T-Kernel Specification

T-Kernel 1.B0.01

Aug. 2002

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History of Revisions

[Version 1.B0.01]

- Added task start address to the information referenced by `TD_RTSK`.
- Corrected the explanation of `tk_snd_mbf()` to note that when `tmout` = `TMO_POL`, it is an implementation-dependent matter whether this system call can be issued from a task-independent portionor while dispatching is disabled.
- Clarified the explanation of `td_hok_svc()` by noting that when a hook routine is set or cleared after invoking a system call or extended SVC, `enter()` or `leave()` is not called in some cases.
- Noted that the maximum value for subsystem ID is implementation-dependent.

System Call Notation

In the parts of this specification that describe system calls, the specification of each system call is explained in the format illustrated below.

System call name

Summary description

Summary description

[C Language Interface]
Indicates the C language interface for invoking the system call.

[Parameters]
Describes the system call parameters, that is, the information passed to the OS when the system call is executed.

[Return Parameters]
Describes the system call return parameters, that is, the information returned by the OS when execution of the system call ends.

[Error Codes]
Describes the errors that can be returned by the system call.
The following error codes are common to all system calls and are not included in the error code listings for each system call.
`E_SYS`, `E_NOSPT`, `E_RSFN`, `E_MACV`, `E_OACV` Error code `E_CTX` is included in the error code listings for individual system calls only when the conditions for its occurrence are clear (e.g., system calls that enter WAIT state). Depending on the implementation, however, the `E_CTX` error code may be returned by other system calls as well. The implementation-specific occurrences of `E_CTX` are not included in the error code specifications for individual system calls.

[Description]
Describes the system call functions.
When the values to be passed in a parameter are selected from various choices, the following notation is used in the parameter descriptions.

`( x || y || z )`	:	Set one of `x`, `y`, or `z`.
`x | y`	:	Both `x` and `y` can be set at the same time (in which case the logical sum of `x` and `y` is taken).
`([x])`	:	Designation of `x` is optional.

[**Example:**]

When `wfmode := (TWF_ANDW || TWF_ORW) | [TWF_CLR]`, `wfmode` can be designated in any of the following four ways.

```
TWF_ANDW
TWF_ORW
(TWF_ANDW | TWF_CLR)
(TWF_ORW | TWF_CLR)
```

[**Additional Notes**]

Supplements the description by noting matters that need special attention or caution, etc.

[**Rationale for the Specification**]
Explains the reason for adopting a particular specification.

Index of T-Kernel/OS System Calls

The T-Kernel/OS system calls described in this specification are listed below in alphabetical order.

Index of T-Kernel/SM Extended SVC Libraries

This index lists in alphabetical order the T-Kernel/SM extended SVC libraries described in this specification.

Index of T-Kernel/DS System Calls

This index lists in alphabetical order the T-Kernel/DS service calls described in this specification.

Chapter 1

T-Kernel Overview

1.1 Position of T-Kernel

The position of T-Kernel in the overall T-Engine system is shown in Figure 1.1.

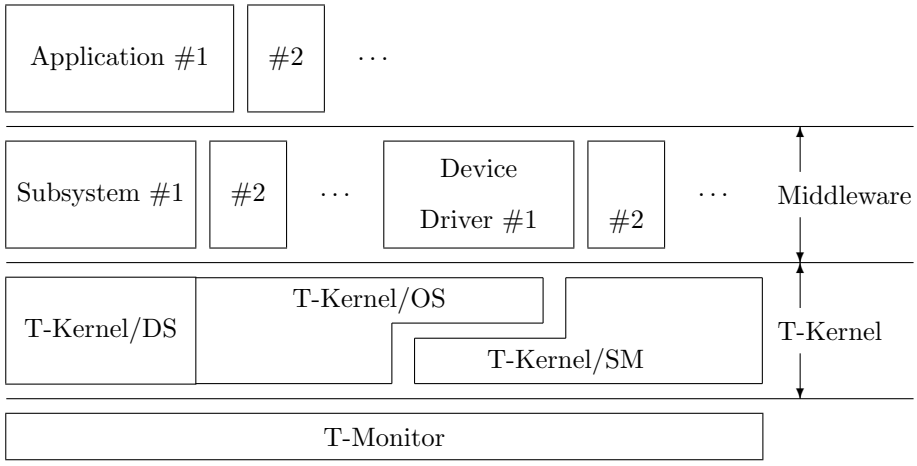


Figure 1.1: Position of T-Kernel

T-Kernel generally refers to all of T-Kernel Operating System (T-Kernel/OS), T-Kernel System Manager (T-Kernel/SM), and T-Kernel Debugger Support (T-Kernel/DS); but in some cases T-Kernel/OS only (narrow definition) is called T-Kernel.
T-Kernel Operating System (T-Kernel/OS) provides the following kinds of functions.

- Task control functions
- Task communication functions
- Memory management functions
- Exception/interrupt control functions

- Time management functions
- Subsystem management functions

T-Kernel System Manager (T-Kernel/SM) provides the following kinds of functions.

- System memory management functions
- Address space management functions
- Device management functions
- Interrupt management functions
- IO port access support functions
- Power management functions
- System configuration information management functions

T-Kernel Debugger Support (T-Kernel/DS) provides the following kinds of functions exclusively for debugging use.

- Kernel internal state reference
- Trace

1.2 Scalability

T-Kernel is a real-time kernel for embedded system use, applicable to a wide range of systems large and small. It is aimed at enhancing portability of software such as device drivers and middleware.
The T-Kernel specification is designed to be applicable even to large-scale systems. The approach of defining subsets to this end, with functions specified in some subsets but not mandatory in others for small-scale systems, has the disadvantage of hampering portability of device drivers, middleware and other software. Functional requirements also vary widely from one target system to another, making it difficult to settle on workable subset specifications.
The T-Kernel specification does not adopt a level division or other subsetting approach. In principle, all operating systems compliant with the T-Kernel specification must implement the specification in it entirety. A target system, however, that does not need all the OS functions is free to implement a scaled-down version of the OS. It is also acceptable to offer T-Kernel users the option of leaving out functions not used in a target system. The important point here is that it is the user, not the OS provider, who decides which functions to omit.

T-Kernel providers

- The entire specification must be implemented. Scaled-down implementations for specific target systems are allowed.
- Providing users with the means for removing or skipping unnecessary functions is also allowed.

Middleware providers

- Middleware must be designed to meet all the T-Kernel requirements. It cannot be limited to specific target systems but must be applicable to a variety of systems and scales.
- Providing users with the means for removing or skipping unnecessary functions is allowed.

A "scaled-down implementation" means one that does not provide the entire range of specified functions but does not behave abnormally (return error, etc.) if a non-implemented function is called. It is important, in other words, that middleware developed for large-scale systems provide an environment enabling it to run without problem on other systems. For example, a system that does not use an MMU can implement the T-Kernel/SM `LockSpace()` as follows.

```
#define LockSpace(addr, len)    (E_OK)
```

The absence of an MMU does not, however, make it allowable not to implement `LockSpace()` or to return the error code `E_NOSPT`.
At the same time, when middleware is created, leaving out `LockSpace()` from an implementation because the target system does not use an MMU would prevent the middleware from supporting a system that does use an MMU.

Chapter 2

Concepts Underlying the T-Kernel Specification

2.1 Meaning of Basic Terminology

1. **Task, invoking task**

   The basic logical unit of concurrent program execution is called a "task". Whereas the programs assigned to one task are executed in sequence, programs assigned to different tasks can be executed in parallel. This concurrent processing is a conceptual phenomenon, from the standpoint of applications; in actual implementation it is accomplished by time-sharing among tasks as controlled by the kernel.

   A task that invokes a system call is called the "invoking task".

2. **Dispatch, dispatcher**

   The switching of tasks executed by the processor is called "dispatching" (or task dispatching). The kernel mechanism by which dispatching is realized is called a "dispatcher" (or task dispatcher).

3. **Scheduling, scheduler**

   The processing to determine which task to execute next is called "scheduling" (or task scheduling). The kernel mechanism by which scheduling is realized is called a "scheduler" (or task scheduler). Generally a scheduler is implemented inside system call processing or in the dispatcher.

4. **Context**

   The environment in which a program runs is generally called "context". For a context to be called identical, at the very least the processor operation mode must be the same and the stack space must be the same (part of the same contiguous area). Note that context is a conceptual matter from the standpoint of applications; even when processing must be executed in independent contexts, in actual implementation both contexts may sometimes use the same processor operation mode and the same stack space.

5. **Precedence**

   The relationship among different processing requests that determines their order of execution is called "precedence". When a higher-precedence process becomes ready for execution while a low-precedence process is in progress, as a general rule the higher-precedence process is run ahead of the other process.

Additional Note

Priority is a parameter assigned by an application to control the order of task or message processing. Precedence, on the other hand, is a concept used in the specification to make clear the order in which processing is to be executed. Precedence among tasks is determined based on task priority.

2.2 Task States and Scheduling Rules

2.2.1 Task States

Task states are classified primarily into the five below. Of these, Wait state in the broad sense is further classified into three states. Saying that a task is in a Run state means it is in either RUN state or READY state.

(a) RUN state
The task is currently being executed. When a task-independent portion is executing, except when otherwise specified, the task that was executing prior to the start of task-independent portion execution is said to be in RUN state.

(b) READY state
The task has completed preparations for running, but cannot run because a task with higher precedence is running. In this state, the task is able to run whenever it becomes the task with the highest precedence among the tasks in READY state.

(c) Wait states
The task cannot run because the conditions for running are not in place. In other words, the task is waiting for the conditions for its execution to be met. While a task is in one of the Wait states, the program counter and register values, and the other information representing the program execution state, are saved. When the task resumes running from this state, the program counter, registers and other values revert to their values immediately prior to going to the Wait state. This state is subdivided into the following three states.

(c.1) WAIT state
Execution is stopped because a system call was invoked that interrupts execution of the invoking task until some condition is met.

(c.2) SUSPEND state
Execution was forcibly interrupted by another task.

(c.3) WAIT-SUSPEND state
The task is in both WAIT state and SUSPEND state at the same time. WAIT-SUSPEND state results when another task requests suspension of a task already in WAIT state

T-Kernel makes a clear distinction between WAIT state and SUSPEND state. A task cannot go to SUSPEND state on its own.

(d) DORMANT state
The task has not yet been started or has completed execution. While a task is in DORMANT state, information presenting its execution state is not saved. When a task is started from DORMANT state, execution starts from the task start address. Except when otherwise specified, the register values are not saved.

(e) NON-EXISTENT state
A virtual state before a task is created, or after it is deleted, and is not registered in the system.

Depending on the implementation, there may also be transient states that do not fall into any of the above categories (see 2.5.1).
When a task going to READY state has higher precedence than the currently running task, a dispatch may occur at the same time as the task goes to READY state and it may make an immediate transition to RUN state. In such a case the task that was in RUN state up to that time is said to have been preempted by the task newly going to RUN state. Note also that in explanations of system call functions, even when a task is said to go to READY state, depending on the task precedence it may go immediately to RUN state.
Task starting means transferring a state from DORMANT state to READY state. A task is therefore said to be in "started" state if it is in any state other than DORMANT or NON-EXISTENT. Task exit means that a task in started state goes to DORMANT state.
Task wait release means that a task in WAIT state goes to READY state, or a task in WAIT-SUSPEND state goes to SUSPEND state. The resumption of a suspended task means that a task in SUSPEND state goes to READY state, or a task in WAIT-SUSPEND state goes to WAIT state.
Task state transitions in a typical implementation are shown in Figure 2.1.
Depending on the implementation, there may be other states besides those shown here.
A feature of T-Kernel is the clear distinction made between system calls that perform operations affecting the invoking task and those whose operations affect other tasks (see Table 2.1). The reason for this is to clarify task state transitions and facilitate understanding of system calls. This distinction between system call operations in the invoking task and operations affecting other tasks can also be seen as a distinction between state transitions from RUN state and those from other states.

Additional Note

	Operations in invoking task (transitions from RUN state)	Operations on other tasks (transitions from other states)
Task transition to a wait state (including SUSPEND)	`tk_slp_tsk` RUN ↓ WAIT	`tk_sus_tsk` READY → SUSPEND WAIT → WAIT-SUSPEND
Task exit	`tk_ext_tsk` RUN ↓ DORMANT	`tk_ter_tsk` READY → DORMANT WAIT → DORMANT
Task deletion	`tk_exd_tsk` RUN ↓ NON-EXISTENT	`tk_del_tsk` DORMANT ↓ NON-EXISTENT

Table 2.1: State Transitions Distinguishing Invoking Task and Other Tasks

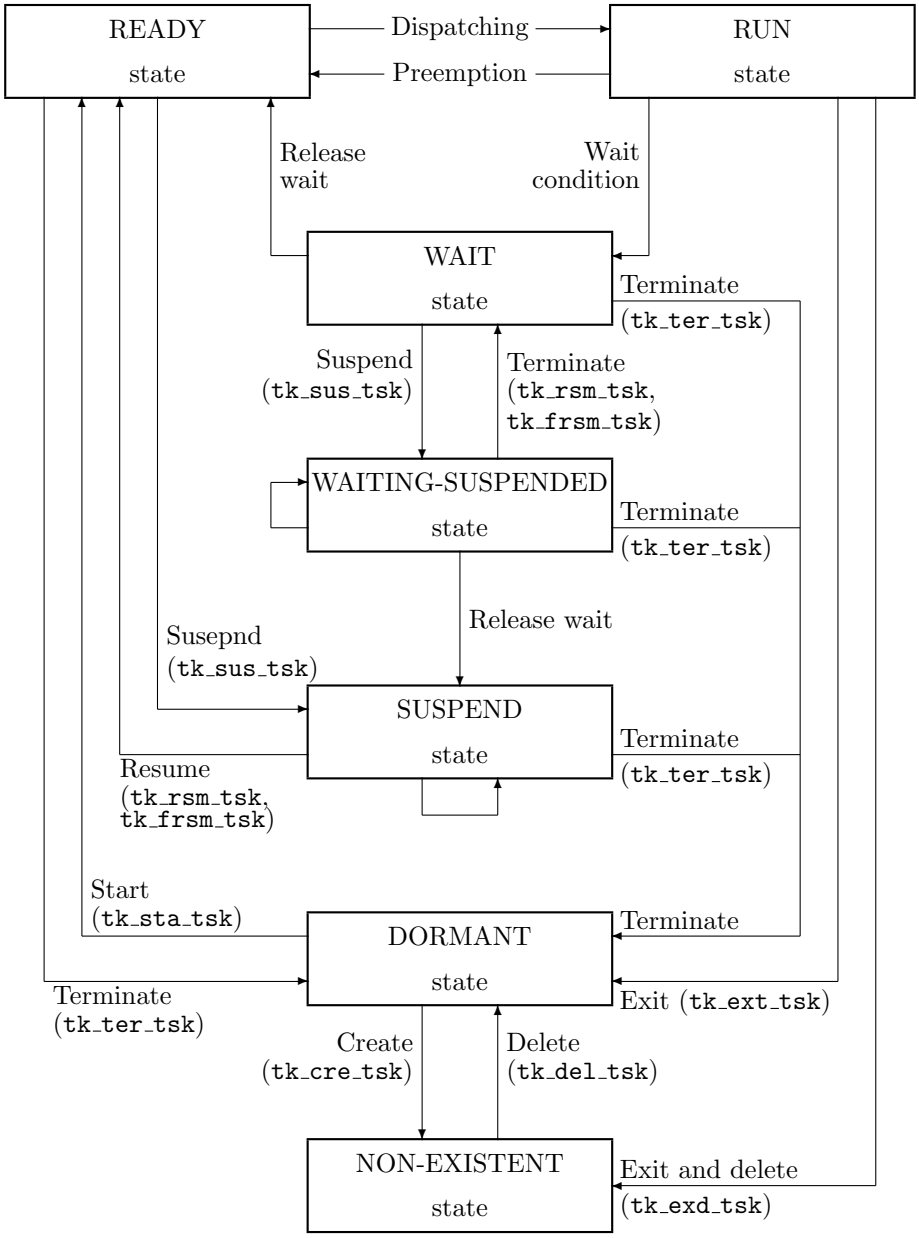


Figure 2.1: Task State Transitions

WAIT state and SUSPEND state are orthogonally related, in that a request for transition to SUSPEND state cannot have any effect on the conditions for task wait release. That is, the task wait release conditions are the same whether the task is in WAIT state or WAIT-SUSPEND state. Thus even if transition to SUSPEND state is requested for a task that is in a state of waiting to acquire some resource (semaphore resource, memory block, etc.), and the task goes to WAIT-SUSPEND state, the

conditions for allocation of the resource do not change but remain the same as before the request to go to SUSPEND state.

Rationale for the Specification

The reason the T-Kernel specification makes a distinction between WAIT state (wait caused by the invoking task) and SUSPEND state (wait caused by another task) is that these states sometimes overlap. By distinguishing this overlapped state as WAIT-SUSPEND state, the task state transitions become clearer and system calls are easier to understand. On the other hand, since a task in WAIT state cannot invoke a system call, different types of WAIT state (e.g., waiting for wakeup, or waiting to acquire a semaphore resource) will never overlap. Since there is only one kind of wait state caused by another task (SUSPEND state), the T-Kernel specification treats overlapping of SUSPEND states as nesting, thereby achieving clarity of task state transitions.

2.2.2 Task Scheduling Rules

The T-Kernel specification adopts a preemptive priority-based scheduling method based on priority levels assigned to each task. Tasks having the same priority are scheduled on a FCFS (First Come First Served) basis. Specifically, task precedence is used as the task scheduling rule, and precedence among tasks is determined as follows based on the priority of each task. If there are multiple tasks that can be run, the one with the highest precedence goes to RUN state and the others go to READY state.
In determining precedence among tasks, of those tasks having different priority levels, that with the highest priority has the highest precedence. Among tasks having the same priority, the one first going to a run state (RUN state or READY state) has the highest precedence. It is possible, however, to use a system call to change the precedence among tasks having the same priority.
When the task with the highest precedence changes from one task to another, a dispatch occurs immediately and the task in RUN state is switched over. If no dispatch occurs, however, the switching of the task in RUN state is held off until dispatch occurs.

