = rx$, $10 = rw$, $11 =$ *same as defined by MxUM*. In our case, it is set to 00 for code and constants and to 11 for data.
MxUM	These 2 bits rules the user mode access control. The first bit means r, the second one w and the third one x.

Trampoline uses 4 descriptors:

Descriptor	Usage	MxUM value
MPU_RGD0	Constants and program[1].	$rwx = 00$ for supervisor mode, $rx = 101$ for user mode.
MPU_RGD1	Private variables of the process.	$rw = 110$ for supervisor and user mode.
MPU_RGD2	Stack of the process.	$rw = 110$ for supervisor and user mode.
MPU_RGD3	Variables of the OS Application if OS Applications are used.	$rw = 110$ for supervisor and user mode.

So values of access control bits should be:

[1]This region is set to the whole addressing space. This is not definitive and should be improved because reading a peripheral control register should be protected. So an additional descriptor has to be used to allow the kernel (supervisor mode) a complete access on all the memory space and no access at all for applications (user mode).

For program and constants:

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1

For variables:

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0

So in hexa:

Kind	Value
Program region access	$0x00000005$
Variable region access	$0x0000001E$

What happen in case of memory protection violation ?

Two exception handler are used to handle a memory protection violation, one for data access, one for code access.

The Data Storage exception is tied to the IVOR 2 vector (VPR offset = 0x020), see page 8-2 of the *MPC5510 Microcontroller Family Reference Manual*.

The Instruction Storage exception is tied to the IVOR 3 vector (VPR offset = 0x030), see page 8-2 of the *MPC5510 Microcontroller Family Reference Manual*.

However, it appears one of these exceptions is raised when the processor is in user mode. The behavior is different in supervisor mode *to be completed*.

Part II

The Goil system generator

CHAPTER

EIGHT

The Goil templates

Goil includes a template interpreter which is used for file generation. Goil generates the structures needed by trampoline to compile the application and may generate other files like a memory mapping file '`MemMap.h`', the compiler abstraction files, '`Compiler.h`' and '`Compiler_cfg.h`' and a linker script depending on which attributes you set in the OIL file.

A template is a file which is located in the default template directory (set with the environment variable GOIL_TEMPLATES or with the **--templates** option on the command line) or in the directory of your project. Goil starts by looking for a template in the directory of your project, then, if the template is not found, in the default templates directory.

Four sets of templates are used:

- code generation templates that are located in the '`code`' subdirectory of the template directory;
- build system templates that are located in the '`build`' subdirectory;
- compiler dependent stuff in the '`compiler`' subdirectory and
- linker script templates in the '`linker`' subdirectory.

Templates are written using a simple language which allow to access the application configuration data and to mix them with text to produce files.

Files are produced by a template program located in the '`root.goilTemplate`' file which is as the root of the template directory. By default the following files are produced:

- '`tpl_app_config.c`' by using the '`tpl_app_config.c.goilTemplate`' file
- '`tpl_app_config.h`' by using the '`tpl_app_config.h.goilTemplate`' file
- '`Makefile`' (if option **-g** or **--generate-makefile** is given) by using the '`Makefile.goilTemplate`' file
- '`script.ld`' (if memory mapping is used and if the default name is not changed) by using the '`script.goilTemplate`' file
- '`MemMap.h`' (if memory mapping is used) by using the '`MemMap.h.goilTemplate`' file
- '`Compiler.h`' (if memory mapping is used) by using the '`Compiler.h.goilTemplate`' file
- '`Compiler_Cfg.h`' (if memory mapping is used) by using the '`Compiler_Cfg.h.goilTemplate`' file

8.1 The configuration data

The configuration data are computed by Goil from the OIL source files, from the options on the command line and from the '`target.cfg`' file. They are available as a set of predefined boolean, string, integer or list variables. All these variables are in capital letters.

Warning: Some configuration data are not listed here because they are dependent on the target. For instance, the `STACKSIZE` data may be an attribute of each item of a *TASKS* list for ppc target but are missing for the c166 target.

8.1.1 The *PROCESSES*, *TASKS*, *BASICTASKS*, *EXTENDEDTASKS*, *ISRS1* and *ISRS2* lists

Theses variables are lists where informations about the processes[1] used in the application are stores:

List	Content
PROCESSES	the list of processes. The items are sorted in the following order: extended tasks, then basic tasks, then ISRs category 2.
TASKS	the list of tasks, basic and extended. The items are sorted in the following order: extended tasks, then basic tasks.
BASICTASKS	the list of basic tasks.
EXTENDEDTASKS	the list of extended tasks.
ISRS1	the list of ISR category 1.
ISRS2	the list of ISR category 2.

Each item of these lists has the following attributes:

Item	Type	Content
`NAME`	string	the name of the process.
`PROCESSKIND`	string	the kind of process: "Task" or "ISR".
`EXTENDEDTASK`	boolean	true if the process is an extended task, false otherwise.
`NONPREEMPTABLE`	boolean	true if the process is a non-preemptable task, false otherwise.
`PRIORITY`	integer	the priority of the process.
`ACTIVATION`	integer	the number of activation of a task. 1 for and extended task or an ISR.
`AUTOSTART`	boolean	true if the process is an autostart task, false otherwise.
`USEINTERNALRESOURCE`	boolean	true if the process is a task that uses an internal resource, false otherwise.
`INTERNALRESOURCE`	string	the name of the internal resource if the process is a task that uses an internal resource, empty string otherwise.
`RESOURCES`	list	The resources used by the process. Each item has the following attribute: `NAME`

[1] In Trampoline, a process is a task or an ISR category 2.

8.1.2 The *COUNTERS*, *HARDWARECOUNTERS* and *SOFTWARECOUNTERS* lists

This list contains all the informations about the counters used in the application, including the *SystemCounter*.

List	Content
COUNTERS	the list of counters, both hardware and software as long as the *SystemCounter*
HARDWARECOUNTERS	the list of hardware counters including the *SystemCounter*.
SOFTWARECOUNTERS	the list of software counters.

Each item of this list has the following attributes:

Item	Type	Content
`NAME`	string	the name of the counter.
`TYPE`	string	the type of counter: "HARDWARE_COUNTER" or "SOFTWARE_COUNTER".
`MAXALLOWEDVALUE`	integer	the maximum allowed value of the counter.
`MINCYCLE`	integer	the minimum cycle value of the counter.
`TICKPERBASE`	integer	the number of ticks needed to increment the counter.
`SOURCE`	string	the interrupt source name of the counter. This can be used to wrap interrupt vector to a counter incrementation function

8.1.3 The *EVENTS* list

This list contains the informations about the events of the application. Each item has the following attributes:

Item	Type	Content
`NAME`	string	the name of the event.
`MASK`	integer	the mask of the event.

8.1.4 The *ALARMS* list

This list contains the informations about the alarms of the application. Each item has the following attributes:

Item	Type	Content
`NAME`	string	the name of the alarm.
`COUNTER`	string	the name of the counter that drives the alarm.
`ACTION`	string	the action to be done when the alarm expire. It can take the following values: “setEvent”, “activateTask” and “callback”. The last action is not available in Autosar mode.
`TASK`	string	the name of the task on which the action is performed. This attribute is defined for “setEvent” and “activate-Task” actions only.
`EVENT`	string	the name of the event to set on the target task. This attribute is defined for “setEvent” action only.
`AUTOSTART`	boolean	true if the alarm is autostart, false otherwise
`ALARMTIME`	integer	the alarm time of the alarm. This attribute is set if `AUTOSTART` is true
`CYCLETIME`	integer	the cycle time of the alarm. This attribute is set if `AUTOSTART` is true
`APPMODE`	string	the application mode in which the alarm is autostart. This attribute is set if `AUTOSTART` is true

8.1.5 The *REGULARRESOURCES* and *INTERNALRESOURCES* lists

These lists contains the informations about the resources of the application.

List	Content
REGULARRESOURCES	the list of STANDARD and LINKED resources.
INTERNALRESOURCES	the list of INTERNAL resources.

Each item has the following attributes:

Item	Type	Content
`NAME`	string	the name of the resource.
`PRIORITY`	integer	the priority of the resource.
`TASKUSAGE`	list	the list of tasks that use the resource. Each item of this list has an attribute `NAME` which is the name of the task.

Item	Type	Content
ISRUSAGE	list	the list of ISRs that use the resource. Each item of this list has an attribute NAME which is the name of the ISR.

8.1.6 The *MESSAGES*, *SENDMESSAGES* and *RECEIVEMESSAGES* lists

These lists contain the informations about the messages of the application.

List	Content
MESSAGES	the list of messages, both send and receive message.
SENDMESSAGES	the list of send messages.
RECEIVEMESSAGES	the list of receive messages.