Additional Note

According to the scheduling rules adopted in the T-Kernel specification, so long as there is a high-precedence task in a run state, a task with lower precedence will simply not run. That is, unless the highest-precedence goes to WAIT state or for other reason cannot run, other tasks are not run. This is a fundamental difference from TSS (Time Sharing System) scheduling in which multiple tasks are treated equally. It is possible, however, to issue a system call changing the precedence among tasks having the same priority. An application can use such a system call to realize round-robin scheduling, which is a typical kind of TSS scheduling.
Figure 2.2 and following illustrate how the task that first goes to a run state (RUN state or READY state) gains precedence among tasks having the same priority. Figure 2.2 shows the precedence among tasks after Task A of priority 1, Task E of priority 3, and Tasks B, C and D of priority 2 are started in that order. The task with the highest precedence, Task A, goes to RUN state.
When Task A exits, Task B with the next-highest precedence goes to RUN state (Figure 2.3). When Task A is again started, Task B is preempted and reverts to READY state; but since Task B went to a run state earlier than Task C and Task D, it still has the highest precedence among tasks with the same priority. In other words, the task precedence reverts to that in Figure 2.2.
Next, consider what happens when Task B goes to WAIT state in the conditions in Figure 2.3. Since task precedence is defined among tasks that can be run, the precedence among tasks becomes as shown

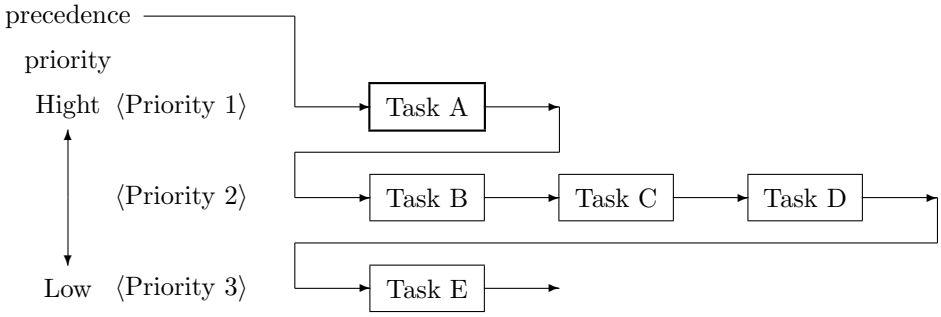


Figure 2.2: Precedence in Initial State

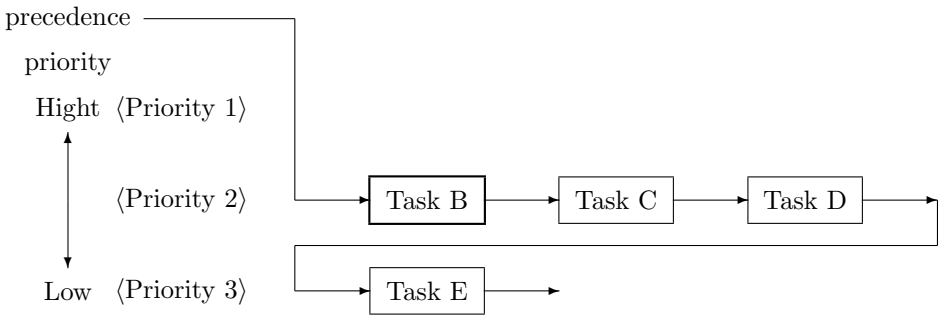


Figure 2.3: Precedence After Task B Goes To RUN State

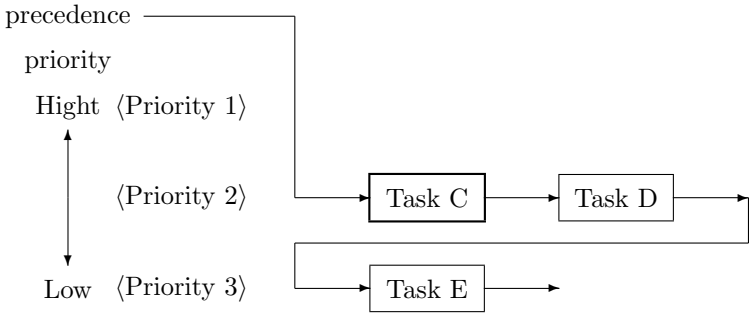


Figure 2.4: Precedence After Task B Goes To WAIT State

in Figure 2.4. Thereafter when the Task B wait state is released, Task B went to run state after Task C and Task D, and thus assumes the lowest precedence among tasks of the same priority (Figure 2.5). Summarizing the above, immediately after a task that went from READY state to RUN state reverts to READY state, it has the highest precedence among tasks of the same priority; but after a task goes from RUN state to WAIT state and then the wait is released, its precedence is the lowest among tasks of the same priority.

Note that after a task goes from SUSPEND state to a run state, it has the lowest precedence among tasks of the same priority. In a virtual memory system, since a task is made to wait for paging by putting the task in SUSPEND state, in such a system the task precedence changes as a result of a paging wait.

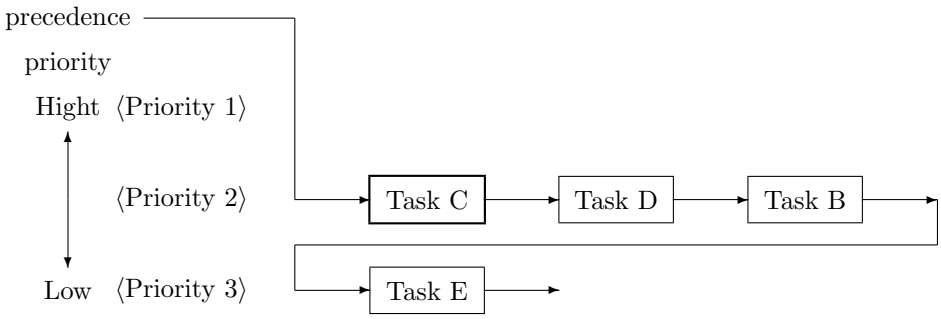


Figure 2.5: Precedence After Task B WAIT State Is Released

2.3 Interrupt Handling

Interrupts in the T-Kernel specification include both external interrupts from devices and interrupts due to CPU exceptions. One interrupt handler may be defined for each interrupt number. Interrupt handlers can be designed for direct starting, basically without OS intervention, or for starting via a high-level language support routine.

2.4 Task Exception Handling

The T-Kernel specification defines task exception handling functions for dealing with exceptions. Note that exceptions other than those in the CPU are treated as interrupts.
A task exception handling function is one that invokes a system call requesting task exception handling, interrupts execution by the designated task, and runs a task exception handler. Execution of the task exception handler takes place in the same context as the interrupted task. Upon return from the task exception handler, the interrupted processing continues. One task exception handler per task can be registered with an application.

2.5 System States

2.5.1 System States While Nontask Portion Is Executing

When programming tasks to run on T-Kernel, the changes in task states can be tracked by looking at a task state transition diagram. In the case of routines such as interrupt handlers or extended SVC handlers, however, the user must perform programming at a level closer to the kernel than tasks. In this case consideration must be made also of system states while a nontask portion is executing, otherwise programming cannot be done properly. An explanation of T-Kernel system states is therefore given here.
System states are classified as in Figure 2.6. Of these, a “transient state” is equivalent to OS running state (system call execution). From the standpoint of the user, it is important that each of the system calls issued by the user be executed indivisibly, and that the internal states while a system call is executing cannot be seen by the user. For this reason the state while the OS running is considered a “transient state” and internally it is treated as a blackbox. In the following cases, however, a transient state is not executed indivisibly.

- When memory is being allocated or freed in the case of a system call that gets or releases memory (while a T-Kernel/SM system memory management function is called).

- In a virtual memory system, when nonresident memory is accessed in system call processing.

When a task is in a transient state such as these, the behavior of a task termination (`tk_ter_tsk`) system call is not guaranteed. Moreover, task suspension (`tk_sus_tsk`) may cause a deadlock or other problem by stopping without clearing the transient state. Accordingly, as a rule `tk_ter_tsk` and `tk_sus_tsk` cannot be used in programs. These system calls should be used only in a subsystem such as a virtual memory system or debugger that is so close to being an OS that it can be thought of as part of the OS.
A task-independent portion and quasi-task portion are states while a handler is executing. The part of a handler that runs in a task context is a quasi-task portion, and the part with a context independent of a task is a task-independent portion. An extended SVC handler, which processes extended system calls defined by the user, is a quasi-task portion, whereas an interrupt handler or time event handler triggered by an external interrupt is a task-independent portion. In a quasi-task portion, tasks have the same kinds of state transitions as ordinary tasks and system calls can be issued even in WAIT state.
A transient state, task-independent portion, and quasi-task portion are together called a nontask portion. When ordinary task programs are running, outside of these, this is "task portion running" state.

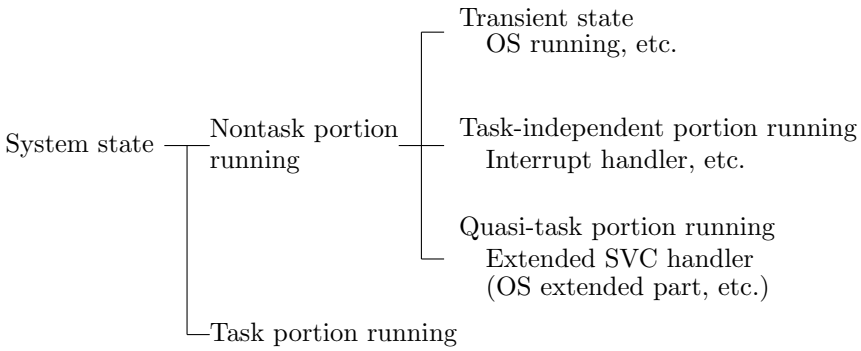


Figure 2.6: Classification of System States

2.5.2 Task-Independent Portion and Quasi-Task Portion

A feature of a task-independent portion (interrupt handlers, time event handlers, etc.) is that it is meaningless to identify the task that was running immediately prior to entering a task-independent portion, and the concept of "invoking task" does not exist. Accordingly, a system call that enters WAIT state, or one that is issued implicitly designating the invoking task, cannot be called fromth a task-independent portion. Moreover, since the currently running task cannot be identified in a task-independent portion, there is no task switching (dispatching). If dispatching is necessary, it is delayed until processing leaves the task-independent portion. This is called delayed dispatching.
If dispatching were to take place in the interrupt handler, which is a task-independent portion, the rest of the interrupt handler routine would be left over for execution after the task started by the dispatching, causing problems in case of interrupt nesting. This is illustrated in Figure 2.7.
In the example shown, Interrupt X is raised during Task A execution, and while its interrupt handler is running, a higher-priority interrupt Y is raised. In this case, if dispatching were to occur immediately on return from interrupt Y (1), starting Task B, the processing of parts (2) to (3) of Interrupt A would be put off until after Task B, with parts (2) to (3) executed only after Task A goes to RUN state. The danger is that the low-priority Interrupt X handler would be preempted not only by a higher-priority

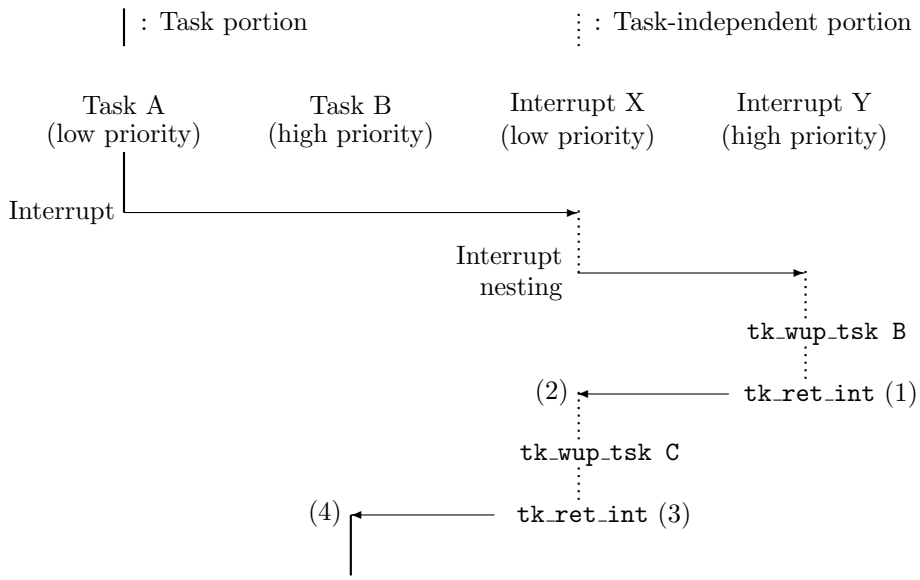
interrupt but even by Task B started by that interrupt. There would no longer be any guarantee of the interrupt handler execution maintaining priority over task execution, making it impossible to write an interrupt handler. This is the reason for introducing the principle of delayed dispatching.
A feature of a quasi-task portion, on the other hand, is that the task executing prior to entering the quasi-task portion (the requesting task) can be identified, making it possible to define task states just as in the task portion; moreover, it is possible to enter WAIT state while in a quasi-task portion. Accordingly, dispatching occurs in a quasi-task portion in the same way as in ordinary task execution. As a result, even though the OS extended part and other quasi-task portion is a nontask portion, its execution does not necessarily have priority at all times over the task portion. This is in contrast to interrupt handlers, which must always be given execution precedence over tasks.
The following two examples illustrate the difference between a task-independent portion and quasi-task portion.

- An interrupt is raised while Task A (priority 8=low) is running, and in its interrupt handler (task-independent portion) `tk_wup_tsk` is issued for Task B (priority 2=high). In accord with the principle of delayed dispatching, however, dispatching does not yet occur at this point. Instead, after `tk_wup_tsk` execution, first the remaining parts of the interrupt handler are executed. Only when `tk_ret_int` is executed at the end of the interrupt handler does dispatching occur, causing Task B to run.

- An extended system call is executed in Task A (priority 8=low), and in its extended SVC handler (quasi-task portion) `tk_wup_tsk` is issued for Task B (priority 2=high). In this case the principle of delayed dispatching is not applied, so dispatching occurs in `tk_wup_tsk` processing. Task A goes to READY state in a quasi-task portion, and Task B goes to RUN state. Task B is therefore executed before the rest of the extended SVC handler is completed. The rest of the extended SVC handler is executed after dispatching occurs again and Task A goes to RUN state.

2.6 Objects

"Object" is the general term for resources handled by T-Kernel. Besides tasks, objects include memory pools, semaphores, event flags, mailboxes and other synchronization and communication mechanisms, as well as time event handlers (cyclic handlers and alarm handlers).
Attributes can generally be designated when an object is created. Attributes determine detailed differences in object behavior or the object initial state. When `TA_XXXXX` is designated for an object, that object is called a "`TA_XXXXX` attribute object". If there is no particular attribute to be defined, `TA_NULL` (= 0) is designated. Generally there is no interface provided for reading attributes after an object is registered.
In an object or handler attribute value, the lower bits indicate system attributes and the upper bits indicate implementation-dependent attributes. This specification does not define the bit position at which the upper and lower distinction is to be made. In principle, however, the system attribute portion is assigned from the least significant bit (LSB) toward the most significant bit (MSB), and implementation-dependent attributes from the MSB toward the LSB. Bits not defining any attribute must be cleared to 0.
In some cases an object may contain extended information. Extended information is designated when the object is registered. Information passed in parameters when an object starts execution has no effect on T-Kernel behavior. Extended information can be read by calling an object status reference system call.



- If dispatching does not take place at (1), the remainder of the handler routine for Interrupt X ((2) to (3)) ends up being put off until later.

Figure 2.7: Interrupt Nesting and Delayed Dispatching

2.7 Memory

2.7.1 Address Space

Memory addressable space is distinguished as system space (shared space) or task space (user space). System space can be accessed equally by all tasks, whereas a task space is accessible only by the tasks belonging to it (see Figure 2.8). Multiple tasks may in some cases belong to the sametask space.
The logical address space of task space and system space depends on the CPU (and MMU) limitations and is therefore implementation-dependent, but in principle task space should be assigned to low addresses and system space to high addresses.

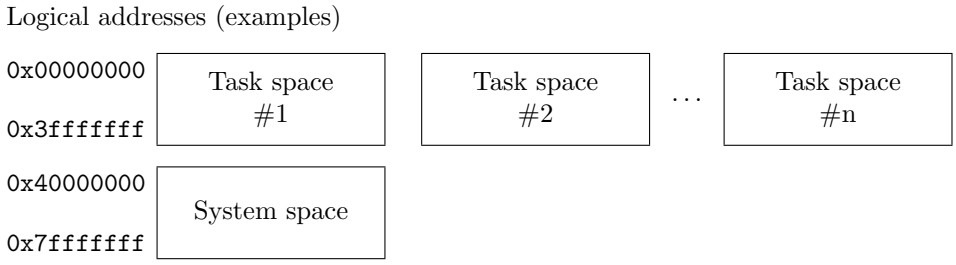


Figure 2.8: Address Space

Since interrupt handlers and other task-independent software are not tasks, they do not have a task

space of their own. Instead, while in a task-independent portion they belong to the task executing just before entering the task-independent portion. This is the same as the task space of the currently running task returned by `tk_get_tid`. When there is no task in RUN state, task space is undefined.
T-Kernel does not create or manage address space. Normally T-Kernel is used along with a subsystem for handling address space management and the like.
In a system with no MMU (or not using an MMU), essentially task space does not exist.

2.7.2 Nonresident Memory

Memory may be resident or nonresident.
When nonresident memory is accessed, data is copied to that memory from a disk or other storage. It therefore requires complicated processing such as disk access by a device driver.
Accordingly, when nonresident memory is accessed, the device driver, etc., must be in operational state. Access is not possible during dispatch disabled or interrupts disabled state, or while a task-independent portion is executing.
Similarly, in OS internal processing, it is necessary to avoid accessing nonresident memory in a critical section. One such case would be when the memory address passed in a system call parameter points to nonresident memory. Whether or not system call parameters are allowed to indicate nonresident memory is an implementation-dependent matter.
Data transfer from a disk or the like due to nonresident memory access is not performed by T-Kernel. Normally T-Kernel is used along with subsystems that handle virtual memory management and other such processing.
In a system that does not use virtual memory, system call parameters or the like pointing to nonresident memory can be ignored, treating all memory as resident.

2.7.3 Protection Levels

T-Kernel assumes four levels of memory protection, from 0 to 3.

- Level 0 has the highest privilege and level 3 the lowest.
- Access can be made only to memory at the currently running protection level or lower.
- Changing from one protection level to another is accomplished by invoking a system call or extended SVC, or by interrupt or CPU exception.

The uses of each protection level are as follows.

Protection level	
0	OS, subsystems, device drivers, etc.
1	System application tasks
2	(reserved)
3	User application tasks

A nontask portion (task-independent portion, quasi-task portion, etc.) runs at protection level 0. Only a task portion can run at protection levels 1 to 3. A task portion can also run at protection level 0.
Some MMUs support only two protection levels, privileged and user level. In such a case protection levels 0 to 2 are assigned to privileged level, and protection level 3 to the user level, as if there were 4 levels. In a system with no MMU, all protection levels 0 to 3 are treated as identical.

Chapter 3

Common T-Kernel Specifications

3.1 Data Types

3.1.1 General Data Types

```
typedef char             B;  /* signed 8-bit integer */
typedef short            H;  /* signed 16-bit integer */
typedef int              W;  /* signed 32-bit integer */
typedef unsigned char   UB;  /* unsigned 8-bit integer */
typedef unsigned short  UH;  /* unsigned 16-bit integer */
typedef unsigned int    UW;  /* unsigned 32-bit integer */

typedef char            VB;  /* 8-bit data without a fixed type */
typedef short           VH;  /* 16-bit data without a fixed type */
typedef int             VW;  /* 32-bit data without a fixed type */
typedef void           *VP;  /* pointer to data without a fixed type */

typedef volatile B      _B;  /* volatile declaration */
typedef volatile H      _H;
typedef volatile W      _W;
typedef volatile UB    _UB;
typedef volatile UH    _UH;
typedef volatile UW    _UW;

typedef int            INT;  /* signed integer of processor bit width*/
typedef unsigned int  UINT;  /* unsigned integer of processor bit width*/

typedef INT             ID;  /* general ID */
typedef INT           MSEC;  /* general time (milliseconds)*/

typedef void       (*FP)();  /* general function address */
typedef INT     (*FUNCP)();  /* general function address */

#define LOCAL       static   /* local symbol definition */
#define EXPORT               /* global symbol definition */
#define IMPORT      extern   /* global symbol reference */
```

```
/*
 * Boolean values
 *   TRUE = 1 is defined, but any value other than 0 is TRUE.
 *   A decision such as bool == TRUE must be avoided for this reason.
 *   Instead use bool != FALSE.
 */
typedef INT           BOOL;
#define TRUE             1   /* True */
#define FALSE            0   /* False */

/*
 * TRON character codes
 */
typedef UH              TC;  /* TRON character code */
#define TNULL       ((TC)0)  /* TRON code string termination */
```

- VB, VH, and VW differ from B, H, and W in that the former mean only the bit width is known, not the contents of the data type, whereas the latter clearly indicate integer type.
- Processor bit width must be 32 bits or above. INT and UINT must therefore always have a width of 32 bits or more.
- BOOL defines TRUE = 1, but any value other than 0 is also TRUE. For this reason a decision such as `bool == TRUE` must be avoided. Instead use `bool != FALSE`.