Each item has the following attributes

Item	Type	Content
NAME	string	the name of the message.
MESSAGEPROPERTY	string	the type of the message. It can be "RECEIVE_ZERO_INTERNAL", "RECEIVE_UNQUEUED_INTERNAL", "RECEIVE_QUEUED_INTERNAL", "SEND_STATIC_INTERNAL", "SEND_ZERO_INTERNAL" or "RECEIVE_ZERO_SENDERS".
NEXT	string	the name of the next message in a receive message chain. This attribute is defined for receive messages only.
SOURCE	string	the name of the send message which is connected to the receive message. This attribute is defined for receive messages only.
CTYPE	string	the C language type of the message. This attribute is not defined for "RECEIVE_ZERO_INTERNAL" and "SEND_ZERO_INTERNAL" messages.
INITIALVALUE	string	initial value of the receive message. This attribute is defined for "RECEIVE_UNQUEUED_INTERNAL" and "RECEIVE_ZERO_SENDERS" messages only.
QUEUESIZE	integer	queue size of a receive queued message. This attribute is defined for "RECEIVE_QUEUED_INTERNAL" messages only.
TARGET	string	target message of a send message. This is the first message in a receive message chain. This attribute is defined for "SEND_STATIC_INTERNAL" and "SEND_ZERO_INTERNAL" messages only.

Item	Type	Content
FILTER	string	the kind of filter to apply. This attribute may take the following values: "ALWAYS", "NEVER", "MASKEDNEWEQUALSX", "MASKEDNEWDIFFERSX", "NEWISEQUAL", "NEWISDIFFERENT", "MASKEDNEWEQUALSMASKEDOLD", "MASKEDNEWDIFFERSMASKEDOLD", "NEWISWITHIN", "NEWISOUTSIDE", "NEWISGREATER", "NEWISLESSOREQUAL", "NEWISLESS", "NEWISGREATEROREQUAL" or "ONEEVERYN".
MASK	integer	Mask of the filter when needed. This attribute is defined for "MASKEDNEWEQUALSX", "MASKEDNEWDIFFERSX", "MASKEDNEWEQUALSMASKEDOLD" and "MASKEDNEWDIFFERSMASKEDOLD" filters only.
X	integer	Value of the filter when needed. This attribute is defined for "MASKEDNEWEQUALSMASKEDOLD" and "MASKEDNEWDIFFERSX" filters only.
MIN	integer	Minimum value of the filter when needed. This attribute is defined for "NEWISWITHIN" and "NEWISOUTSIDE" filters only.
MAX	integer	Maximum value of the filter when needed. This attribute is defined for "NEWISWITHIN" and "NEWISOUTSIDE"
PERIOD	integer	Period of the filter. This attribute is defined for "ONEEVERYN" filter only.
OFFSET	integer	Offset of the filter. This attribute is defined for "ONEEVERYN" filter only.
ACTION	string	the action (or notification) to be done when the message is delivered. It can take the following values: "setEvent" or "activateTask".
TASK	string	the name of the task on which the notification is performed. This attribute is defined for "setEvent" and "activateTask" actions only.
EVENT	string	the name of the event to set on the target task. This attribute is defined for "setEvent" notification only.

8.1.7 The *SCHEDULETABLES* list

This list contains the informations about the schedule tables of the application.

Item	Type	Content
NAME	string	the name of the schedule table.
COUNTER	string	the name of the counter which drives the schedule table.

Item	Type	Content
PERIODIC	boolean	true if the schedule table is a periodic one, false otherwise.
SYNCSTRATEGY	string	the synchronization strategy of the schedule table. This attribute may take the following values: “SCHEDTABLE_NO_SYNC”, “SCHEDTABLE_IMPLICIT_SYNC” or “SCHEDTABLE_EXPLICIT_SYNC”.
PRECISION	integer	the precision of the synchronization. This attribute is define when SYNCSTRATEGY is “SCHEDTABLE_EXPLICIT_SYNC”.
STATE	string	the state of the schedule table. This attribute may take the following values: “SCHEDULETABLE_STOPPED”, “SCHEDULETABLE_AUTOSTART_SYNCHRON”, “SCHEDULETABLE_AUTOSTART_RELATIVE” or “SCHEDULETABLE_AUTOSTART_ABSOLUTE”.
DATE	integer	the start date of the schedule table. This attribute has an actuel value when STATE is “SCHEDULETABLE_AUTOSTART_RELATIVE” or “SCHEDULETABLE_AUTOSTART_ABSOLUTE”, otherwise it is set to 0.
LENGTH	integer	The length of the schedule table.
EXPIRYPOINTS	list	The expiry points of the schedule table. See the following table for items attributes.

Each item of the EXPIRYPOINTS list has the following attributes:

Item	Type	Content
ABSOLUTEOFFSET	integer	the absolute offset of the expiry points.
RELATIVEOFFSET	integer	the relative offset of the expiry points from the previous expiry point.
MAXRETARD	integer	maximum retard to keep the schedule table synchronous.
MAXADVANCE	integer	maximum advance to keep the schedule table synchronous.
ACTIONS	list	the actions to perform on the expiry point. See the following table for items attributes.

Each item of the ACTIONS list has the following attributes:

Item	Type	Content
ACTION	string	the action to be done when the alarm expire. It can take the following values: “setEvent”, “activateTask”, “incrementCounter” and “finalizeScheduleTable”.

Item	Type	Content
TASK	string	the name of the task on which the action is performed. This attribute is defined for "setEvent" and "activateTask" actions only.
EVENT	string	the name of the event to set on the target task. This attribute is defined for "setEvent" action only.
TARGETCOUNTER	string	the name of the counter to increment. This attribute is defined for "incrementCounter" action only.

8.1.8 The *OSAPPLICATIONS* list

This list contains the informations about the OS Applications of the application.

Item	Type	Content
NAME	string	the name of the OS Application.
RESTART	string	the name of the restart task. This attribute is not defined is there is no restart task for the OS Application.
PROCESSACCESSVECTOR	string	access right for the processes
PROCESSACCESSITEMS	string	access right for the processes as bytes in a table
PROCESSACCESSNUM	integer	number of elements in the previous table
ALARMACCESSVECTOR	string	access right for the alarms
ALARMACCESSITEMS	string	access right for the alarms as bytes in a table
ALARMACCESSNUM	integer	number of elements in the previous table
RESOURCEACCESSVECTOR	string	access right for the resources
RESOURCEACCESSITEMS	string	access right for the resources as bytes in a table
RESOURCEACCESSNUM	integer	number of elements in the previous table
SCHEDULETABLEACCESSVECTOR	string	access right for the schedule tables
SCHEDULETABLEACCESSITEMS	string	access right for the schedule tables as bytes in a table
SCHEDULETABLEACCESSNUM	integer	number of elements in the previous table
COUNTERACCESSVECTOR	string	access right for the software counters
COUNTERACCESSITEMS	string	access right for the software counters as bytes in a table
COUNTERACCESSNUM	integer	number of elements in the previous table
PROCESSES	list	list of the processes that belong to the OS Application. Each item has an attribute NAME which is the name of the process.
HASSTARTUPHOOK	boolean	true if the OS Application has a startup hook.
HASSHUTDOWNHOOK	boolean	true if the OS Application has a shutdown hook.
TASKS	list	list of the tasks that belong to the OS Application. Each item has an attribute NAME which is the name of the task.

Item	Type	Content
`ISRS`	list	list of the ISRs that belong to the OS Application. Each item has an attribute `NAME` which is the name of the ISR.
`ALARMS`	list	list of the alarms that belong to the OS Application. Each item has an attribute `NAME` which is the name of the alarm.
`RESOURCES`	list	list of the resources that belong to the OS Application. Each item has an attribute `NAME` which is the name of the resource.
`REGULARRESOURCES`	list	list of the standard or linked resources that belong to the OS Application. Each item has an attribute `NAME` which is the name of the resource.
`INTERNALRESOURCES`	list	list of the internal resources that belong to the OS Application. Each item has an attribute `NAME` which is the name of the resource.
`SCHEDULETABLES`	list	list of the schedule tables that belong to the OS Application. Each item has an attribute `NAME` which is the name of the schedule table.
`COUNTERS`	list	list of the counters that belong to the OS Application. Each item has an attribute `NAME` which is the name of the counter.
`MESSAGES`	list	list of the messages that belong to the OS Application. Each item has an attribute `NAME` which is the name of the messages.

8.1.9 The *TRUSTEDFUNCTIONS* list

This list contains the informations about the trusted functions of the application. Each item contains one attribute only.

Item	Type	Content
`NAME`	string	the name of the trusted function.

8.1.10 The *READLIST* list

This list contains the informations about the ready list. Items are sorted by priority from 0 to the maximum computed priority. The only attribute of each item is the size of the queue.

Item	Type	Content
SIZE	integer	the size of the queue for the corresponding priority.

8.1.11 The *SOURCEFILES*, *CFLAGS*, *CPPFLAGS*, *ASFLAGS*, *LDFLAGS* and *TRAMPOLINE-SOURCEFILES* lists

The *SOURCEFILES* list contains the source files as found in attributes `APP_SRC` of the OS object in the OIL file.

Item	Type	Content
FILE	string	the source file name.

The *CFLAGS* list contains the flags for the C compiler as found in attributes `CFLAGS` of the OS object in the OIL file.

Item	Type	Content
CFLAG	string	the C compiler flag.

The *CPPFLAGS* list contains the flags for the C++ compiler as found in attributes `CPPFLAGS` of the OS object in the OIL file.

Item	Type	Content
CPPFLAG	string	the C++ compiler flag.