[Additional Notes]

Parameters such as stksz, wupcnt, and message size that clearly do not take negative values are also in principle signed integer (INT) data type. This is in keeping with the overall TRON rule that integers should be treated as signed numbers to the extent possible. As for the timeout (`TMO tmout`) parameter, its being a signed integer enables the use of TMO_FEVR(= −1) having special meaning. Parameters with unsigned data type are those treated as bit patterns (object attribute, event flag, etc.).

3.1.2 Other Defined Data Types

The following names are used for other data types that appear frequently or have special meaning, in order to make the parameter meaning clear.

```
typedef INT         FN;    /* Function code */
typedef INT        RNO;    /* Rendezvous number */
typedef UINT       ATR;    /* Object/handler attributes */
typedef INT         ER;    /* Error code */
typedef INT        PRI;    /* Priority */
typedef INT        TMO;    /* Timeout designation */
typedef UINT    RELTIM;    /* Relative time */

typedef struct systim {    /* System time */
        W   hi;            /* High 32 bits */
        UW  lo;            /* Low 32 bits */
} SYSTIM;
```



```
/*
 * Common constants
 */

#define NULL         0     /* Null pointer */
#define TA_NULL      0     /* No special attributes indicated */
#define TMO_POL      0     /* Polling */
#define TMO_FEVR   (-1)    /* Eternal wait */
```

- A data type that combines two or more data types is represented by its main data type. For example, the value returned by `tk_cre_tsk` can be a task ID or error code, but since it is mainly a task ID, the data type is ID.

3.2 System Calls

3.2.1 System Call Format

T-Kernel adopts C as the standard high-level language, and standardizes interfaces for system call execution from C language routines.
The method for interfacing at the assembly language level is implementation-dependent and not standardized here. Calling by means of a C language interface is recommended even when an assembly language program is created. In this way portability is assured for programs written in assembly language even if the OS changes, so long as the CPU is the same.
The following common rules are established for system call interfaces.

- All system calls are defined as C functions.
- A function return code of 0 or a positive value indicates normal completion, while negative values are used for error codes.

All system call interfaces are provided as libraries. C language macros, inline functions and inline assembly code are not used. The reason is that C macros and inline functions can be used only from a C program. Moreover, since inline functions and inline assembly are not standard C features, their functioning is in many cases compiler-dependent, diminishing portability.

3.2.2 System Calls Possible from Task-Independent Portion

It must be possible to issue the following system calls from a task-independent portion and in dispatch disabled state. Whether other system calls can be issued from a task-independent portion or in dispatch disabled state is implementation-dependent.

tk_sta_tsk	Start task
tk_wup_tsk	Wakeup task
tk_rel_wai	Release wait
tk_sus_tsk	Suspend task
tk_sig_sem	Signal semaphore
tk_set_flg	Set event flag
tk_sig_tev	Send event to task
tk_rot_rdq	Rotate task queue
tk_get_tid	Get task ID
tk_sta_cyc	Start cyclic handler
tk_stp_cyc	Stop cyclic handler
tk_sta_alm	Start alarm handler
tk_stp_alm	Stop alarm handler
tk_ref_tsk	Reference task status
tk_ref_cyc	Reference cyclic handler status
tk_ref_alm	Reference alarm handler status
tk_ref_sys	Reference system status
tk_ret_int	Return from interrupt handler

3.2.3 Restricting System Call Invocation

The protection levels at which a system call is invokable can be restricted. In this case, if a system call is issued from a task (task portion) running at lower than the designated protection level, the error code E_OACV is returned.
Extended SVC calling cannot be restricted.
If, for example, system call issuing from a protection level lower than 1 is prohibited, system calls cannot be made from tasks running at protection levels 2 and 3. Tasks running at those levels will only be able to make extended SVC calls, and are programmed using subsystem functions only.
This kind of restriction is used when T-Kernel is combined with an upper OS, to prevent tasks based on the upper OS specification from directly accessing T-Kernel functions. It allows T-Kernel to be used as a microkernel.
The protection level restriction on system call invocation is set using the system configuration information management functions (see 5.7).

3.2.4 Modifying a Parameter Packet

Some parameters passed to system calls use a packet format. The packet format parameters are of two kinds, either input parameters passing information to a system call (e.g., T_CTSK) or output parameters returning information from a system call (e.g., T_RTSK).
Additional information that is implementation-dependent can be added to a parameter packet. It is not allowable, however, to change the data types and order of information defined in the standard specification or to delete any of this information. When implementation-dependent information is added, it must be positioned after the standard defined information.
When implementation-dependent information is added to a packet of input information passed to a system call (T_CTSK, etc.), if the system call is invoked while this additional information is not yet initialized (memory contents indeterminate), the system call must still function normally.
Ordinarily a flag indicating that valid values are set in the additional information is defined in the attribute flag implementation-dependent area included in the standard specification. When that flag is set (1), the additional information is to be used; and when the flag is not set (0), the additional information is not initialized (memory contents indeterminate) and the default settings are to be used.

The reason for this specification is to ensure that a program developed within the scope of the standard specification will be able to run on an OS with implementation-dependent functional extensions, simply by recompiling.

3.2.5 Function Codes

Function codes are numbers assigned to each system call and used to identify the system call.
The system call function codes are not specified here but are to be defined in implementation.
See at `tk_def_ssy` on extended SVC function codes.

3.2.6 Error Codes

System call return codes are in principle to be signed integers. When an error occurs, a negative error code is returned; and if processing is completed normally, `E_OK` (= 0) or a positive value is returned. The meaning of returned values in the case of normal completion is specified separately for each system call. An exception to this principle is that there are some system calls that do not return when called. A system call that does not return is declared in the C language API as having no return code (that is, a void type function).
An error code consists of the main error code and sub error code. The low 16 bits of the error code are the sub error code, and the remaining high bits are the main error code. Main error codes are classified into error classes based on the necessity of their detection, the circumstances in which they occur and other factors. Since T-Kernel/OS does not use a sub error code, these bits are always 0.

```
#define MERCD(er)       ( (ER)(er) >> 16 )  /* Main error code */
#define SERCD(er)       ( (H)(er) )         /* Sub error code  */
#define ERCD(mer, ser)  ( (ER)(mer) << 16 | (ER)(UH)(ser) )
```

3.2.7 Timeout

A system call that may enter WAIT state has a timeout function. If processing is not completed by the time the designated timeout interval has elapsed, the processing is canceled and the system call returns error code `E_TMOUT`.
In accord with the principle that there should be no side-effects from calling a system call if that system call returns an error code, the calling of a system call that times out should in principle result in no change in system state. An exception to this is when the functioning of the system call is such that it cannot return to its original state if processing is canceled. This is indicated in the system call description.
If the timeout interval is set to 0, a system call does not enter even when a situation arises in which it would ordinarily go to WAIT state. In other words, a system call with timeout set to 0 when it is invoked has no possibility of entering WAIT state. Invoking a system call with timeout set to 0 is called polling; that is, a system call that performs polling has no chance of entering WAIT state.
The descriptions of individual system calls as a rule describe the behavior when there is no timeout (in other words, when an endless wait occurs). Even if the system call description says that the system call "enters WAIT state" or "is put in WAIT state", if a timeout is set and that time interval elapses before processing is completed, the WAIT state is released and the system call returns error code `E_TMOUT`. In the case of polling, the system call returns `E_TMOUT` without entering WAIT state.
Timeout designation (TMO type) is made as a positive integer, or as `TMO_POL` (= 0) for polling, or as `TMO_FEVR` (= −1) for endless wait. If a timeout interval is set, the timeout processing must be guaranteed to take place even after the designated interval from the system call issuing has elapsed.

[Additional Notes]

Since a system call that performs polling does not enter WAIT state, there is no change in the precedence of the task calling it.
In a general implementation, when the timeout is set to 1, timeout processing takes place on the second time tick after a system call is invoked. Since a timeout of 0 cannot be designated (0 being allocated to TMO_POL), in this kind of implementation timeout does not occur on the initial time tick after the system call is invoked.

3.2.8 Relative Time and System Time

When the time of an event occurrence is designated relative to another time, such as the time when a system call was invoked, relative time (RELTIM type) is used. If relative time is used to designate event occurrence time, it is necessary to guarantee that the event processing will take place after the designated time has elapsed from the time base. Relative time (RELTIM type) is used also when event occurrence interval or other designation besides event occurrence time is made. In such cases the method of interpreting the designated relative time is determined for each case.
When time is designated as an absolute value, system time (SYSTIM type) is used. The T-Kernel specification provides a function for setting system time, but even if the system time is changed using this function, there is no change in the real world time (actual time) at which an event occurred that was designated using relative time. What changes is the system time at which an event occurred that was designated as relative time.

- SYSTIM: System time
  Time base 1 millisecond, 64-bit signed integer

```
typedef struct systim {
        W   hi; /* high 32 bits */
        UW  lo; /* low  32 bits */
} SYSTIM;
```

- RELTIM: Relative time
  Time base 1 millisecond, 32-bit or higher unsigned integer (UINT)

```
typedef UINT    RELTIM;
```

- TMO: Timeout time Time base 1 millisecond, 32-bit or higher signed integer (INT)

```
typedef INT     TMO;
```

  Endless wait can be designated as TMO_FEVR = (−1).

Additional Note

Timeout or other such processing must be guaranteed to occur after the time designated as RELTIM or TMO has elapsed. For example, if the timer interrupt cycle is 1 ms and a timeout of 1 ms is designated, timeout occurs on the second timer interrupt. (The first timer interrupt does not exceed 1 ms.)

3.3 High-Level Language Support Routines

High-level language support routine capability is provided so that even if a task or handler is written in high-level language, the kernel-related processing can be kept separate from the language environment-related processing. Whether or not a high-level language support routine is used is designated in `TA_HLNG`, one of the object attributes and handler attributes.

When `TA_HLNG` is not designated, a task or handler is started directly from the start address passed in a parameter to `tk_cre_tsk` or `tk_def_???`; whereas when `TA_HLNG` is designated, first the high-level language startup processing routine (high-level language support routine) is started, then from this routine an indirect jump is made to the task start address or handler address passed in a parameter to `tk_cre_tsk` or `tk_def_???`. Viewed from the OS, the task start address or handler address is a parameter pointing to the high-level language support routine. Separating the kernel processing from the language environment processing in this way facilitates support for different language environments.

Use of high-level language support routines has the further advantage that when a task or handler is written as a C language function, a system call for task exit or return from a handler can be executed automatically, simply by performing a function return (`return` or "`}`").

In a system that uses an MMU, however, whereas it is relatively easy to realize a high-level language support routine in the case of an interrupt handler or the like that runs at the same protection level as the OS, it is more difficult in the case of a task or task exception handler running at a different protection level than the OS. For this reason, when a high-level language support routine is used for a task, there is no guarantee that the task will exit by a return from the function. In the case of a task exception handler, the high-level language support routine is supplied as source code and is to be embedded in the user program.

The internal working of a high-level language support routine is as illustrated in Figure 3.1.

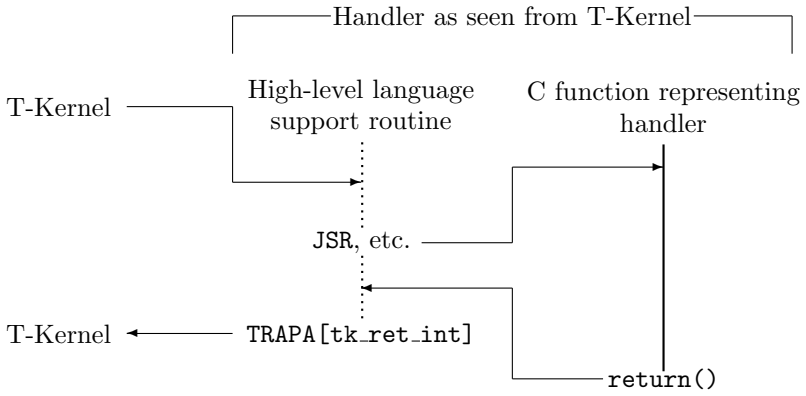


Figure 3.1: Behavior of High-Level Language Support Routine

Chapter 4

T-Kernel/OS Functions

This chapter describes in detail the system calls provided by the T-Kernel Operating System (T-Kernel/OS).

4.1 Task Management Functions

Task management functions are functions that directly manipulate or reference task states. Functions are provided for creating and deleting a task, for task starting and exit, canceling a task start request, changing task priority, and referencing task state. A task is an object identified by an ID number called a task ID. Task states and scheduling rules are explained at 2.2.
For control of execution order, a task has a base priority and current priority. When simply "task priority" is talked about, this means the current priority. The base priority of a task is initialized as the startup priority when a task is started. If the mutex function is not used, the task current priority is always identical to its base priority. For this reason, the current priority immediately after a task is started is the task startup priority. When the mutex function is used, the current priority is set as discussed at 4.5.1.
The kernel does not perform processing for freeing of resources acquired by a task (semaphore resources, memory blocks, etc.) upon task exit, other than mutex unlocking. Freeing of task resources is the responsibility of the application.

tk_cre_tsk

Create Task

[C Language Interface]

```
ID tskid = tk_cre_tsk ( T_CTSK *pk_ctsk ) ;
```

[Parameters]

T_CTSK*	pk_ctsk	Information about the task to be created

pk_ctsk detail:

VP	exinf	Extended information
ATR	tskatr	Task attributes
FP	task	Task start address
PRI	itskpri	Initial task priority
INT	stksz	Stack size (bytes)
INT	sstksz	System stack size (bytes)
VP	stkptr	User stack pointer
VP	uatb	Task space page table
INT	lsid	Logical space ID
ID	resid	Resource ID

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	tskid	Task ID
	or	Error Code

[Error Codes]

E_NOMEM	Insufficient memory (memory for control block or user stack cannot be allocated)
E_LIMIT	Number of tasks exceeds the system limit
E_RSATR	Reserved attribute (tskatr is invalid or cannot be used), or the designated coprocessor does not exist
E_NOSPT	Unsupported function (when TA_USERSTACK or TA_TASKSPACE is not supported)
E_PAR	Parameter error
E_ID	Invalid resource ID (resid)
E_NOCOP	The designated coprocessor cannot be used (not installed, or abnormal operation detected)

[Description]

Creates a task, assigning to it a task ID number. This system call allocates a TCB (Task Control Block) to the created task and initializes it based on itskpri, task, stksz and other parameters.
After the task is created, it is initially in DORMANT state.

`itskpri` designates the initial priority at the time the task is started.
Task priority values are designated from 1 to 140, with the smaller numbers indicating higher priority.
`exinf` can be used freely by the user to insert miscellaneous information about the task. The information set here is passed to the task as startup parameter information and can be referred to by calling `tk_ref_tsk`. If a larger area is needed for indicating user information, or if the information may need to be changed after the task is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in `exinf`. The OS pays no attention to the contents of `exinf`.
`tskatr` indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of `tskatr` is as follows.

```
tskatr := (TA_ASM || TA_HLNG)
       | [TA_SSTKSZ] | [TA_USERSTACK] | [TA_TASKSPACE] | [TA_RESID]
       | (TA_RNG0 || TA_RNG1 || TA_RNG2 || TA_RNG3)
       | [TA_COP0] | [TA_COP1] | [TA_COP2] | [TA_COP3] | [TA_FPU]
```

`TA_ASM`	Indicates that the task is written in assembly language
`TA_HLNG`	Indicates that the task is written in high-level language
`TA_SSTKSZ`	Designates the system stack size
`TA_USERSTACK`	Points to the user stack
`TA_TASKSPACE`	Points to the task space
`TA_RESID`	Designates the resource group to which the task belongs
`TA_RNG`*n*	Indicates that the task runs at protection level *n*
`TA_COP`*n*	Designates use of the *n*th coprocessor (including floating point coprocessor or DSP)
`TA_FPU`	Designates use of a floating point coprocessor (when a coprocessor designated in `TA_COP`*n* is a general-purpose FPU particularly for floating point processing and not dependent on the CPU)

The function for designating implementation-dependent attributes can be used, for example, to designate that a task is subject to debugging. One use of the remaining system attribute fields is for indicating multiprocessor attributes in the future.

```
#define TA_ASM          0x00000000  /* Assembly program            */
#define TA_HLNG         0x00000001  /* High-level language program */
#define TA_SSTKSZ       0x00000002  /* System stack size           */
#define TA_USERSTACK    0x00000004  /* User stack pointer          */
#define TA_TASKSPACE    0x00000008  /* Task space pointer          */
#define TA_RESID        0x00000010  /* Task resource group         */
#define TA_RNG0         0x00000000  /* Run at protection level 0   */
#define TA_RNG1         0x00000100  /* Run at protection level 1   */
#define TA_RNG2         0x00000200  /* Run at protection level 2   */
#define TA_RNG3         0x00000300  /* Run at protection level 3   */
#define TA_COP0         0x00001000  /* Use ID=0 coprocessor        */
#define TA_COP1         0x00002000  /* Use ID=1 coprocessor        */
#define TA_COP2         0x00004000  /* Use ID=2 coprocessor        */
#define TA_COP3         0x00008000  /* Use ID=3 coprocessor        */
```

When `TA_HLNG` is designated, starting the task jumps to the task address not directly but by going through a high-level language environment configuration program (high-level language support routine). The task takes the following form in this case.


```
void task( INT stacd, VP exinf )
{
    /*
        (processing)
     */
     tk_ext_tsk(); or tk_exd_tsk();  /* Exit task */
}
```

The startup parameters passed to the task include the task startup code `stacd` designated in `tk_sta_tsk`, and the extended information `exinf` designated in `tk_cre_tsk`.
The task cannot (must not) be terminated by a simple return from the function, otherwise the operation will be indeterminate (implementation-dependent).
The form of the task when the `TA_ASM` attribute is designated in implementation-dependent, but `stacd` and `exinf` must be passed as startup parameters.
The task runs at the protection level designated in the `TA_RNG`*n* attribute. When a system call or extended SVC is called, the protection level goes to 0, then goes back to its original level upon return from the system call or extended SVC.
Each task has two stack areas, a system stack and user stack. The user stack is used at the protection level designated in `TA_RNG`*n*, while the system stack is used at protection level 0. When the calling of a system call or extended SVC causes the protection level to change, the stack is also switched.
Note that a task running at `TA_RNG0` does not switch protection levels, so there is no stack switching either. When `TA_RNG0` is designated, the combined total of the user stack size and system stack size is the size of one stack, employed as both a user stack and system stack.
When `TA_SSTKSZ` is designated, `sstksz` is valid. If `TA_SSTKSZ` is not designated, `sstksz` is ignored and the default size applies.
When `TA_USERSTACK` is designated, `stkptr` is valid. In this case a user stack is not provided by the OS, but must be allocated by the caller. `stksz` must be set to 0. If `TA_USERSTACK` is not designated, `stkptr` is ignored. Note that if `TA_RNG0` is set, `TA_USERSTACK` cannot be designated.
When `TA_TASKSPACE` is designated, `uatb` and `lsid` are valid and are set as task space. If `TA_TASKSPACE` is not designated, `uatb` and `lsid` are ignored and task space is undefined. During the time task space is undefined, only system space can be accessed; access to task (user) space is not allowed. Whether or not `TA_TASKSPACE` was designated, task space can be changed after a task is created. Note that when task space is changed, in no case does it revert to the task space set at task creation, even when the task returns to DORMANT state, but the task always uses the most recently set task space.
When `TA_RESID` is designated, `resid` is valid and designates the resource group to which the task belongs. If `TA_RESID` is not designated, resid is ignored and the task belongs to the system resource group. Note that if the resource group of a task is changed, in no case does it revert to the resource group set at task creation, even when the task returns to DORMANT state, but the task always retains the most recently set resource group (see `tk_cre_res`).

[Additional Notes]

A task runs either at the protection level set in `TA_RNG`*n* or at protection level 0. For example, a task for which `TA_RNG3` is designated in no case runs at protection level 1 or 2.
In a system with separate interrupt stack, interrupt handlers also use the system stack. An interrupt handler runs at protection level 0.
The system stack default size is decided taking into account the amount taken up by system call execution and, in a system with separate interrupt stack, the amount used by interrupt handlers.
The system stack is system space resident memory used at protection level 0. If `TA_USERSTACK` is not designated, the user stack is system space resident memory used at the protection level designated in the

TA_RNG*n* attribute. If TA_USERSTACK is designated, the user stack memory attributes are as designated by the caller of this system call. Task space may be made nonresident memory. The definition of TA_COP*n* is dependent on the CPU and other hardware and is not portable. TA_FPU is provided as a portable designation method only for the definition in TA_COP*n* of a floating point processor. If, for example, the floating point processor is TA_COP0, then TA_FPU = TA_COP0. If there is no particular need to designate use of a coprocessor for floating point operations, TA_FPU = 0 is set.
Even in a system without an MMU, for the sake of portability all attributes including TA_RNG*n* must be accepted. It is possible, for example, to handle all TA_RNG*n* designations as equivalent to TA_RNG0, but error must not be returned. In the case of TA_USERSTACK and TA_TASKSPACE, however, E_NOSPT may be returned, since there are many cases where these cannot be supported without an MMU.

tk_del_tsk

Delete Task

[C Language Interface]

```
ER ercd = tk_del_tsk ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (the task is not in DORMANT state)

[Description]

Deletes the task designated in tskid.
This system call changes the state of the task designated in tskid from DORMANT state to NON-EXISTENT state (no longer exists in the system), releasing the TCB and stack area that were assigned to the task. The task ID number is also released. When this system call is issued for a task not in DORMANT state, error code E_OBJ is returned.
This system call cannot designate the invoking task. If the invoking task is designated, error code E_OBJ is returned since the invoking task is not in DORMANT state. The invoking task is deleted not by this system call but by the tk_exd_tsk system call.

tk_sta_tsk

Start Task

[C Language Interface]

```
ER ercd = tk_sta_tsk ( ID tskid, INT stacd ) ;
```

[Parameters]

ID	tskid	Task ID
INT	stacd	Task start code

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (the task is not in DORMANT state)

[Description]

Starts the task designated in tskid.
This system call changes the state of the designated task from DORMANT state to READY state.
Parameters to be passed to the task when it starts can be set in stacd. These parameters can be referred to from the started task, enabling use of this feature for simple message passing.
The task priority when it starts is the task startup priority (itskpri) designated when the started task was created.
Start requests by this system call are not queued. If this system call is issued while the target task is in a state other than DORMANT state, the system call is ignored and error code E_OBJ is returned to the calling task.

tk_ext_tsk

Exit Task

[C Language Interface]

```
void tk_ext_tsk ( ) ;
```

[Parameters]

None

[Return Parameters]

Does not return to the context issuing the system call.

[Error Codes]

The following error can be detected; but since this system call does not return to the context issuing the system call even when error is detected, an error code cannot be passed directly in a system call return parameter. The behavior in case an error occurs is implementation-dependent.

E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Exits the invoking task normally and changes its state to DORMANT state.

[Additional Notes]

When a task terminates by tk_ext_tsk, the resources acquired by the task up to that time (memory blocks, semaphores, etc.) are not automatically freed. The user is responsible for releasing such resources before the task exits.
tk_ext_tsk is a system call that does not return to the context from which it was called. Even if an error code is returned when an error of some kind is detected, normally no error checking is performed in the context from which the system call was invoked, leaving the possibility that the program will hang. For this reason these system calls do not return even if error is detected.
As a rule, the task priority and other information included in the TCB is reset when the task returns to DORMANT state. If, for example, the task priority is changed by tk_chg_pri and later terminated by tk_ext_tsk, the task priority reverts to the startup priority (itskpri) designated when the task was started. It does not keep the task priority in effect at the time tk_ext_tsk was executed.
System calls that do not return to the calling context are those named tk_ret_??? or tk_ext_??? (tk_exd_???).

tk_exd_tsk

Exit and Delete Task

[C Language Interface]

```
void tk_exd_tsk ( ) ;
```

[Parameters]

None.

[Return Parameters]

Does not return to the context issuing the system call.

[Error Codes]

The following error can be detected; but since this system call does not return to the context issuing the system call even when error is detected, an error code cannot be passed directly in a system call return parameter. The behavior in case an error occurs is implementation-dependent.

`E_CTX`	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Terminates the invoking task normally and also deletes it.
This system call changes the state of the invoking task to NON-EXISTENT state (no longer exists in the system).

[Additional Notes]

When a task terminates by `tk_exd_tsk`, the resources acquired by the task up to that time (memory blocks, semaphores, etc.) are not automatically freed. The user is responsible for releasing such resources before the task exits.
`tk_exd_tsk` is a system call that does not return to the context from which it was called. Even if an error code is returned when an error of some kind is detected, normally no error checking is performed in the context from which the system call was invoked, leaving the possibility that the program will hang. For this reason these system calls do not return even if error is detected.

tk_ter_tsk

Terminate Task

[C Language Interface]

```
ER ercd = tk_ter_tsk ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (the target task is in DORMANT state or is the invoking task)

[Description]

Forcibly terminates the task designated in tskid.
This system call changes the state of the target task designated in tskid to DORMANT state.
Even if the target task was in a wait state (including SUSPEND state), the wait state is released and the task is terminated. If the target task was in some kind of queue (semaphore wait, etc.), executing tk_ter_tsk results in its removal from the queue.
This system call cannot designate the invoking task. If the invoking task is designated, error code E_OBJ is returned
The relationships between target task states and the results of executing tk_ter_tsk are summarized in Table 4.1.

Target Task State	tk_ter_tsk ercd Parameter	Processing
RUN or READY state (except if invoking task)	E_OK	Forced termination
RUN state (invoking task)	E_OBJ	No operation
WAIT state	E_OK	Forced termination
DORMANT state	E_OBJ	No operation
NON-EXISTENT state	E_NOEXS	No operation

Table 4.1: Target Task State and Execution Result (tk_ter_tsk)

[Additional Notes]

When a task is terminated by `tk_ter_tsk`, the resources acquired by the task up to that time (memory blocks, semaphores, etc.) are not automatically freed. The user is responsible for releasing such resources before the task terminates.
As a rule, the task priority and other information included in the TCB are reset when the task returns to DORMANT state. If, for example, the task priority is changed by `tk_chg_pri` and later terminated by `tk_ter_tsk`, the task priority reverts to the startup priority (`itskpri`) designated when the task was started. It does not keep the task priority in effect at the time `tk_ter_tsk` was executed.
Forcible termination of another task is intended for use only by a debugger or a few other tasks closely related to the OS. As a rule, this system call is not to be used by ordinary applications or middleware, for the following reason.
Forced termination occurs regardless of the running state of the target task.
If, for example, a task were forcibly terminated while the task was calling a middleware function, the task would terminate right while the middleware was executing. If such a situation were allowed, normal operation of the middleware could not be guaranteed.
This is an example of how task termination cannot be allowed when the task status (what it is executing) is unknown. Ordinary applications therefore must not use the forcible termination function.

tk_chg_pri

Change Task Priority

[C Language Interface]

```
ER ercd = tk_chg_pri ( ID tskid, PRI tskpri ) ;
```

[Parameters]

ID	tskid	Task ID
PRI	tskpri	Task priority

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (tskpri is invalid or cannot be used)
E_ILUSE	Illegal use (upper priority limit exceeded)

[Description]

Changes the base priority of the task designated in tskid to the value designated in tskpri. The current priority of the task also changes as a result.
Task priority values are designated from 1 to 140, with the smaller numbers indicating higher priority.
When TSK_SELF (= 0) is designated in tskid, the invoking task is the target task. Note, however, that when tskid = TSK_SELF is designated in a system call issued from a task-independent portion, error code E_ID is returned. When TPRI_INI (= 0) is designated as tskpri, the target task base priority is changed to the initial priority when the task was started (itskpri).
A priority changed by this system call remains valid until the task is terminated. When the task reverts to DORMANT state, the task priority before its exit is discarded, with the task again assigned to the initial priority when the task was started (itskpri). A priority changed while the task is already in DORMANT state, however, becomes valid, so that the task has the new priority as its initial priority the next time it is started.
If as a result of this system call execution the target task current priority matches the base priority (this condition is always met when the mutex function is not used), processing is as follows.
If the target task is in a run state, the task precedence changes according to its priority. The target task has the lowest precedence among tasks of the same priority after the change.
If the target task is in some kind of priority-based queue, the order in that queue changes in accord with the new task priority. Among tasks of the same priority after the change, the target task is queued at the end.
If the target task has locked a TA_CEILING attribute mutex or is waiting for a lock, and the base priority designated in tskpri is higher than any of the ceiling priorities, error code E_ILUSE is returned.

[Additional Notes]

In some cases when this system call results in a change in the queued order of the target task in a task priority-based queue, it may be necessary to release the wait state of another task waiting in that queue (in a message buffer send queue, or in a queue waiting to acquire a variable-size memory pool).
In some cases when this system call results in a base priority change while the target task is waiting for a `TA_INHERIT` attribute mutex lock, dynamic priority inheritance processing may be necessary.
When a mutex function is not used and the system call is issued designating the invoking task as the target task, setting the new priority to the base priority of the invoking task, the order of execution of the invoking task becomes the lowest among tasks of the same priority. This system call can therefore be used to relinquish execution privilege.

tk_chg_slt

Change Task Time Slice

[C Language Interface]

```
ER ercd = tk_chg_slt ( ID tskid, RELTIM slicetime ) ;
```

[Parameters]

ID	tskid	Task ID
RELTIM	slicetime	Time slice (ms)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (slicetime is invalid)

[Description]

Changes the time slice of the task designated in tskid to the value designated in slicetime.
The time slice function is used for round robin scheduling of tasks. When a task runs continuously for the length of time designated in slicetime or longer, its precedence is switched to the lowest among tasks of the same priority, automatically yielding the execution privilege to the next task.
Setting slicetime = 0 indicates unlimited time, and the task does not automatically yield execution privilege.
When a task is created, by default it is set to slicetime = 0. The invoking task can be designated by setting tskid = TSK_SELF = 0.
Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.
The time slice as changed by this system call remains valid until the task is terminated. When the task reverts to DORMANT state, the time slice before termination is discarded, and the value at the time of task creation (slicetime = 0) is assigned. A time slice changed while the task is already in DORMANT state, however, becomes valid, being applied the next time the task is started.

[Additional Notes]

The time while execution privilege is preempted by a higher-priority task does not count in the continuous run time; moreover, even if execution privilege is preempted by a higher-priority task, the run time is not treated as discontinuous. In other words, the time while execution privilege is preempted by a higher-priority task is ignored for the purposes of counting run time.

If the designated task is the only one running at its priority, the time slice is effectively meaningless and the task runs continuously.
If a task of `slicetime` = 0 is included in tasks of the same priority, as soon as that task obtains execution right, round robin scheduling is stopped.
The method of counting run time is implementation-dependent, but does not need to be especially precise. In fact, applications should not expect very high precision.

tk_get_tsp

Get Task Space

[C Language Interface]

```
ER ercd = tk_get_tsp ( ID tskid, T_TSKSPC *pk_tskspc ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

T_TSKSPC	tskspc	Task space information
ER	ercd	Error code

```
typedef struct t_tskspc {
        VP      uatb;   Task space page table address
        INT     lsid;   Task space ID (logical space ID)
} T_TSKSPC;
```

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

Gets the current task space information for the task designated in tskid.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

The accuracy of T_TSKSPC (uatb, lsid) designation is implementation-dependent, but the above definitions should be followed to the extent possible.

tk_set_tsp

Set Task Space

[C Language Interface]

```
ER ercd = tk_set_tsp ( ID tskid, T_TSKSPC *pk_tskspc ) ;
```

[Parameters]

ID	tskid	Task ID
T_TSKSPC	tskspc	Task space

```
typedef struct t_tskspc {
        VP      uatb;   Task space page table address
        INT     lsid;   Task space ID (logical space ID)
} T_TSKSPC;
```

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (pk_tskspc is invalid or cannot be used)

[Description]

Sets the task space of the task designated in tskid.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.
The OS is not aware of the effects of task space changes. If, for example, a task space is changed while a task is using it for its execution, the task may hang or encounter other problems. The caller is responsible for avoiding such problems.

[Additional Notes]

The accuracy of T_TSKSPC (uatb, lsid) designation is implementation-dependent, but the above definitions should be followed to the extent possible.

tk_get_rid

Get Task Resource Group

[C Language Interface]

```
ID resid = tk_get_rid ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ID	resid	Resource ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Task does not belong to a resource group

[Description]

Returns the resource group to which the task designated in tskid currently belongs.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

If a resource group is deleted, this system call may return the resource ID of the deleted resource group. Whether or not an error code (E_OBJ) is returned is implementation-dependent. (See tk_cre_res, tk_del_res.)

tk_set_rid

Set Task Resource Group

[C Language Interface]

```
ID oldid = tk_set_rid ( ID tskid, ID resid ) ;
```

[Parameters]

ID	tskid	Task ID
ID	resid	New resource ID

[Return Parameters]

ID	oldid	Old resource ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid or resid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskidor resid does not exist)

[Description]

Changes the current resource group of the task designated in tskid to the resource group designated in resid. The resource ID of the old resource group before the change is passed in a return parameter. The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

In some cases error is not returned even if resid was previously deleted. Whether or not an error code (E_NOEXS) is returned is implementation-dependent. In principle it is the responsibility of the caller not to designate a deleted resource group.

tk_get_reg

Get Task Registers

[C Language Interface]

```
ER ercd = tk_get_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

T_REGS	pk_regs	General registers
T_EIT	pk_eit	Registers saved when EIT occurs
T_CREGS	pk_cregs	Control registers
ER	ercd	Error code

The contents of T_REGS, T_EIT, and T_CREGS are defined for each CPU and implementation.

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task)
E_CTX	Context error (called from task-independent portion)

[Description]

Gets the current register contents of the task designated in tskid.
If NULL is set in pk_regs, pk_eit, or pk_cregs, the corresponding registers are not referenced.
The referenced register values are not necessarily the values at the time the task portion was executing.
If this system call is issued for the invoking task, error code E_OBJ is returned.

[Additional Notes]

In principle, all registers in the task context can be referenced. This includes not only physical CPU registers but also those treated by the OS as virtual registers.

tk_set_reg

Set Task Registers

[C Language Interface]

```
ER ercd = tk_set_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs ) ;
```

[Parameters]

ID	tskid	Task ID
T_REGS	pk_regs	General registers
T_EIT	pk_eit	Registers saved when EIT occurs
T_CREGS	pk_cregs	Control registers

The contents of T_REGS, T_EIT, and T_CREGS are defined for each CPU and implementation.

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task)
E_CTX	Context error (called from task-independent portion)
E_PAR	Invalid register value (implementation-dependent)

[Description]

Sets the current register contents of the task designated in tskid.
If NULL is set in pk_regs, pk_eit, or pk_cregs, the corresponding registers are not referenced.
The set register values are not necessarily the values while the task portion is executing. The OS is not aware of the effects of register value changes. It is possible, however, that some registers or register bits cannot be changed if the OS does not allow such changes (implementation-dependent).
If this system call is issued for the invoking task, error code E_OBJ is returned.

tk_get_cpr

Get Coprocessor Registers

[C Language Interface]

```
ER ercd = tk_get_cpr ( ID tskid, INT copno, T_COPREGS *pk_copregs ) ;
```

[Parameters]

ID	tskid	Task ID
INT	copno	Coprocessor number (0 to 3)

[Return Parameters]

T_COPREGS	pk_copregs	Coprocessor registers
ER	ercd	Error code

```
typedef union {
        T_COP0REG   cop0;   Coprocessor number 0 register
        T_COP1REG   cop1;   Coprocessor number 1 register
        T_COP2REG   cop2;   Coprocessor number 2 register
        T_COP3REG   cop3;   Coprocessor number 3 register
} T_COPREG;
```

The contents of T_COP*n*REG are defined for each CPU and implementation.

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task)
E_CTX	Context error (called from task-independent portion)
E_PAR	Parameter error (copno is invalid or the designated coprocessor does not exist)

[Description]

Gets the current contents of the register designated in copno of the task designated in tskid.
The referenced register values are not necessarily the values at the time the task portion was executing.
If this system call is issued for the invoking task, error code E_OBJ is returned.

[Additional Notes]

In principle, all registers in the task context can be referenced. This includes not only physical CPU registers but also those treated by the OS as virtual registers.

tk_set_cpr

Set Coprocessor Registers

[C Language Interface]

```
ER ercd = tk_set_cpr ( ID tskid, INT copno, T_COPREGS *pk_copregs ) ;
```

[Parameters]

ID	tskid	Task ID
INT	copno	Coprocessor number (0 to 3)
T_COPREGS	pk_copregs	Coprocessor registers

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task)
E_CTX	Context error (called from task-independent portion)
E_PAR	Parameter error (copno is invalid or the designated coprocessor does not exist), or the set register value is invalid (implementation-dependent)

[Description]

Sets the contents of the register designated in copno of the task designated in tskid.
The set register values are not necessarily the values while the task portion is executing. The OS is not aware of the effects of register value changes. It is possible, however, that some registers or register bits cannot be changed if the OS does not allow such changes (implementation-dependent).
If this system call is issued for the invoking task, error code E_OBJ is returned.

tk_inf_tsk

Get Task Information

[C Language Interface]