The *ASFLAGS* list contains the flags for the assembler as found in attributes `ASFLAGS` of the OS object in the OIL file.

Item	Type	Content
ASFLAG	string	the assembler flag.

The *LDFLAGS* list contains the flags for the linker as found in attributes LDFLAGS of the OS object in the OIL file.

Item	Type	Content
LDFLAG	string	the linker flag.

The *TRAMPOLINESOURCEFILES* list contains the trampoline source files used by the application.

Item	Type	Content
DIRECTORY	string	the directory of the source file relative to the Trampoline root directory ('os', 'com' or 'autosar').
FILE	string	the source file name.

8.1.12 The *INTERRUPTSOURCES* list

This list is extracted from the 'target.cfg' file. Each item has the following attribute:

Item	Type	Content
NAME	string	the name of the interrupt source. This is one of the name used in the OIL file as value for the SOURCE attribute
NUMBER	string	the id of the interrupt source.

8.1.13 Scalar data

The following scalar data are defined:

Data	Type	Content
APPNAME	string	name of executable as given in the APP_NAME attribute in the OS object
ARCH	string	name of the architecture. This is the first item in the target.
ASSEMBLEREXE	string	name of the assembler executable used. This is the ASSEMBLER attribute in the OS object. It is set to *as* by default. It is used for build dependent templates.

Data	Type	Content
ASSEMBLER	string	name of the assembler used. This is the ASSEMBLER attribute in the MEMMAP attribute of the OS object. It is used for assembler dependent templates.
AUTOSAR	boolean	true if Trampoline is compiled with the Autosar extension.
BOARD	string	name of the board. This is the third item (if any) in the target.
CHIP	string	name of the chip. This is the second item (if any) in the target.
COMPILEREXE	string	name of the compiler executable used. This is the COMPILER attribute in the OS object. It is set to *gcc* by default. It is used for build dependent templates. Do not confuse with the COMPILER data.
COMPILER	string	name of the compiler used. This is the COMPILER attribute in the MEMMAP attribute of the OS object. It is used for compiler dependent templates.
CPUNAME	string	name given to the OIL CPU object
EXTENDED	boolean	true if Trampoline is compiled in extended error handling mode.
FILENAME	string	the name of the file which will be written as the result of the computation of the current template.
FILEPATH	string	the full absolute path of the file which will be written as the result of the computation of the current template.
NATIVEFILEPATH	string	the full absolute path of the file which will be written as the result of the computation of the current template in native OS format.
ITSOURCESLENGTH	integer	number of interrupt sources as defined in the 'target.cfg' file.
LINKEREXE	string	name of the linker executable used. This is the LINKER attribute in the OS object. It is set to *gcc* by default. It is used for build dependent templates. Do not confuse with the LINKER data.
LINKER	string	name of the linker used. This is the LINKER attribute in the MEMMAP attribute of the OS object. It is used for linker dependent templates.
LINKSCRIPT	string	name of the link script file as given in the MEMMAP attribute of the OS object.
MAXTASKPRIORITY	integer	the highest computed priority among the tasks.
OILFILENAME	string	name of the root OIL source file
PROJECT	string	name of the project. The name of the project is the **-p** (or **--project**) value if it is set or the name of the oil file without the extension.
SCALABILITYCLASS	integer	the Autosar scalability class used by the application. If Autosar is not enabled, SCALABILITYCLASS is set to 0.
TARGET	string	name of the target. This is the **-t** (or **--target**) option value of goil.