```
ER ercd = tk_inf_tsk ( ID tskid, T_ITSK *pk_itsk, BOOL clr ) ;
```

[Parameters]

ID	tskid	Task ID
T_ITSK*	pk_itsk	Address of packet for returning task information
BOOL	clr	Clear task information

[Return Parameters]

ER	ercd	Error code

pk_itsk detail:

RELTIM	stime	Cumulative system-level run time (ms)
RELTIM	utime	Cumulative user-level run time (ms)

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

Gets statistical information for the task designated in tskid.
If clr = TRUE $\neq 0$, the cumulative information is reset (cleared to 0) after getting the information.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

The system-level run time is that while running at TA_RNG0, and the user-level run time is that while running at protection levels other than TA_RNG0. A task created to run at TA_RNG0 is therefore counted entirely as system-level run time.
The method of counting run time is implementation-dependent, but does not need to be especially precise. In fact, applications should not expect very high precision.

tk_ref_tsk

Reference Task Status

[C Language Interface]

```
ER ercd = tk_ref_tsk ( ID tskid, T_RTSK *pk_rtsk ) ;
```

[Parameters]

ID	tskid	Task ID
T_RTSK*	pk_rtsk	Address of packet for returning task status

[Return Parameters]

ER	ercd	Error code

pk_rtsk detail:

VP	exinf	Extended information
PRI	tskpri	Current task priority
PRI	tskbpri	Base priority
UINT	tskstat	Task state
UINT	tskwait	Wait factor
ID	wid	Waiting object ID
INT	wupcnt	Queued wakeup requests
INT	suscnt	Nested suspend requests
RELTIM	slicetime	Maximum continuous run time allowed (ms)
UINT	waitmask	Disabled wait factors
UINT	texmask	Allowed task exceptions
UINT	tskevent	Task events

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completione
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

Gets the state of the task designated in tskid.
tskstat takes the following values.

tskstat:	TTS_RUN	0x0001	RUN
	TTS_RDY	0x0002	READY
	TTS_WAI	0x0004	WAIT
	TTS_SUS	0x0008	SUSPEND
	TTS_WAS	0x000c	WAIT-SUSPEND
	TTS_DMT	0x0010	DORMANT
	TTS_NODISWAI	0x0080	Wait state disabled

Task states such as TTS_RUN and TTS_WAI are expressed by corresponding bits, which is useful when making a complex state decision (e.g., deciding that the state is one of either RUN or READY state). Note that of the above states, TTS_WAS is a combination of TTS_SUS and TTS_WAI, but TTS_SUS is never combined with other states (TTS_RUN, TTS_RDY, TTS_DMT). In the case of TTS_WAI (including TTS_WAS), if wait states are disabled by tk_dis_wai, TTS_NODISWAI is set. TTS_NODISWAI is never combined with states other than TTS_WAI.
When tk_ref_tsk is executed for an interrupted task from an interrupt handler, RUN (TTS_RUN) is returned as tskstat.
When tskstat is TTS_WAI (including TTS_WAS), the values of tskwait and wid are as shown in Table 4.2.

tskwait	Value	Description	wid
TTW_SLP	0x00000001	Wait caused by tk_slp_tsk	0
TTW_DLY	0x00000002	Wait caused by tk_dly_tsk	0
TTW_SEM	0x00000004	Wait caused by tk_wai_sem	semid
TTW_FLG	0x00000008	Wait caused by tk_wai_flg	flgid
TTW_MBX	0x00000040	Wait caused by tk_rcv_mbx	mbxid
TTW_MTX	0x00000080	Wait caused by tk_loc_mtx	mtxid
TTW_SMBF	0x00000100	Wait caused by tk_snd_mbf	mbfid
TTW_RMBF	0x00000200	Wait caused by tk_rcv_mbf	mbfid
TTW_CAL	0x00000400	Wait on rendezvous call	porid
TTW_ACP	0x00000800	Wait for rendezvous acceptance	porid
TTW_RDV	0x00001000	Wait for rendezvous completion	0
(TTW_CAL|TTW_RDV)	0x00001400	Wait on rendezvous call or wait for rendezvous completion	0
TTW_MPF	0x00002000	Wait for tk_get_mpf	mpfi
TTW_MPL	0x00004000	Wait for tk_get_mpl	mplid
TTW_EV1	0x00010000	Wait for task event #1	0
TTW_EV2	0x00020000	Wait for task event #2	0
TTW_EV3	0x00040000	Wait for task event #3	0
TTW_EV4	0x00080000	Wait for task event #4	0
TTW_EV5	0x00100000	Wait for task event #5	0
TTW_EV6	0x00200000	Wait for task event #6	0
TTW_EV7	0x00400000	Wait for task event #7	0
TTW_EV8	0x00800000	Wait for task event #8	0

Table 4.2: Values of tskwait and wid

When tskstat is not TTS_WAI (including TTS_WAS), both tskwait and wid are 0.
waitmask is the same bit array as tskwait.
For a task in DORMANT state, wupcnt = 0, suscnt = 0, and tskevent = 0.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.
When the task designated with tk_ref_tsk does not exist, error code E_NOEXS is returned.

[Additional Notes]

Even when `tskid` = `TSK_SELF` is designated with this system call, the ID of the invoking task is not known. Use `tk_get_tid` to find out the ID of the invoking task.

4.2 Task-Dependent Synchronization Functions

Task-dependent synchronization functions achieve synchronization among tasks by direct manipulation of task states. They include functions for task sleep and wakeup, for canceling wakeup requests, for forcibly releasing task WAIT state, for changing a task state to SUSPEND state, for delaying execution of the invoking task, and for disabling task WAIT state.
Wakeup requests for a task are queued. That is, when it is attempted to wake up a task that is not sleeping, the wakeup request is remembered, and the next time the task is to go to a sleep state (waiting for wakeup), it does not enter that state. The queuing of task wakeup requests is realized by having the task keep a task wakeup request queuing count. When the task is started, this count is cleared to 0.
Suspend requests for a task are nested. That is, if it is attempted to suspend a task already in SUSPEND state (including WAIT-SUSPEND state), the request is remembered, and later when it is attempted to resume the task in SUSPEND state (including WAIT-SUSPEND state), it is not resumed. The nesting of suspend requests is realized by having the task keep a suspend request nesting count. When the task is started, this count is cleared to 0.

tk_slp_tsk

Sleep Task

[C Language Interface]

```
ER ercd = tk_slp_tsk ( TMO tmout ) ;
```

[Parameters]

TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (tmout $\leq (-2)$)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Changes the state of the invoking task from RUN state to sleep state (WAIT for tk_wup_tsk).
If tk_wup_tsk is issued for the invoking task before the time designated in tmout has elapsed, this system call completes normally. If timeout occurs before tk_wup_tsk is issued, error code E_TMOUT is returned. Designating tmout = TMO_FEVR $= (-1)$ means endless wait. In this case, the task stays in waiting state until tk_wup_tsk is issued.

[Additional Notes]

Since tk_slp_tsk is a system call that puts the invoking task into a wait state, tk_slp_tsk can never be nested. It is possible, however, for another task to issue tk_sus_tsk for a task that was put in a wait state by tk_slp_tsk. In this case the task goes to WAIT-SUSPEND state.
For simply delaying a task, tk_dly_tsk should be used rather than tk_slp_tsk.
The task sleep function is intended for use by applications and as a rule should not be used by middleware. The reason is that attempting to achieve synchronization by putting a task to sleep in two or more places would cause confusion, leading to misoperation. For example, if sleep were used by both an application and middleware for synchronization, a wakeup request might arise in the application while middleware has the task sleeping. In such a situation, normal operation would not be possible in either the application or middleware. Proper task synchronization is not possible because it is not clear where the wait for wakeup originated. Task sleep is often used as a simple means of task synchronization. Applications should be able to use it freely, which means as a rule it should not be used by middleware.

tk_wup_tsk

Wakeup Task

[C Language Interface]

```
ER ercd = tk_wup_tsk ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task or for a task in DORMANT state)
E_QOVR	Queuing or nesting overflow (too many queued wakeup requests in wupcnt)

[Description]

If the task designated in tskid was put in WAIT state by tk_slp_tsk, this system call releases the WAIT state.
This system call cannot be called for the invoking task. If the invoking task is designated, error code E_OBJ is returned.
If the target task has not called tk_slp_tsk and is not in WAIT state, the wakeup request by tk_wup_tsk is queued. That is, the calling of tk_wup_tsk for the target task is recorded, then when tk_slp_tsk is called after that, the task does not go to WAIT state. This is what is meant by queuing of wakeup requests.
The queuing of wakeup requests works as follows. Each task keeps a wakeup request queuing count (wupcnt) in its TCB.
Its initial value (when tk_sta_tsk is executed) is 0. When tk_wup_tsk is issued for a task not sleeping (not in WAIT state), the count is incremented by 1; but each time tk_slp_tsk is executed, the count is decremented by 1. When tk_slp_tsk is executed for a task whose wakeup queuing count is 0, the queuing count does not go into negative territory but rather the task goes to WAIT state.
It is always possible to queue tk_wup_tsk one time (wupcnt = 1), but the maximum queuing count (wupcnt) is implementation-dependent and may be set to any appropriate value of 1 or above. In other words, issuing tk_wup_tsk once for a task not in WAIT state does not return error, but whether error is returned for the second or subsequent time tk_wup_tsk is called is an implementation-dependent matter. When calling tk_wup_tsk causes wupcnt to exceed the maximum allowed value, error code E_QOVR is returned.

tk_can_wup

Cancel Wakeup Task

[C Language Interface]

```
INT wupcnt = tk_can_wup ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

INT	wupcnt	Number of queued wakeup requests
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for a task in DORMANT state)

[Description]

Passes in the return parameter the wakeup request queuing count (wupcnt) for the task designated in tskid, at the same time canceling all wakeup requests. That is, this system call clears the wakeup request queuing count (wupcnt) to 0 for the designated task.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

When processing is performed that involves cyclic wakeup of a task, this system call is used to determine whether the processing was completed within the allotted time. Before processing of a prior wakeup request is completed and tk_slp_tsk is called, the task monitoring this calls tk_can_wup. If wupcnt in the return parameter is 1 or above, this means the previous wakeup request was not processed within the allotted time. A processing delay or other measure can then be taken accordingly.

tk_rel_wai

Release Wait

[C Language Interface]

```
ER ercd = tk_rel_wai ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for a task not in WAIT state (including when called for the invoking task, or for a task in DORMANT state))

[Description]

If the task designated in tskid is in some kind of wait state (not including SUSPEND state), forcibly releases that state.
This system call returns error code E_RLWAI to the task whose WAIT state was released.
Wait release requests by tk_rel_wai are not queued. That is, if the task designated in tskid is already in WAIT state, the WAIT state is cleared; but if it is not in WAIT state when this system call is issued, error code E_OBJ is returned to the caller. Likewise, error code E_OBJ is returned when this system call is issued designating the invoking task.
The tk_rel_wai system call does not release a SUSPEND state. If it is issued for a task in WAIT-SUSPEND state, the task goes to SUSPEND state. If it is necessary to release SUSPEND state, the separate system call tk_frsm_tsk is used. The states of the target task when tk_rel_wai is called and the results of its execution in each state are shown in Table 4.3.

[Additional Notes]

A function similar to timeout can be realized by using an alarm handler or the like to issue this system call after a given task has been in WAIT state for a set time.
The main differences between tk_rel_wai and tk_wup_tsk are the following.

- Whereas tk_wup_tsk releases only WAIT state effected by tk_slp_tsk, tk_rel_wai releases also WAIT state caused by other factors (tk_wai_flg, tk_wai_sem, tk_rcv_msg, tk_get_blk, etc.).
- Seen from the task in WAIT state, release of the WAIT state by tk_wup_tsk returns a Normal completion (E_OK), whereas release by tk_rel_wai returns an error code (E_RLWAI).

Target Task State	tk_rel_tsk ercd Parameter	Processing
Run state (RUN, READY) (not for invoking task)	E_OBJ	No operation
RUN state (for invoking task)	E_OBJ	No operation
WAIT state	E_OK	Wait released*
DORMANT state	E_OBJ	No operation
NON-EXISTENT state	E_NOEXS	No operation

*Error code E_RLWAI is returned to the target task. The target task is guaranteed to be released from its wait state without any resource allocation (without the wait release conditions being met).

Table 4.3: Task States and Results of tk_rel_wai Execution

- Wakeup requests by tk_wup_tsk are queued if tk_slp_tsk has not yet been executed. If tk_rel_wai is issued for a task not in WAIT state, error code E_OBJ is returned.

tk_sus_tsk

Suspend Task

[C Language Interface]

```
ER ercd = tk_sus_tsk ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for the invoking task or for a task in DORMANT state)
E_CTX	A task in RUN state was designated in dispatch disabled state
E_QOVR	Queuing or nesting overflow (too many nested requests in suscnt)

[Description]

Puts the task designated in tskid in SUSPEND state and interrupts execution by the task.
SUSPEND state is released by issuing system call tk_rsm_tsk or tk_frsm_tsk.
If tk_sus_tsk is called for a task already in WAIT state, the state goes to a combination of WAIT state and SUSPEND state (WAIT-SUSPEND state). Thereafter when the task wait release conditions are met, the task goes to SUSPEND state. If tk_rsm_tsk is issued for the task in WAIT-SUSPEND state, the task state reverts to WAIT state.
Since SUSPEND state means task interruption by a system call issued by another task, this system call cannot be issued for the invoking task. If the invoking task is designated, error code E_OBJ is returned.
When this system call is issued from a task-independent portion, if a task in RUN state is designated while dispatching is disabled, error code E_CTX is returned.
If tk_sus_tsk is issued more than once for the same task, the task is put in SUSPEND state multiple times. This is called nesting of suspend requests. In this case, the task reverts to its original state only when tk_rsm_tsk has been issued for the same number of times as tk_sus_tsk (suscnt). Accordingly, nesting of the pair tk_sus_tsk — tk_rsm_tsk is possible.
The nesting of suspend requests (issuing tk_sus_tsk two or more times for the same task) and limits on nesting count are implementation-dependent.
If tk_sus_tsk is issued multiple times in a system that does not allow suspend request nesting, or if the nesting count exceeds the allowed limit, error code E_QOVR is returned.

[Additional Notes]

When a task is in WAIT state for resource acquisition (semaphore wait, etc.) and is also in SUSPEND state, the resource allocation (semaphore allocation, etc.) takes place under the same conditions as when the task is not in SUSPEND state. Resource allocation is not delayed by the SUSPEND state, and there is no change whatsoever in the priority of resource allocation or release from WAIT state. In this way SUSPEND state is in an orthogonal relation with other processing and task states.
In order to delay resource allocation to a task in SUSPEND state (temporarily lower its priority), the user can employ `tk_sus_tsk` and `tk_rsm_tsk` in combination with `tk_chg_pri`.
Task suspension is intended only for very limited uses closely related to the OS, such as page fault processing in a virtual memory system or breakpoint processing in a debugger. As a rule it should not be used in ordinary applications or in middleware.
The reason is that task suspension takes place regardless of the target task running state. If, for example, a task is put in SUSPEND state while it is calling a middleware function, the task will be stopped in the course of middleware internal processing. In some cases middleware performs resource management or other mutual exclusion control. If a task stops inside middleware while it has resources allocated, other tasks may not be able to use that middleware. This situation can cause a chain reactions, with other tasks stopping and leading to system-wide deadlock.
For this reason a task must not be stopped without knowing its status (what it is doing at the time), and ordinary tasks should not use the task suspension function.

tk_rsm_tsk
tk_frsm_tsk

Resume Task
Force Resume Task

[**C Language Interface**]

```
ER ercd = tk_rsm_tsk ( ID tskid ) ;
ER ercd = tk_frsm_tsk ( ID tskid ) ;
```

[**Parameters**]

ID	tskid	Task ID

[**Return Parameters**]

ER	ercd	Error code

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (the designated task is not in SUSPEND state (including when this system call designates the invoking task or a task in DORMANT state))

[**Description**]

Releases the SUSPEND state of the task designated in tskid.
If the target task was earlier put in SUSPEND state by the tk_sus_tsk system call, this system call releases that SUSPEND state and resumes the task execution.
When the target task is in a combined WAIT state and SUSPEND state (WAIT-SUSPEND state), executing tk_rsm_tsk releases only the SUSPEND state, putting the task in WAIT state.
This system call cannot be issued for the invoking task. If the invoking task is designated, error code E_OBJ is returned.
Executing tk_rsm_tsk one time clears only one nested suspend request (suscnt). If tk_sus_tsk was issued more than once for the target task (suscnt $\geq$ 2), the target task remains in SUSPEND state even after tk_rsm_tsk is executed. When tk_frsm_tsk is issued, on the other hand, all suspend requests are released (suscnt is cleared to 0) even if tk_sus_tsk was issued more than once (suscnt $\geq$ 2). The SUSPEND state is always cleared, and unless the task was in WAIT-SUSPEND state its execution resumes.

[**Additional Notes**]

After a task in RUN state or READY state is put in SUSPEND state by tk_sus_tsk and then resumed by tk_rsm_tsk or tk_frsm_tsk, the task has the lowest precedence among tasks of the same priority.

When, for example, the following system calls are executed for tasks A and B of the same priority, the result is as indicated below.

```
tk_sta_tsk (tskid=task_A, stacd_A);
tk_sta_tsk (tskid=task_B, stacd_B);
   /* By the rule of FCFS, precedence becomes task_A --> task_B. */

tk_sus_tsk (tskid=task_A);
tk_rsm_tsk (tskid=task_A);
   /* In this case precedence becomes task_B --> task_A.         */
```


tk_dly_tsk

Delay Task

[C Language Interface]

```
ER ercd = tk_dly_tsk ( RELTIM dlytim ) ;
```

[Parameters]

RELTIM	dlytim	Delay time

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory
E_PAR	Parameter error (dlytim is invalid)
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state

[Description]

Temporarily stops execution of the invoking task and waits for time dlytim to elapse. The state while the task waits for the delay time to elapse is a WAIT state and is subject to release by tk_rel_wai.
If the task issuing this system call goes to SUSPEND state or WAIT-SUSPEND state while it is waiting for the delay time to elapse, the time continues to be counted in the SUSPEND state.
The time base for dlytim (time unit) is the same as that for system time (= 1 ms).

[Additional Notes]

This system call differs from tk_slp_tsk in that normal completion, not an error code, is returned when the delay time elapses and tk_dly_tsk terminates. Moreover, the wait is not released even if tk_wup_tsk is executed during the delay time. The only way to terminate tk_dly_tsk before the delay time elapses is by calling tk_ter_tsk or tk_rel_wai.

tk_sig_tev

Send Task Event

[C Language Interface]

```
ER ercd = tk_sig_tev ( ID tskid, INT tskevt ) ;
```

[Parameters]

ID	tskid	Task ID
INT	tskevt	Task event number (1 to 8)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (called for a task in DORMANT state)
E_PAR	Parameter error (tskevt is invalid)

[Description]

Sends the task event designated in tskevt to the task designated in tskid. There are eight task event types stored for each task, designated by numbers 1 to 8.
The task event send count is not saved, only whether the event occurs or not.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

The task event function is used for synchronization much like tk_slp_tsk and tk_wup_tsk, but differs from the use of those system calls in the following ways.

- The wakeup request (task event) count is not kept.
- Wakeup requests can be classified by the eight event types.

Using the same event type for synchronization in two or more places in the same task would cause confusion. Event type allocation should be clearly defined. The task event function is intended for use in middleware, and as a rule should not be used in ordinary applications. Use of tk_slp_tsk and tk_wup_tsk is recommended for applications.

tk_wai_tev

Wait for Task Event

[C Language Interface]

```
INT tevptn = tk_wai_tev ( INT waiptn, TMO tmout ) ;
```

[Parameters]

INT	waiptn	Task event pattern
TMO	tmout	Timeout designation

[Return Parameters]

INT	tevptn	Task event status when wait released
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (waiptn or tmout is invalid)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Waits for the occurrence of one of the task events designated in waiptn.
When the wait is released by a task event, the task events designated in waiptn are cleared (raised task event &= ~waiptn).
The task event status occurring when the wait was released (the state before clearing) is passed in the return code (tevptn).
The parameters waiptn and tevptn consist of logical OR values of the bits for each task event in the form $1 << (\text{task event number} - 1)$.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (tk_sig_tev is not executed), the system call terminates, returning timeout error code E_TMOUT. Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms). When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if no task event occurs.
When TMO_FEVR = (−1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for a task event without timing out.

tk_dis_wai

Disable Task Wait

[C Language Interface]

```
INT tskwait = tk_dis_wai ( ID tskid, UINT waitmask ) ;
```

[Parameters]

ID	tskid	Task ID
UINT	waitmask	Task wait disabled setting

[Return Parameters]

INT	tskwait	Task state after task wait disabled
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (waitmask is invalid)

[Description]

Disables waits for the wait factors set in waitmask by the task designated in tskid.
If the task is already waiting for a factor designated in waitmask, that wait is released.
waitmask is designated as the logical OR of any combination of the following wait factors.

```
#define TTW_SLP     0x00000001  /* Wait caused by sleep              */
#define TTW_DLY     0x00000002  /* Wait for task delay               */
#define TTW_SEM     0x00000004  /* Wait for semaphore                */
#define TTW_FLG     0x00000008  /* Wait for event flag               */
#define TTW_MBX     0x00000040  /* Wait for mailbox                  */
#define TTW_MTX     0x00000080  /* Wait for mutex                    */
#define TTW_SMBF    0x00000100  /* Wait for message buffer sending   */
#define TTW_RMBF    0x00000200  /* Wait for message buffer receipt   */
#define TTW_CAL     0x00000400  /* Wait on rendezvous call           */
#define TTW_ACP     0x00000800  /* Wait for rendezvous acceptance    */
#define TTW_RDV     0x00001000  /* Wait for rendezvous completion    */
#define TTW_MPF     0x00002000  /* Wait for fixed-size memory pool   */
#define TTW_MPL     0x00004000  /* Wait for variable-size memory pool */
#define TTW_EV1     0x00010000  /* Wait for task event #1            */
#define TTW_EV2     0x00020000  /* Wait for task event #2            */
#define TTW_EV3     0x00040000  /* Wait for task event #3            */
#define TTW_EV4     0x00080000  /* Wait for task event #4            */
#define TTW_EV5     0x00100000  /* Wait for task event #5            */
```



```
#define TTW_EV6     0x00200000  /* Wait for task event #6          */
#define TTW_EV7     0x00400000  /* Wait for task event #7          */
#define TTW_EV8     0x00800000  /* Wait for task event #8          */
#define TTX_SVC     0x80000000  /* Extended SVC disabled           */
```

TTX_SVC is a special designation disabling not task wait but the calling of an extended SVC. If TTX_SVC is designated when a task attempts to call an extended SVC, E_DISWAI is returned without calling the extended SVC. This designation does not have the effect of terminating an already called extended SVC.
A tskwait value of 0 means the task has not entered WAIT state (or the wait was released). If tskwait is not 0, this means the task is in WAIT state for a cause other than those disabled in waitmask.
When a task wait is cleared by tk_dis_wai or the task is prevented from entering WAIT state while this system call is in effect, E_DISWAI is returned. When a system call for which there is the possibility of entering a WAIT state is invoked during wait disabled state, E_DISWAI is returned even if the processing could be performed without waiting.
For example, even if message buffer space is available when tk_snd_mbf is called and message buffer sending is possible without entering a WAIT state, E_DISWAI is returned and the message is not sent.
A wait disable set while an extended SVC is executing will be cleared automatically upon return from the extended SVC to its caller. It is automatically cleared also when an extended SVC is called, reverting to the original setting upon return from the extended SVC. A wait disable setting is cleared also when the task reverts to DORMANT state. The setting made while a task is in DORMANT state, however, is valid and the wait disable is applied the next time the task is started.
In the case of semaphores and most other objects, TA_NODISWAI can be designated when the object is created. An object created with TA_NODISWAI designated cannot have waits disabled, and rejects any wait disable attempt by tk_dis_wai.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

[Additional Notes]

The wait disable function is provided for preventing execution of an extended SVC handler and is for use mainly (though not exclusively) in break functions.
Wait disable in the case of a rendezvous is more complex than other cases. Essentially, wait disabled state is detected based on a change in the rendezvous wait state, then the wait is released. Some specific examples are given here.
When waiting by TTW_CAL is not disabled but TTW_RDV waits are disabled, a task enters into wait on rendezvous call state; but when the rendezvous is accepted and a wait for rendezvous completion would normally begin, the wait is released and E_DISWAI is returned. At this time a message is sent to the receiving task, the receiving task declares acceptance of the message and the task goes to rendezvous established state. Only when the accepting task replies (tk_rpl_rdv) does it become clear that there is no other task in the rendezvous, and error code E_OBJ is returned. Wait disable applies also when a rendezvous is forwarded. In that case the attribute of the destination rendezvous port applies. That is, if the TA_NODISWAI attribute is designated for the destination port, wait disable is rejected. If TTW_CAL wait is disabled after going to wait for rendezvous completion state, and a rendezvous is forwarded in that state, the state goes to WAIT on rendezvous call as a result of the forwarding, so wait is disabled by the TTW_CAL designation. In that case E_DISWAI is returned to both the rendezvous calling task (tk_cal_por) and forwarding task (tk_fwd_por).

tk_ena_wai

Enable Task Wait

[C Language Interface]

```
ER ercd = tk_ena_wai ( ID tskid ) ;
```

[Parameters]

ID	tskid	Task ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)

[Description]

Releases all wait disable conditions set by tk_dis_wai for the task designated in tskid.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

4.3 Task Exception Handling Functions

Task exception handling functions handle exception events occurring in a task, in the context of that task, interrupting normal task processing.
A task exception handler is executed as a part of the task where the task exception occurred, in the context of that task and at the protection level designated when the task was created. The task states in a task exception handler, except for those states concerning task exceptions, are the same as the states when running an ordinary task portion; and the same system calls are available.
A task exception handler can be started only when the target task is running a task portion. If the task is running any other portion when a task exception is raised, the task exception handler is started only after the task returns to the task portion. If a quasi-task portion (extended SVC) is executing when a task exception is raised, a break function corresponding to that extended SVC is called. The break function interrupts the extended SVC processing, and the task returns to the task portion.
Requested task exceptions are cleared when the task exception handler is called (when the task exception handler starts running).
Task exceptions are designated by task exception codes from 0 to 31, of which 0 is the highest priority and 31 the lowest. Task exception code 0 is handled differently from the others, as explained below.

Task exception codes 1 to 31 :

- These task exception handlers are not nested. A task exception (other than task exception code 0) raised while a task exception handler is running will be made pending.
- On return from a task exception handler, the task resumes from the point where processing was interrupted by the exception.
- It is also possible to use `longjmp()` or the like to jump to any point in the task without returning from the task exception handler.

Task exception code 0:

- This exception can be nested even while a task exception handler is executing for an exception of task exception code 1 to 31. Execution of task exception code 0 handlers is not nested.
- A task exception handler runs after setting the user stack pointer to the initial setting when the task was started. In a system without a separate user stack and system stack, however, the stack pointer is not reset to its initial setting.
- A task exception code 0 handler does not return to task processing. The task must be terminated.

tk_def_tex

Define Task Exception Handler

[C Language Interface]

```
ER ercd = tk_def_tex ( ID tskid, T_DTEX *pk_dtex ) ;
```

[Parameters]

ID	tskid	Task ID
T_DTEX*	pk_dtex	Task exception handler definition information

pk_dtex detail:

ATR	texatr	Task exception handler attributes
FP	texhdr	Task exception handler address

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (the task designated in tskid runs at protection level 0 (TA_RNG0))
E_RSATR	Reserved attribute (texatr is invalid or cannot be used)
E_PAR	Parameter error (pk_dtex is invalid or cannot be used)

[Description]

Defines a task exception handler for the task designated in tskid. Only one task exception handler can be defined per task; if one is already defined, the last-defined handler is valid. Setting pk_dtex = NULL cancels a definition.
Defining or canceling a task exception handler clears pending task exception requests and disables all task exceptions.
The parameter texatr indicates system attributes in is low bits and implementation-dependent attributes in its high bits. The texatr system attributes are not assigned in the present version, and system attributes are not used.
A task exception handler takes the following form.

```
void texhdr( INT texcd )
{
    /*
```



```
        Task exception handling
        */

        /* Task exception handler termination */
        if ( texcd == 0 ) {
         tk_ext_tsk() or tk_exd_tsk();
        } else {
            tk_end_tex();
            return or longjmp();
        }
    }
```

A task exception handler behaves only like a `TA_ASM` attribute object and cannot be called via a high-level language support routine. The entry part of the task exception handler must be written in assembly language. The OS vendor must provide the assembly language source of the entry routine for calling the above C language task exception handler. That is, source code equivalent to a high-level language support routine must be provided.
A task set to protection level `TA_RNG0` when it is created cannot use task exceptions.

[Additional Notes]

At the time a task is created, no task exception handler is defined and task exceptions are disabled. When a task reverts to DORMANT state, the task exception handler definition is canceled and task exceptions are disabled. Pending task exceptions are cleared. It is possible, however, to define a task exception handler for a task in DORMANT state.
Task exceptions are software interrupts raised by `tk_ras_tex`, with no direct relation to CPU exceptions.

tk_ena_tex
tk_dis_tex

Enable Task Exceptions
Disable Task Exceptions

[**C Language Interface**]

```
ER ercd = tk_ena_tex ( ID tskid, UINT texptn ) ;
ER ercd = tk_dis_tex ( ID tskid, UINT texptn ) ;
```

[**Parameters**]

ID	tskid	Task ID
UINT	texmask	Task exception pattern

[**Return Parameters**]

ER	ercd	Error code

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist or no task exception handler is defined)
E_OBJ	Invalid object state (the task designated in tskid is in DORMANT state)
E_PAR	Parameter error (texptn is invalid or cannot be used)

[**Description**]

Enables or disables task exceptions for the task designated in tskid.
The parameter texptn is a logical OR bit array representing task exception codes in the form 1 << task exception code.
tk_ena_tex enables the task exceptions designated in texptn. tk_dis_tex disables the task exceptions designated in texptn. With the current exception enabled status as texmask, designation is made as follows.

Enable: `texmask |= texptn`
Disable: `texmask &= ~texptn`

A disabled task exception is ignored, and is not made pending.
If exceptions are disabled for a task while there are pending task exceptions, the pending task exception requests are discarded (their pending status is cleared).
Task exceptions cannot be enabled for a task with no task exception handler defined.

tk_ras_tex

Raise Task Exception

[C Language Interface]

```
ER ercd = tk_ras_tex ( ID tskid, INT texcd ) ;
```

[Parameters]

ID	tskid	Task ID
INT	texcd	Task exception code (0 to 31)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist or no task exception handler is defined)
E_OBJ	Invalid object state (called for a task in DORMANT state)
E_PAR	Parameter error (texcd is invalid or cannot be used)
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Raises the task exception designated in texcd for the task designated in tskid.
If a task exception handler is already running in the task designated in tskid, the newly raised task exception is made pending. If an exception is pending, a break function is not executed even if the target task is executing an extended SVC. In the case of texcd = 0, however, exceptions are not made pending even if the target task is executing an exception handler. If the target task is running a task exception handler for an exception of task exception codes 1 to 31, the task exception is accepted; and if an extended SVC is executing, a break function is called. If the target task is running a task exception handler for an exception of task exception code 0, task exceptions are ignored.
The invoking task can be designated by setting tskid = TSK_SELF = 0.
If this system call is issued from a task-independent portion, error code E_CTX is returned.

[Additional Notes]

If the target task is executing an extended SVC, the break handler or the extended SVC runs in the context that called tk_ras_tex. In such a case tk_ras_tex does not return control until the break function processing ends. Task exceptions raised in the task that called tk_ras_tex while the break function is running are held until the break function ends.

tk_end_tex

End Task Exception Handler

[C Language Interface]

```
INT texcd = tk_end_tex ( BOOL enatex ) ;
```

[Parameters]

BOOL	enatex	Task exception handler calling enabled flag

[Return Parameters]

INT	texcd	Raised exception code
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_CTX	Context error (called for other than a task exception handler or task exception code 0 (detection is implementation-dependent))

[Description]

Ends a task exception handler and enables the new task exception handler. If there are pending task exceptions, the highest-priority task exception code among them is passed in the return code. If there are no pending task exceptions, 0 is returned.
If `enatex` = FALSE and there are pending task exception, calling the new task exception handler is not allowed. In this case, the exception handler designated in return code `texcd` is in running state upon return from `tk_end_tex`. If there are no pending task exceptions, calling the new task exception handler is allowed.
If `enatex` = TRUE, calling the new task exception handler is allowed regardless of whether there are pending task exceptions. Even if there are pending task exceptions, the task exception handler is in terminated status.
There is no way of ending a task exception handler other than by calling `tk_end_tex`. A task exception handler continues executing from the time it is started until `tk_end_tex` is called. Even if return is made from a task exception handler without calling `tk_end_tex`, the task exception handler will still be running at the point of return. Similarly, even if `longjmp` is used to get out of a task exception handler without calling `tk_end_tex`, the task exception handler will still be running at the jump destination.
Calling `tk_end_tex` while task exceptions are pending results in a new task exception being accepted. At this time even when `tk_end_tex` is called from an extended SVC handler, a break function cannot be called for that extended SVC handler. If extended SVC calls are nested, then when the extended SVC nesting goes down one level, the break function corresponding to the extended SVC return destination can be called. Calling of a task exception handler takes place upon return to the task portion. The `tk_end_tex` system call cannot be issued in the case of task exception code 0, since the task exception handler cannot be ended. The behavior when `tk_end_tex` is called for a handler of task exception code 0 is undefined (implementation-dependent).

This system call cannot be issued from other than a task exception handler. The behavior when it is called from other than a task exception handler is undefined (implementation-dependent).

[Additional Notes]

When `tk_end_tex` (TRUE) is set and there are pending task exceptions, another task exception handler call is made immediately following `tk_end_tex`. Moreover, for that reason a task exception handler is called without restoring the stack, giving rise to possible stack overflow. Ordinarily `tk_end_tex` (FALSE) can be used, and processing looped as illustrated below while there are task exceptions pending.

```
void texhdr( INT texcd )
 {
    if ( texcd == 0 ) tk_exd_tsk();
    do {
    /*
        Task exception handling
    */
    } while ( (texcd = tk_end_tex(FALSE)) > 0 );
 }
```

Strictly speaking, if a task exception were to occur during the interval after 0 is returned by `tk_ena_tex` ending the loop and before exit from `texhdr`, the possibility exists of reentering `texhdr` without restoring the stack. Since task exceptions are software driven, however, ordinarily they do not occur with no relation to tasks; so in practice this is not a problem.

tk_ref_tex

Reference Task Exception Status

[**C Language Interface**]

```
ER ercd = tk_ref_tex ( ID tskid, T_RTEX *pk_rtex ) ;
```

[**Parameters**]

ID	tskid	Task ID
T_RTEX*	pk_rtex	Address of packet for returning task exception status

[**Return Parameters**]

ER	ercd	Error code

pk_rtex detail:

UINT	pendtex	Pending task exceptions
UINT	texmask	Allowed task exceptions

(Other implementation-dependent parameters may be added beyond this point.)

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[**Description**]

Gets the status of task exceptions for the task designated in tskid.
pendtex indicates the currently pending task exceptions. A raised task exception is indicated in pendtex from the time the task exception is raised until its task exception handler is called.
texmask indicates allowed task exceptions.
Both pendtex and texmask are bit arrays of the form 1 << task exception code.
The invoking task can be designated by setting tskid = TSK_SELF = 0. Note, however, that when a system call is issued from a task-independent portion and tskid = TSK_SELF = 0 is designated, error code E_ID is returned.

4.4 Synchronization and Communication Functions

Synchronization and communication functions use objects independent of tasks used to synchronize tasks and achieve communication between tasks. The objects available for these purposes include semaphores, event flags, and mailboxes.

4.4.1 Semaphore

A semaphore is an object indicating the availability of a resource and its quantity as a numerical value. A semaphore is used to realize mutual exclusion control and synchronization when using a resource. Functions are provided for creating and deleting a semaphore, acquiring and returning resources corresponding to semaphores, and referencing semaphore status. A semaphore is an object identified by an ID number called a semaphore ID.

A semaphore contains a resource count indicating whether the corresponding resource exists and in what quantity, and a queue of tasks waiting to acquire the resource. When a task (the task making event notification) returns m resources, it increments the semaphore resource count by m. When a task (the task waiting for an event) acquires n resources, it decreases the semaphore resource count by n. If the number of semaphore resources is insufficient (i.e., further reducing the semaphore resource count would cause it to go into negative territory), a task attempting to acquire resources goes into WAIT state until the next time resources are returned. A task waiting for semaphore resources is put in the semaphore queue.

To prevent too many resources from being returned to a semaphore, a maximum resource count can be set for each semaphore. Error is reported if it is attempted to return resources to a semaphore that would cause this maximum count to be exceeded.

tk_cre_sem

Create Semaphore

[C Language Interface]

```
ID  semid = tk_cre_sem ( T_CSEM *pk_csem ) ;
```

[Parameters]

T_CSEM*	pk_csem	Information about the semaphore to be created

pk_csem detail:

VP	exinf	Extended information
ATR	sematr	Semaphore attributes
INT	isemcnt	Initial semaphore count
INT	maxsem	Maximum semaphore count

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	semid	Semaphore ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Semaphore count exceeds the system limit
E_RSATR	Reserved attribute (sematr is invalid or cannot be used)
E_PAR	Parameter error (pk_csem is invalid; isemcnt or maxsem is negative or invalid)

[Description]

Creates a semaphore, assigning to it a semaphore ID.
This system call allocates a control block to the created semaphore, setting the initial count to isemcnt and maximum count (upper limit) to maxsem. It must be possible to set maxsem to at least 65535. Whether values above 65536 can be set is implementation-dependent.
exinf can be used freely by the user to set miscellaneous information about the created semaphore. The information set in this parameter can be referenced by tk_ref_sem. If a larger area is needed for indicating user information, or if the information may need to be changed after the semaphore is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
sematr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of sematr is as follows.