Data	Type	Content
TEMPLATEPATH	string	path to the template root directory. This is the **--templates** option value of goil or the value of the GOIL_TEMPLATES environment variable.
TIMESTAMP	string	current date
TRAMPOLINEPATH	string	path to the trampoline root directory. This is the TRAMPOLINE_BASE_PATH attribute of the OS object. It defaults to "..".
USECOMPILERSETTINGS	boolean	true if memory mapping is enabled (Goil generates the 'Compiler.h' and 'Compiler_Cfg.h' files and Trampoline includes them).
USEBUILDFILE	boolean	true if a build file is used for the project ie option **-g** or **--generate-makefile** is given.
USECOM	boolean	true if the application uses OSEK COM.
USEERRORHOOK	boolean	true if Trampoline uses the Error Hook.
USEGETSERVICEID	boolean	true if Trampoline uses the service ids access macros.
USEINTERRUPTTABLE	boolean	true if the wrapping of interrupt vector to glue functions used to increment a counter or to activate an ISR2 (for instance) should be generated. The actual code generation is up to the port.
USELOGFILE	boolean	true if goil generates a log file, ie option **-l** or **--logfile** is given.
USEMEMORYMAPPING	boolean	true if memory mapping is enabled (Goil generates the 'MemMap.h' file and Trampoline includes it).
USEMEMORYPROTECTION	boolean	true if Trampoline uses the Memory Protection.
USEOSAPPLICATION	boolean	true if Trampoline uses OS Applications.
USEPARAMETERACCESS	boolean	true if Trampoline uses the parmaters access macros.
USEPOSTTASKHOOK	boolean	true if Trampoline uses the Post-Task Hook.
USEPRETASKHOOK	boolean	true if Trampoline uses the Pre-Task Hook.
USEPROTECTIONHOOK	boolean	true if Trampoline uses the Protection Hook.
USERESSCHEDULER	boolean	true if Trampoline uses the RES_SCHEDULER resource.
USESHUTDOWNHOOK	boolean	true if Trampoline uses the Shutdown Hook.
USESTACKMONITORING	boolean	true if Trampoline uses the Stack Monitoring.
USESTARTUPHOOK	boolean	true if Trampoline uses the Startup Hook.
USESYSTEMCALL	boolean	true if services are called using a System Call (i.e. a software interrupt).
USETIMINGPROTECTION	boolean	true if Trampoline uses Timing Protection.
USETRACE	boolean	true if tracing is enabled.

8.2 The Goil template language (or GTL)

A template is a text file with file extension '.goilTemplate'. This kind of file mixes literal text with an embedded program. Some instructions (see section 8.5.6) in the embedded program outputs text as a result of the program execution and this text is put in place of the instructions. The resulting file is then stored.

The template interpreter starts in literal text mode. Switching from literal text mode to program mode and back to text mode is done when a '`%`' is encountered. A literal '`%`' and a literal '\' may be used by escaping them with a '\'.

8.3 GTL types

GTL supports 5 types: **string**, **integer**, **boolean**, **list** and **struct**. The 4 first types have readers to get informations about a variable. A reader is invoke with the following syntax:

`[`*`expression reader`*`]`

A struct is an aggregate of data. The '::' allows to get a member of the struct. For instance one of the member of *TIMINGPROTECTION* is `TIMEFRAME` so to get `TIMEFRAME`, the following syntax is used:

`TIMINGPROTECTION::TIMEFRAME`

8.3.1 string readers

The following readers are available for string variables:

Item	Type	Meaning
HTMLRepresentation	string	this reader returns a representation of the string suitable for an HTML encoded representation. '`&`' is encoded by & , '`"`' by " , '<' by < and '>' by > .
identifierRepresentation	string	this reader returns an unique representation of the string conforming to a C identifier. Any Unicode character that is not a latin letter is transformed into its hexadecimal code point value, enclosed by '_' characters. This representation is unique: two different strings are transformed into different C identifiers. For example: value3 is transformed to value_33_; += is transformed to _2B__3D; An_Identifier is transformed to An_5F_Identifier.
lowercaseString	string	this reader returns lowercased representation of the string.
length	integer	this reader returns the number of characters in the string
stringByCapitalizingFirstCharacter	string	if the string is empty, this reader returns the empty string; otherwise, it returns the string, the first character being replaced with the corresponding upper case character.
uppercaseString	string	this reader returns uppercased representation of the receiver

8.3.2 boolean readers

The following readers are available for boolean variables:

Item	Type	Meaning
trueOrFalse	string	this reader returns “true” or “false” according to the boolean value
yesOrNo	string	this reader returns “yes” or “no” according to the boolean value
unsigned	integer	this reader returns 0 or 1 according to the boolean value

8.3.3 integer readers

The following readers are available for integer variables:

Item	Type	Meaning
string	string	This reader returns the integer value as a character string.
hexString	string	this reader returns an hexadecimal string representation of the integer value.

8.3.4 list readers

The following reader is available for list variables:

Item	Type	Meaning
length	integer	this reader returns the number of objects currently in the list.

8.4 GTL operators

8.4.1 Unary operators

Operator	Operand Type	Result Type	Meaning
+	integer	integer	no operation.
$\sim$	integer	integer	bitwise not.
not	boolean	boolean	boolean not.
exists	*any variable*	boolean	true if the variable is defined, false otherwise. But see below

A second form of **exists** is:

`exists` *var* **default** (*expression*)

var and *expression* should have the same type. If *var* exists, the returned value is the content of *var*. If it does not exist, *expression* is returned.

8.4.2 Binary operators

Operator	Operands Type	Result Type	Meaning
+	integer	integer	add.
-	integer	integer	substract.
*	integer	integer	multiply.
/	integer	integer	divide.
&	integer	integer	Bitwise and.
&	boolean	boolean	boolean and.
$\vert$	integer	integer	Bitwise or.
$\vert$	boolean	boolean	boolean or.
$\wedge$	integer	integer	Bitwise xor.
$\wedge$	boolean	boolean	boolean xor.
.	string	string	string concatenation.
$<<$	integer	integer	shift left.
$>>$	integer	integer	shift right.
!=	*any*	boolean	comparison (different).
==	*any*	boolean	comparison (equal).
$<$	integer *or* boolean	boolean	comparison (lower than).
$<=$	integer *or* boolean	boolean	comparison (lower or equal).
$>$	integer *or* boolean	boolean	comparison (greater).
$>=$	integer *or* boolean	boolean	comparison (greater or equal).

8.4.3 Constants

Constant	Type	Meaning
emptyList	list	this constant is an empty list
true	boolean	true boolean
false	boolean	false boolean
yes	boolean	true boolean
no	boolean	false boolean

8.5 GTL instructions

8.5.1 The *let* instruction

Data assignment instruction. The general form is:

```
let var := expression
```

A second form allows to add a string to a list (only, this should be extended in the future)

```
let var += expression
```

var is a list and *expression* is a string.

The scope of a variable depends on the location where the variable is assigned the first time. For instance, in the following code:

```
let a := 1
foreach TASKS do
  let b := INDEX
  let a := INDEX
end foreach
!a !b
```

Because a is assigned outside the **foreach** loop, it contains the value of the last INDEX after the **foreach**. Because b is assigned inside the **foreach** loop, it does not exist after the loop anymore and **!b** will trigger and error.

8.5.2 The *if* instruction

Conditional execution. The forms are:

```
if expression then ... end if
if expression then ... else ... end if
if expression then ... elsif expression then ... end if
if expression then ... elsif expression then ... else ... end if
```

The *expression* must be boolean. In the following example, the blue text (within the %) is produced only if the USECOM boolean variable is true:

```
if USECOM then %
#include "tpl_com.h" %
end if
```

8.5.3 The *foreach* instruction

This instruction iterates on the elements of a list. Each element may have many attributes that are available as variables within the **do** section of the foreach loop. The simplest form is the following one

```
foreach expression do ... end foreach
```

In the following example, for each element in the ALARMS list, the text between the **do** and the **end foreach** is produced with the NAME attribute of the current element of the ALARMS list inserted at the specified location. INDEX is not an attribute of the current element. It is generated for each element and ranges from 0 to the number of elements in the list minus 1.

```
foreach ALARMS do
%
/* Alarm % !NAME % identifier */
#define % !NAME %_id % !INDEX %
CONST(AlarmType, AUTOMATIC) % !NAME % = % !NAME %_id;
%
end foreach
```

A more general form of the `foreach` instruction is:

```
foreach expression prefixedby string
  before ...
  do ...
  between ...
  after ...
end foreach
```

prefixedby is optional and allows to prefix the attribute names by *string*. If the list is not empty, the **before** section are executed once before the first execution of the **do** section. The **between** section is executed between the execution of the **do** section. If the list is not empty, the **after** section is executed once after the last execution of the **do** section.

In the following example, a table of pointers to alarm descriptors is generated:

```
foreach ALARMS
  before %
tpl_time_obj *tpl_alarm_table[ALARM_COUNT] = {
%
  do %  &% !NAME %_alarm_desc%
  between %,
%
  after %
};
%
end foreach
```

8.5.4 The *for* instruction

The **for** instruction iterates along a literal list of elements.

```
for var in expression, ... , expression do
  ...
end for
```

At each iteration, *var* gets the value of the current *expression*. As in the **foreach** instruction, INDEX is generated and ranges from 0 to the number of elements in the list minus 1.

8.5.5 The *loop* instruction

The **loop** instruction is the classical integer loop. Its simplest form is:

```
loop var from expression to expression do
  ...
end loop
```

Like in the foreach instruction, **before**, **between** and **after** sections may be used:

```
loop var from expression to expression
  before ...
  do ...
  between ...
  after ...
end loop
```

8.5.6 The *!* instruction

! emits an expression. The form is:

```
! expression
```

8.5.7 The *?* instruction

? stores in a variable a number of spaces equal to the current column in the output. The form is:

```
? var
```

8.5.8 The *template* instruction

The **template** instruction includes the output of another template in the output of the current template. Its simplest form is the following one:

```
template template_file_name
```

If the file *template_file_name*.goilTemplate does not exist, an error occurs. To include the output of a template without generating an error, use the following form:

```
template if exists template_file_name
```

A third form allows to execute instructions when the included template file is not found:

```
template if exists template_file_name or ... end template
```

At last, it is possible to search templates in a hierarchy (code, linker, compiler, build) different from the current one. For instance to include a template located in the linker hierarchy, use one of the following forms:

```
template template_file_name in hierarchy
template if exists template_file_name in hierarchy
template if exists template_file_name in hierarchy or ... end template
```

In all cases, the included template inherits from the current variables table but works on its own local copy.