```
sematr:= (TA_TFIFO || TA_TPRI) | (TA_FIRST || TA_CNT) | [TA_NODISWAI]
```

TA_TFIFO	Tasks are queued in FIFO order
TA_TPRI	Tasks are queued in priority order
TA_FIRST	The first task in the queue has precedence
TA_CNT	Tasks with fewer requests have precedence
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

The queuing order of tasks waiting for a semaphore can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting.
TA_FIRST and TA_CNT designate precedence of resource acquisition. TA_FIRST and TA_CNT do not change the order of the queue, which is determined by TA_TFIFO or TA_TPRI. When TA_FIRST is designated, resources are allocated starting from the first task in the queue regardless of request count. As long as the first task in the queue cannot obtain the requested number of resources, tasks behind it in the queue are prevented from obtaining resources.
TA_CNT means resources are assigned based on the order in which tasks are able to obtain the requested number of resources. The request counts are checked starting from the first task in the queue, and tasks to which their requested amount can be allocated receive resources. This is not the same as allocating in order of fewest requests.

```
#define TA_TFIFO    0x00000000  /* manage queue by FIFO                     */
#define TA_TPRI     0x00000001  /* manage queue by priority                 */
#define TA_FIRST    0x00000000  /* first task in queue has precedence       */
#define TA_CNT      0x00000002  /* tasks with fewer requests have precedence */
#define TA_NODISWAI 0x00000080  /* reject wait disabling                    */
```


tk_del_sem

Delete Semaphore

[C Language Interface]

```
ER ercd = tk_del_sem ( ID semid ) ;
```

[Parameters]

ID	semid	Semaphore ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (semid is invalid or cannot be used)
E_NOEXS	Object does not exist (the semaphore designated in semid does not exist)

[Description]

Deletes the semaphore designated in semid.
The semaphore ID and control block area are released as a result of this system call.
This system call completes normally even if there is a task waiting for condition fulfillment in the semaphore, but error code E_DLT is returned to the task in WAIT state.

tk_sig_sem

Signal Semaphore

[C Language Interface]

```
ER ercd = tk_sig_sem ( ID semid, INT cnt ) ;
```

[Parameters]

ID	semid	Semaphore ID
INT	cnt	Resource return count

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (semid is invalid or cannot be used)
E_NOEXS	Object does not exist (the semaphore designated in semid does not exist)
E_QOVR	Queuing or nesting overflow (semcnt over limit)
E_PAR	Parameter error (cnt ≤ 0)

[Description]

Returns to the semaphore designated in semid the number of resources indicated in cnt. If there is a task waiting for the semaphore, its request count is checked and resources allocated if possible. A task allocated resources goes to READY state. In some conditions more than one task may be allocated resources and put in READY state.
If the semaphore count increases to the point where the maximum count (maxcnt) would be exceeded by the return of more resources, error code E_QOVR is returned. In this case no resources are returned and the count (semcnt) does not change.

[Additional Notes]

Error is not returned even if semcnt goes over the semaphore initial count (isemcnt). When semaphores are used not for mutual exclusion control but for synchronization (like tk_wup_tsk and tk_slp_tsk), the semaphore count (semcnt) will sometimes go over the initial setting (isemcnt). The semaphore function can be used for mutual exclusion control by setting isemcnt and the maximum semaphore count (maxsem) to the same value and checking for error occurring when the count increases.

tk_wai_sem

Wait on Semaphore

[C Language Interface]

```
ER ercd = tk_wai_sem ( ID semid, INT cnt, TMO tmout ) ;
```

[Parameters]

ID	semid	Semaphore ID
INT	cnt	Resource request count
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (semid is invalid or cannot be used)
E_NOEXS	Object does not exist (the semaphore designated in semid does not exist)
E_PAR	Parameter error (tmout $\leq (-2)$, cnt ≤ 0)
E_DLT	The object being waited for was deleted (the designated semaphore was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Gets from the semaphore designated in semid the number of resources indicated in cnt. If the requested resources can be allocated, the task issuing this system call does not enter WAIT state but continues executing. In this case the semaphore count (semcnt) is decreased by the size of cnt. If the resources are not available, the task issuing this system call enters WAIT state, and is put in the queue of tasks waiting for the semaphore. The semaphore count (semcnt) for this semaphore does not change in this case.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (tk_sig_sem is not executed), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if no resources are acquired.
When TMO_FEVR = (-1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for resource acquisition without timing out.

tk_ref_sem

Reference Semaphore Status

[C Language Interface]

```
ER ercd = tk_ref_sem ( ID semid, T_RSEM *pk_rsem ) ;
```

[Parameters]

ID	semid	Semaphore ID
T_RSEM*	pk_rsem	Address of packet for returning status information

pk_rsem detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
INT	semcnt	Semaphore count

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (semid is invalid or cannot be used)
E_NOEXS	Object does not exist (the semaphore designated in semid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the semaphore designated in semid, passing in the return parameters the current semaphore count (semcnt), information on tasks waiting for the semaphore (wtsk), and extended information (exinf).
wtsk indicates the ID of a task waiting for the semaphore. If there are two or more such tasks, the ID of the task at the head of the queue is returned. If there are no waiting tasks, wtsk = 0 is returned.
If the designated semaphore does not exist, error code E_NOEXS is returned.

4.4.2 Event Flag

An event flag is an object used for synchronization, consisting of a pattern of bits used as flags to indicate the existence of the corresponding event. Functions are provided for creating and deleting an event flag, for event flag setting and clearing, event flag waiting, and event flag status reference. An event flag is identified by an ID number, called an event flag ID.
In addition to the bit pattern indicating the existence of corresponding events, an event flag has a queue of tasks waiting for the event flag. The event flag bit pattern is sometimes called simply event flag. The event notifier sets or clears the designated bits of the event flag. A task can be made to wait for all or some of the event flag bits to be set. A task waiting for an event flag is put in the queue of that event flag.

tk_cre_flg

Create Event Flag

[C Language Interface]

```
ID flgid = tk_cre_flg ( T_CFLG *pk_cflg ) ;
```

[Parameters]

T_CFLG*	pk_cflg	Information about the event flag to be created

pk_cflg detail:

VP	exinf	Extended information
ATR	flgatr	Event flag attributes
UINT	iflgptn	Initial event flag pattern

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	flgid	Event flag ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Number of event flags exceeds the system limit
E_RSATR	Reserved attribute (flgatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cflg is invalid)

[Description]

Creates an event flag, assigning to it an event flag ID.
This system call allocates a control block to the created event flag and sets its initial value to iflgptn. An event flag handles one word's worth of bits as a group. All operations are performed in single word units.
exinf can be used freely by the user to set miscellaneous information about the created event flag. The information set in this parameter can be referenced by tk_ref_flg. If a larger area is needed for indicating user information, or if the information may need to be changed after the event flag is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
flgatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of flgatr is as follows.

```
flgatr:= (TA_TFIFO || TA_TPRI) | (TA_WMUL || TA_WSGL) | [TA_NODISWAI]
```


TA_TFIFO	Tasks are queued in FIFO order
TA_TPRI	Tasks are queued in priority order
TA_WSGL	Waiting for multiple tasks is not allowed (Wait Single Task)
TA_WMUL	Waiting for multiple tasks is allowed (Wait Multiple Task)
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

When TA_WSGL is designated, multiple tasks cannot be in WAIT state at the same time. Designating TA_WMUL allows waiting by multiple tasks at the same time.
The queuing order of tasks waiting for an event flag can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting.
When TA_WSGL is designated, however, since tasks cannot be queued, designation of TA_TFIFO or TA_TPRI makes no difference.
When multiple tasks are waiting for an event flag, tasks are checked in order from the head of the queue, and the wait is released for tasks meeting the conditions. The first task to have its WAIT state released is therefore not necessarily the first in the queue. If multiple tasks meet the conditions, wait state is released for each of them.

```
#define TA_TFIFO    0x00000000  /* manage queue by FIFO           */
#define TA_TPRI     0x00000001  /* manage queue by priority       */
#define TA_WSGL     0x00000000  /* prohibit multiple task waiting */
#define TA_WMUL     0x00000008  /* allow multiple task waiting    */
#define TA_NODISWAI 0x00000080  /* prohibit wait disabling        */
```


tk_del_flg

Delete Event Flag

[C Language Interface]

```
ER ercd = tk_del_flg ( ID flgid ) ;
```

[Parameters]

ID	flgid	Event flag ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (flgid is invalid or cannot be used)
E_NOEXS	Object does not exist (the event flag designated in flgid does not exist)

[Description]

Deletes the event flag designated in flgid.
Issuing this system call releases the corresponding event flag ID and control block memory space.
This system call is completed normally even if there are tasks waiting for the event flag, but error code E_DLT is returned to each task in WAIT state.

tk_set_flg
tk_clr_flg

Set Event Flag
Clear Event Flag

[**C Language Interface**]

```
ER ercd = tk_set_flg ( ID flgid, UINT setptn ) ;
ER ercd = tk_clr_flg ( ID flgid, UINT clrptn ) ;
```

[**Parameters**]

For `tk_set_flg`

ID	`flgid`	Event flag ID
UINT	`setptn`	Bit pattern to be set

For `tk_clr_flg`

ID	`flgid`	Event flag ID
UINT	`clrptn`	Bit pattern to be cleared

[**Return Parameters**]

ER	`ercd`	Error code

[**Error Codes**]

`E_OK`	Normal completion
`E_ID`	Invalid ID number (`flgid` is invalid or cannot be used)
`E_NOEXS`	Object does not exist (the event flag designated in `flgid` does not exist)

[**Description**]

`tk_set_flg` sets the bits indicated in `setptn` in a one-word event flag designated in `flgid`. That is, a logical sum is taken of the values of the event flag designated in `flgid` and the values indicated in `setptn`. `tk_clr_flg` clears the bits of the one-word event flag based on the corresponding zero bits of `clrptn`. That is, a logical product is taken of the values of the event flag designated in `flgid` and the values indicated in `clrptn`.
After event flag values are changed by `tk_set_flg`, if the condition for releasing the wait state of a task that called `tk_wai_flg` is met, the WAIT state of that task is cleared, putting it in RUN state or READY state (or SUSPEND state if the waiting task was in WAIT-SUSPEND state).
Issuing `tk_clr_flg` never results in wait conditions being released for a task waiting for the designated event flag; that is, dispatching never occurs with `tk_clr_flg`.
Nothing will happen to the event flag if all bits of `setptn` are cleared to 0 with `tk_set_flg` or if all bits of `clrptn` are set to 1 with `tk_clr_flg`. No error will result in either case.
Multiple tasks can wait for a single event flag if that event flag has the `TA_WMUL` attribute. The event flag in that case has a queue for the waiting tasks. A single `tk_set_flg` call for such an event flag may result in the release of multiple waiting tasks.

tk_wai_flg

Wait Event Flag

[**C Language Interface**]

```
ER ercd = tk_wai_flg ( ID flgid, UINT waiptn, UINT wfmode, UINT *p_flgptn, TMO tmout ) ;
```

[**Parameters**]

ID	flgid	Event flag ID
UINT	waiptn	Wait bit pattern
UINT	wfmode	Wait release condition
TMO	tmout	Timeout designation

[**Return Parameters**]

ER	ercd	Error code
UINT	flgptn	Event flag bit pattern

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (flgid is invalid or cannot be used)
E_NOEXS	Object does not exist (the event flag designated in flgid does not exist)
E_PAR	Parameter error (waiptn = 0, wfmode is invalid, or tmout $\leq (-2)$)
E_OBJ	Invalid object state (multiple tasks are waiting for an event flag with TA_WSGL attribute)
E_DLT	The object being waited for was deleted (the designated event flag was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[**Description**]

Waits for the event flag designated in flgid to be set, fulfilling the wait release condition designated in wfmode.
If the event flag designated in flgid already meets the wait release condition set in wfmode, the waiting task continues executing without going to WAIT state.
wfmode is designated as follows.

```
wfmode := (TWF_ANDW || TWF_ORW) | [TWF_CLR || TWF_BITCLR]
```

TWF_ANDW	0x00	AND wait condition
TWF_ORW	0x01	OR wait condition
TWF_CLR	0x10	Clear all
TWF_BITCLR	0x20	Clear condition bit only

If TWF_ORW is designated, the issuing task waits for any of the bits designated in waiptn to be set for the event flag designated in flgid (OR wait). If TWF_ANDW is designated, the issuing task will wait for all of the bits designated in waiptn to be set for the event flag designated in flgid (AND wait).
If TWF_CLR specification is not designated, the event flag values will remain unchanged even after the conditions have been satisfied and the task has been released from WAIT state. If TWF_CLR is designated, all bits of the event flag will be cleared to 0 once wait conditions of the waiting task have been met. If TWF_BITCLR is designated, then when the conditions are met and the task is released from WAIT state, only the bits matching the event flag wait release conditions are cleared to 0 (event flag values &= ~wait release conditions).
The return parameter flgptn returns the value of the event flag after the WAIT state of a task has been released due to this system call. If TWF_CLR or TWF_BITCLR was designated, the value before event flag bits were cleared is returned. The value returned by flgptn fulfills the wait release conditions of this system call. The contents of flgptn are indeterminate if the wait is released due to timeout or the like.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met, the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if the condition is not met.
When TMO_FEVR = (−1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for the condition to be met without timing out.
In the case of a timeout, the event flag bits are not cleared even if TWF_CLR or TWF_BITCLR was designated.
Setting waiptn to 0 results in Parameter error E_PAR.
A task cannot execute tk_wai_flg for an event flag having the TA_WSGL attribute while another task is waiting for it. Error code E_OBJ will be returned for the task issuing the subsequent tk_wai_flg, regardless of whether that task would have gone to WAIT state; i.e., regardless of whether the wait release conditions would be met.
If an event flag has the TA_WMUL attribute, multiple tasks can wait for it at the same time. Waiting tasks can be queued, and the WAIT states of multiple tasks can be released by issuing tk_set_flg just once. If multiple tasks are queued for an event flag with TA_WMUL attribute, the behavior is as follows.

- Tasks are queued in either FIFO or priority order. (Release of wait state does not always start from the head of the queue, however, depending on factors such as waiptn and wfmode settings.)
- If TWF_CLR or TWF_BITCLR was designated by a task in the queue, the event flag is cleared when that task is released from WAIT state.
- Tasks later in the queue than a task designating TWF_CLR or TWF_BITCLR will see the event flag after it has already been cleared.

If multiple tasks having the same priority are released from waiting simultaneously as a result of tk_set_flg, the order of tasks in the ready queue (precedence) after release will continue to be the same as their original order in the event flag queue.

[Additional Notes]

If a logical sum of all bits is designated as the wait release condition when tk_wai_flg is called (waiptn=0xfff... ff, wfmode=TWF_ORW), it is possible to transfer messages using one-word bit patterns in combination with tk_set_flg. However, it is not possible to send a message containing only 0s

for all bits. Moreover, if the next message is sent before a previous message has been read by `tk_wai_flg`, the previous message will be lost; that is, message queuing is not possible.
Since setting `waiptn` = 0 will result in an `E_PAR` error, it is guaranteed that the `waiptn` of tasks waiting for an event flag will not be 0. The result is that if `tk_set_flg` sets all bits of an event flag to 1, the task at the head of the queue will always be released from waiting no matter what its wait condition is.
The ability to have multiple tasks wait for the same event flag is useful in situations like the following. Suppose, for example, that Task B and Task C are waiting for `tk_wai_flg` calls (2) and (3) until Task A issues (1) `tk_set_flg`. If multiple tasks are allowed to wait for the event flag, the result will be the same regardless of the order in which system calls (1)(2)(3) are executed (see Figure 4.1). On the other hand, if multiple task waiting is not allowed and system calls are executed in the order (2), (3), (1), an `E_OBJ` error will result from the execution of (3) `tk_wai_flg`.

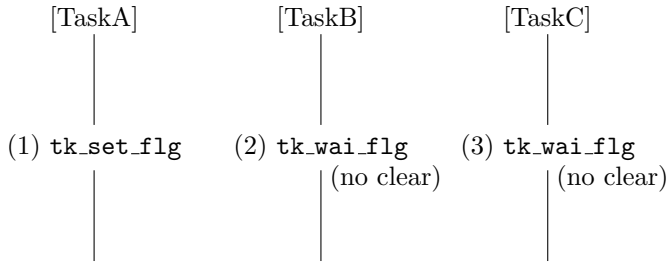


Figure 4.1: Multiple Tasks Waiting for One Event Flag

[Rationale for the Specification]

The reason for returning `E_PAR` error for designating `waiptn` = 0 is that if `waiptn` = 0 designation were allowed, it would not be possible to get out of WAIT state regardless of the subsequent event flag values.

tk_ref_flg

Reference Event Flag Status

[C Language Interface]

```
ER ercd = tk_ref_flg ( ID flgid, T_RFLG *pk_rflg ) ;
```

[Parameters]

ID	flgid	Event flag ID
T_RFLG*	pk_rflg	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rflg detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
UINT	flgptn	Event flag bit pattern

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (flgid is invalid or cannot be used)
E_NOEXS	Object does not exist (the event flag designated in flgid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the event flag designated in flgid, passing in the return parameters the current flag pattern (flgptn), waiting task information (wtsk), and extended information (exinf).
wtsk returns the ID of a task waiting for this event flag. If more than one task is waiting (only when the TA_WMUL was designated), the ID of the first task in the queue is returned. If there are no waiting tasks, wtsk = 0 is returned. If the designated event flag does not exist, error code E_NOEXS is returned.

4.4.3 Mailbox

A mailbox is an object used to achieve synchronization and communication by passing messages in system (shared) memory space. Functions are provided for creating and deleting a mailbox, sending and receiving messages in a mailbox, and referencing the mailbox status. A mailbox is an object identified by an ID number called a mailbox ID.
A mailbox has a message queue for sent messages, and a task queue for tasks waiting to receive messages. At the message sending end (making event notification), messages to be sent go in the message queue. On the message receiving end (waiting for event notification), a task fetches one message from the message queue. If there are no queued messages, the task goes to a state of waiting for receipt from the mailbox until the next message is sent. Tasks waiting for message receipt from a mailbox are put in the task queue of that mailbox.
Since the contents of messages using this function are in memory shared by the sending and receiving sides, only the start address of a message located in this shared space is actually sent and received. The contents of the messages themselves are not copied. T-Kernel manages messages in the message queue by means of a link list. An application program must allocate space at the beginning of a message to be sent, for link list use by T-Kernel. This area is called the message header. The message header and the message body together are called a message packet. When a system call sends a message to a mailbox, the start address of the message packet (`pk_msg`) is passed in a parameter. When a system call receives a message from a mailbox, the start address of the message packet is passed in a return parameter. If messages are assigned a priority in the message queue, the message priority (`msgpri`) of each message must be designated in the message header (see Figure 4.2). The user puts the message contents not at the beginning of the packet but after the header part (`msgcont` in the figure).

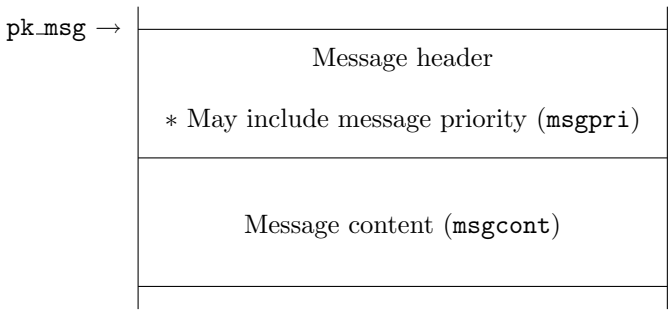


Figure 4.2: Format of Messages Using a Mailbox

T-Kernel overwrites the contents of the header when a message is put in the message queue (except for the message priority area). An application, on the other hand, must not overwrite the header of a message in the queue (including the message priority area). The behavior if an application overwrites the message header is not defined. This restriction applies not only to the direct writing of a message header by an application program, but also to the passing of a header address to T-Kernel and having T-Kernel overwrite the message header with the contents. Accordingly, the behavior when a message already in the message queue is again sent to a mailbox is undefined.

[Additional Notes]

Since the application program allocates the message header space for this mailbox function, there is no limit on the number of messages that can be queued. A system call sending a message does not enter

WAIT state.
Memory blocks allocated dynamically from a fixed-size memory pool or variable-size memory pool, or else a statically allocated area can be used for message packets; but these must not be located in task space.
Generally, a sending task allocates a memory block from a memory pool, sending that as a message packet. After a task on the receiving end fetches the message, it returns the memory block directly to its memory pool.

tk_cre_mbx

Create Mailbox

[C Language Interface]

```
ID mbxid = tk_cre_mbx ( T_CMBX* pk_cmbx ) ;
```

[Parameters]

T_CMBX*	pk_cmbx	Information about the mailbox to be created

pk_cmbx detail:

VP	exinf	Extended information
ATR	mbxatr	Mailbox attributes

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	mbxid	Mailbox ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for a control block or buffer cannot be allocated)
E_LIMIT	Number of mailboxes exceeds the system limit
E_RSATR	Reserved attribute (mbxatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cmbx is invalid)

[Description]

Creates a mailbox, assigning to it a mailbox ID.
This system call allocates a control block, etc. for the created mailbox.
exinf can be used freely by the user to set miscellaneous information about the created mailbox. The information set in this parameter can be referenced by tk_ref_mbx. If a larger area is needed for indicating user information, or if the information may need to be changed after the mailbox is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
mbxatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of mbxatr is as follows.