8.5.9 The *write* instruction

The write instruction defines a block where the template processing output is captured to be written to a file. The general form is:

```
write to expression :
  ...
end write
```

Where *expression* is a string expression.

In the following example, the result of the 'script' template is written to the link script file.

```
if exists LINKER then
  write to PROJECT."/".LINKSCRIPT:
    template script in linker
  end write
end if
```

8.5.10 The *error* and *warning* instructions

It can be useful to generate an error or a warning if a data is not defined or if it looks strange. For instance if a target needs a `STACKSIZE` for a task or if the `STACKSIZE` is too large for a 16bit target. **error** and **warning** have 2 forms:

```
error var expression
warning var expression
```

and

```
error here expression
warning here expression
```

expression must be of type string. In the first form, *var* is a configuration data. The file location of this configuration may be a location in the OIL file or in the template file if the variable was assigned in the template. In the second form, **here** means the current location in the template file.

In the following example an error is generated for each task with not STACKSIZE attribute in the OIL file:

```
foreach TASKS do
  if not exists STACKSIZE then
    error NAME "STACKSIZE of Task " . NAME . " is not defined"
  end if
end foreach
```

In this second example, an error is generated if a template is not found:

```
template if exists interrupt_wrapping or
  error here "interrupt_wrapping.goilTemplate not found"
end template
```

8.6 Examples

Here are examples of code generation using GTL.

8.6.1 Computing the list of process ids

```
foreach PROCESSES do
  if PROCESSKIND == "Task" then
%
/* Task % !NAME % identifier */
#define % !NAME %_id % !INDEX %
CONST(TaskType, AUTOMATIC) % !NAME % = % !NAME %_id;
%
  else
%
/* ISR % !NAME % identifier */
#define % !NAME %_id % !INDEX
    if AUTOSAR then
    #
    # ISR ids constants are only available for AUTOSAR
    #
%
CONST(ISRType, AUTOMATIC) % !NAME % = % !NAME %_id;
%
    end if
  end if
end foreach
```

8.6.2 Computing an interrupt table

```
if USEINTERRUPTTABLE then
  loop ENTRY from 0 to ITSOURCESLENGTH - 1
    before
%
#define OS_START_SEC_CONST_UNSPECIFIED
```

```
#include "tpl_memmap.h"
CONST(tpl_it_vector_entry, OS_CONST)
tpl_it_table[% !ITSOURCESLENGTH %] = {
%
    do
      let entryFound := false
      foreach INTERRUPTSOURCES prefixedby interrupt_ do
        if ENTRY == interrupt_NUMBER then
          # check first for counters
          foreach HARDWARECOUNTERS prefixedby counter_ do
            if counter_SOURCE == interrupt_NAME & not entryFound then
              %  { tpl_tick_% !interrupt_NAME %, (void *)NULL }%
              let entryFound := true
            end if
          end foreach
          if not entryFound then
            foreach ISRS2 prefixedby isr2_ do
              if isr2_SOURCE == interrupt_NAME & not entryFound then
                %  { tpl_central_interrupt_handler_2, (void*)%
                !([TASKS length] + INDEX) % }%
                let entryFound := true
              end if
            end foreach
          end if
        end if
      end foreach
      if not entryFound then
        %  { tpl_null_it, (void *)NULL }%
      end if
   between %,
%
    after
%
};
#define OS_STOP_SEC_CONST_UNSPECIFIED
#include "tpl_memmap.h"
%
 end loop
end if
```

8.6.3 Generation of all the files

This is the default 'root.goilTemplate' file

```
write to PROJECT."/tpl_app_config.c":
  template tpl_app_config_c in code
end write

write to PROJECT."/tpl_app_config.h":
  template tpl_app_config_h in code
end write

write to PROJECT."/tpl_app_define.h":
  template tpl_app_define_h in code
```

```
end write

if exists COMPILER then
  write to PROJECT."/MemMap.h":
    template MemMap_h in compiler
  end write
  write to PROJECT."/Compiler.h":
    template Compiler_h in compiler
  end write
  write to PROJECT."/Compiler_Cfg.h":
    template Compiler_Cfg_h in compiler
  end write
end if

if exists LINKER then
  write to PROJECT."/".LINKSCRIPT:
    template script in linker
  end write
end if
```

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