```
mbxatr:= (TA_TFIFO || TA_TPRI) | (TA_MFIFO || TA_MPRI) | [TA\_NODISWAI]
```


TA_TFIFO	Tasks are queued in FIFO order
TA_TPRI	Tasks are queued in priority order
TA_MFIFO	Messages are queued in FIFO order
TA_MPRI	Messages are queued in priority order
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

The queuing order of tasks waiting for a mailbox can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting.
TA_MFIFO and TA_MPRI are used to designate the order of messages in the message queue (messages waiting to be received). If the attribute is TA_MFIFO, messages are ordered by FIFO; TA_MPRI designates queuing of messages in priority order. Message priority is set in a special field in the message packet. Message priority is designated by positive values, with 1 indicating the highest priority and higher numbers indicating successively lower priority. The largest value that can be expressed in the PRI type is the lowest priority. Messages having the same priority are ordered as FIFO.

```
#define TA_TFIFO     0x00000000  /* manage task queue by FIFO        */
#define TA_TPRI      0x00000001  /* manage task queue by priority    */
#define TA_MFIFO     0x00000000  /* manage message queue by FIFO     */
#define TA_MPRI      0x00000002  /* manage message queue by priority */
#define TA_NODISWAI  0x00000080  /* reject wait disabling            */
```

[Additional Notes]

The body of a message passed by the mailbox function is located in system (shared) memory; only its start address is actually sent and received. For this reason a message must not be located in task space.

tk_del_mbx

Delete Mailbox

[C Language Interface]

```
ER ercd = tk_del_mbx ( ID mbxid ) ;
```

[Parameters]

ID	mbxid	Mailbox ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mailbox designated in mbxid does not exist)

[Description]

Deletes the mailbox designated in mbxid.
Issuing this system call releases the mailbox ID and control block memory space, etc., associated with the mailbox.
This system call completes normally even if there are tasks waiting for messages in the deleted mailbox, but error code E_DLT is returned to each of the tasks in WAIT state. Even if there are messages still in the deleted mailbox, the mailbox is deleted without returning an error code.

tk_snd_mbx

Send Message to Mailbox

[C Language Interface]

```
ER ercd = tk_snd_mbx ( ID mbxid, T_MSG *pk_msg ) ;
```

[Parameters]

ID	mbxid	Mailbox ID
T_MSG*	pk_msg	Message packet address

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mailbox designated in mbxid does not exist)
E_PAR	Parameter error (pk_msg is a value that cannot be used)

[Description]

Sends the message packet having pk_msg as its start address to the mailbox designated in mbxid. The message packet contents are not copied; only the start address (pk_msg) is passed at the time of message receipt.
If tasks are already waiting for messages in the same mailbox, the WAIT state of the task at the head of the queue is released, and the pk_msg passed to tk_snd_mbx is sent to that task, becoming a parameter returned by tk_rcv_mbx. If there are no tasks waiting for messages in the designated mailbox, the sent message goes in the message queue of that mailbox. In neither case does the task issuing tk_snd_mbx enter WAIT state.
pk_msg is the start address of the packet containing the message, including header. The message header has the following format.

```
typedef struct t_msg {
        ?       ?           /* Implementation-dependent contents (fixed size) */
} T_MSG;

typedef struct t_msg_pri {
    T_MSG   msgque;       /* message queue area */
    PRI     msgpri;       /* message priority   */
} T_MSG_PRI;
```

The message header is T_MSG (if TA_MFIFO attribute is designated) or T_MSG_PRI (if TA_MPRI). In either case the message header has a fixed size, which can be obtained by sizeof (T_MSG) or sizeof(T_MSG_PRI). The actual message must be put in the area after the header. There is no limit on message size, which may be variable-length.

[Additional Notes]

Messages are sent by `tk_snd_mbx` regardless of the status of the receiving tasks. In other words, message sending is asynchronous. What waits in the queue is not the task itself, but the sent message. So while there are queues of waiting messages and receiving tasks, the sending task does not go to WAIT state.

tk_rcv_msg

Receive Message from Mailbox

[C Language Interface]

```
ER ercd = tk_rcv_mbx ( ID mbxid, T_MSG **ppk_msg, TMO tmout ) ;
```

[Parameters]

ID	mbxid	Mailbox ID
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code
T_MSG*	pk_msg	Start address of message packet

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mailbox designated in mbxid does not exist)
E_PAR	Parameter error (tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (the mailbox was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Receives a message from the mailbox designated in mbxid. If no messages have been sent to the mailbox (the message queue is empty), the task issuing this system call enters WAIT state and is queued for message arrival. If there are messages in the mailbox, the task issuing this system call fetches the first message in the message queue, passing this in the return parameter pk_msg.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (no message arrives), the system call terminates, returning timeout error code E_TMOUT. Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if no message arrives.
When TMO_FEVR = (-1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for message arrival without timing out.

[Additional Notes]

pk_msg is the start address of the packet containing the message, including header. The message header is T_MSG (if TA_MFIFO attribute is designated) or T_MSG_PRI (if TA_MPRI).

tk_ref_mbx

Reference Mailbox Status

[C Language Interface]

```
ER ercd = tk_ref_mbx ( ID mbxid, T_RMBX *pk_rmbx ) ;
```

[Parameters]

ID	mbxid	Mailbox ID
T_RMBX*	pk_rmbx	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rmbx detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
T_MSG*	pk_msg	Start address of next message packet to be received

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mailbox designated in mbxid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the mailbox designated in mbxid, passing in the return parameters the next message to be received (the first message in the message queue), waiting task information (wtsk), and extended information (exinf).
wtsk indicates the ID of a task waiting for the mailbox. If there are multiple waiting tasks, the ID of the first task in the queue is returned. If there are no waiting tasks, wtsk = 0 is returned.
If the designated mailbox does not exist, error code E_NOEXS is returned.
pk_msg indicates the message that will be received the next time tk_rcv_mbx is issued. If there are no messages in the message queue, pk_msg = NULL is returned. At least one of pk_msg = NULL and wtsk = 0 is always true for this system call.

4.5 Extended Synchronization and Communication Functions

Extended synchronization and communication functions use objects independent of tasks to realize more sophisticated synchronization and communication between tasks. The functions specified here include mutex, message buffer, and rendezvous port functions.

4.5.1 Mutex

A mutex is an object for mutual exclusion control among tasks that use shared resources. Priority inheritance mutexes and priority ceiling mutexes are supported, as tools for managing the problem of unbounded priority inversion that can occur in mutual exclusion control. Functions are provided for creating and deleting a mutex, locking and unlocking a mutex, and referencing mutex status. A mutex is identified by an ID number called a mutex ID.
A mutex has a status (locked or unlocked) and a queue for tasks waiting to lock the mutex. For each mutex, T-Kernel keeps track of the tasks locking it; and for each task, it keeps track of the mutexes it has locked. Before a task uses a resource, it locks a mutex corresponding to that resource. If the mutex is already locked by another task, the task waits for the mutex to become unlocked. Tasks in mutex lock waiting state are put in the mutex queue. When a task finishes with a resource, it unlocks the mutex.
A mutex with `TA_INHERIT`(= 0x02) designated as mutex attribute supports priority inheritance protocol, while one with `TA_CEILING`(= 0x03) designated supports priority ceiling protocol. When a priority ceiling mutex is created, a ceiling priority is assigned to it, indicating the base priority of the task having the highest base priority among the tasks able to lock that mutex. If a task having a higher base priority than the ceiling priority of the mutex tries to lock it, error code `E_ILUSE` is returned. If `tk_chg_pri` is issued in an attempt to set the base priority of a task locking a priority ceiling mutex to a value higher than the ceiling priority of that mutex, `E_ILUSE` is returned by the `tk_chg_pri` system call.
When these protocols are used, unbounded priority inversion is prevented by changing the current priority of a task in a mutex operation. Strict adherence to the priority inheritance protocol and priority ceiling protocol requires that the task current priority must always be changed to match the peak value of the following priorities. This is called strict priority control.

- The task base priority.
- When tasks lock priority inheritance mutexes, the current priority of the task having the highest current priority of the tasks waiting for those mutexes.
- When tasks lock priority ceiling mutexes, the ceiling priority of the mutex having the highest ceiling priority among those mutexes.

Note that when the current priority of a task waiting for a priority inheritance mutex changes as the result of a base priority change brought about by mutex operation or `tk_chg_pri`, it may be necessary to change the current priority of the task locking that mutex. This is called dynamic priority inheritance. Further, if this task is waiting for another priority inheritance mutex, dynamic priority inheritance processing may be necessary also for the task locking that mutex.
The T-Kernel specification defines, in addition to the above strict priority control, a simplified priority control limiting the situations in which the current priority is changed. The choice between the two is an implementation-dependent matter. In the simplified priority control, whereas all changes in the direction of raising the task current priority are carried out, changes in the direction of lowering that priority are made only when a task is no longer locking any mutexes. (In this case the task current priority reverts to the base priority.) More specifically, processing to change the current priority is needed only in the following circumstances.

- When a task with a higher current priority than that of the task locking a priority inheritance mutex starts waiting for that mutex.
- When a task waiting for a priority inheritance mutex is changed to a higher current priority than that of the task locking that mutex.
- When a task locks a priority ceiling mutex having a higher ceiling priority than the task's current priority.

- When a task is no longer locking any mutexes.

When the current priority of a task is changed in connection with a mutex operation, the following processing is performed. If the task whose priority changed is in a run state, the task precedence is changed in accord with the new priority. Its precedence among other tasks having the same priority is implementation-dependent. Likewise, if the task whose priority changed is waiting in a queue of some kind, its order in that queue is changed based on its new priority. Its order among other tasks having the same priority is implementation-dependent.
When a task terminates and there are mutexes still locked by that task, all the mutexes are unlocked. The order in which multiple locked mutexes are unlocked is implementation-dependent. See the description of `tk_unl_mtx` for the specific processing involved.

[Additional Notes]

A `TA_TFIFO` attribute mutex or `TA_TPRI` attribute mutex has functionality equivalent to that of a semaphore with a maximum of one resource (binary semaphore). The main differences are that a mutex can be unlocked only by the task that locked it, and a mutex is automatically unlocked when the task locking it terminates.
The term "priority ceiling protocol" is used here in a broad sense. The protocol described here is not the same as the algorithm originally proposed. Strictly speaking, it is what is otherwise referred to as a highest locker protocol or by other names.
When the change in current priority of a task due to a mutex operation results in that task's order being changed in a priority-based queue, it may be necessary to release the waiting state of other tasks waiting for that task or for that queue.

[Rationale for the Specification]

The precedence of tasks having the same priority as the result of a change in task current priority in a mutex operation is left as implementation-dependent, for the following reason.
Depending on the application, the mutex function may lead to frequent changes in current priority. It would not be desirable for this to result in constant task switching, which is what would happen if the precedence were made the lowest each time among tasks of the same priority. Ideally task precedence rather than priority should be inherited, but that results in large overhead in implementation. This aspect of the specification is therefore made an implementation-dependent matter.

tk_cre_mtx

Create Mutex

[C Language Interface]

```
ID mtxid = tk_cre_mtx ( T_CMTX *pk_cmtx ) ;
```

[Parameters]

T_CMTX*	pk_cmtx	Information about the mutex to be created

pk_cmtx detail:

VP	exinf	Extended information
ATR	mtxatr	Mutex attributes
PRI	ceilpri	Mutex ceiling priority

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	mtxid	Mutex ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Number of mutexes exceeds the system limit
E_RSATR	Reserved attribute (mtxatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cmtx or ceilpri is invalid)

[Description]

Creates a mutex, assigning to it a mutex ID.
exinf can be used freely by the user to set miscellaneous information about the created mutex. The information set in this parameter can be referenced by tk_ref_mtx. If a larger area is needed for indicating user information, or if the information may need to be changed after the mutex is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
mtxatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of mtxatr is as follows.

```
mtxatr:= (TA_TFIFO || TA_TPRI || TA_INHERIT || TA_CEILING)| [TA_NODISWAI]
```


TA_TFIFO	Tasks are queued in FIFO order
TA_TPRI	Tasks are queued in priority order
TA_INHERIT	Priority inheritance protocol
TA_CEILING	Priority ceiling protocol
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

When the TA_TFIFO attribute is designated, the order of the mutex task queue is FIFO. If TA_TPRI, TA_INHERIT, or TA_CEILING is designated, tasks are ordered by their priority. TA_INHERIT indicates that priority inheritance protocol is used, and TA_CEILING designates priority ceiling protocol.
Only when TA_CEILING is designated does ceilpri have validity, setting the mutex ceiling priority.

```
#define TA_TFIFO    0x00000000  /* manage task queue by FIFO     */
#define TA_TPRI     0x00000001  /* manage task queue by priority */
#define TA_INHERIT  0x00000002  /* priority inheritance protocol */
#define TA_CEILING  0x00000003  /* priority ceiling protocol     */
#define TA_NODISWAI 0x00000080  /* reject wait disabling         */
```


tk_del_mtx

Delete Mutex

[C Language Interface]

```
ER ercd = tk_del_mtx ( ID mtxid ) ;
```

[Parameters]

ID	mtxid	Mutex ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mtxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mutex designated in mtxid does not exist)

[Description]

Deletes the mutex designated in mtxid.
Issuing this system call releases the mutex ID and control block memory space allocated to the mutex. This system call completes normally even if there are tasks waiting to lock the deleted mutex, but error code E_DLT is returned to each of the tasks in WAIT state.
When a mutex is deleted, a task locking the mutex will have fewer locked mutexes. If the mutex was a priority inheritance mutex or priority ceiling mutex, it is possible that the priority of the task locking it will change as a result of its deletion.

tk_loc_mtx

Lock Mutex

[C Language Interface]

```
ER ercd = tk_loc_mtx ( ID mtxid, TMO tmout ) ;
```

[Parameters]

ID	mtxid	Mutex ID
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mtxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mutex designated in mtxid does not exist)
E_PAR	Parameter error (tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (the mutex was deleted while waiting for a lock)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)
E_ILUSE	Illegal use (multiple lock, or upper priority limit exceeded)

[Description]

Locks the mutex designated in mtxid. If the mutex can be locked immediately, the task issuing this system call continue executing without entering WAIT state, and the mutex goes to locked status. If the mutex cannot be locked, the task issuing this system call enters WAIT state. That is, the task is put in the queue of this mutex.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met, the system call terminates, returning timeout error code E_TMOUT. Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms). When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if the resource cannot be locked. When TMO_FEVR = (-1) is set in tmout, this means infinity was designated as the timeout value, and the task continues wait to until the resource is locked.
If the invoking task has already locked the designated mutex, error code E_ILUSE (multiple lock) is returned.
If the designated mutex is a priority ceiling mutex and the base priority[2] of the invoking task is higher than the ceiling priority of the mutex, error code E_ILUSE (upper priority limit exceeded) is returned.

[2]**Base priority:** The task priority before it is automatically raised by the mutex. This is the priority last set by tk_chg_pri (including while the mutex is locked), or if tk_chg_pri has never been issued, the priority set when the task

[Additional Notes]

Priority inheritance mutex (`TA_INHERIT` attribute)
If the invoking task is waiting to lock a mutex and the current priority of the task currently locking that mutex is lower than that of the invoking task, the priority of the locking task is raised to the same level as the invoking task. If the wait ends before the waiting task can obtain a lock (timeout or other reason), the priority of the task locking that mutex can be lowered (implementation-dependent option) to the highest of the following three priorities.

a. The highest priority among the current priorities of task waiting to lock the mutex.

b. The highest priority among all the other mutexes locked by the task currently locking this mutex.

c. The base priority of the locking task.

Priority ceiling mutex (`TA_CEILING` attribute)
If the invoking task obtains a lock and its current priority is lower than the mutex ceiling priority, the priority of the invoking task is raised to the mutex ceiling priority.

---

was created.

tk_unl_mtx

Unlock Mutex

[C Language Interface]

```
ER ercd = tk_unl_mtx ( ID mtxid ) ;
```

[Parameters]

ID	mtxid	Mutex ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mtxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mutex designated in mtxid does not exist)
E_ILUSE	Illegal use (not a mutex locked by the invoking task)

[Description]

Unlocks the mutex designated in mtxid. If there are tasks waiting to lock the mutex, the WAIT state of the task at the head of the queue for that mutex is released and that task locks the mutex.
If a mutex that was not locked by the invoking task is designated, error code E_ILUSE is returned.

[Additional Notes]

If the unlocked mutex is a priority inheritance mutex or priority ceiling mutex, task priority must be lowered as follows. If as a result of this operation the invoking task no longer has any locked mutexes, the invoking task priority is lowered to its base priority. If the invoking task continues to have locked mutexes after this operation, the invoking task priority is lowered to whichever of the following priority levels is highest.

a. The highest priority of all remaining locked mutexes.

b. The base priority.

Note that the lowering of priority when locked mutexes remain is an implementation-dependent optional specification.
If a task terminates (goes to DORMANT state or NON-EXISTENT state) without explicitly unlocking mutexes, all its locked mutexes are automatically unlocked.

tk_ref_mtx

Reference Mutex Status

[C Language Interface]

```
ER ercd = tk_ref_mtx ( ID mtxid, T_RMTX *pk_rmtx ) ;
```

[Parameters]

ID	mtxid	Mutex ID
T_RMTX*	pk_rmtx	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rmtx detail:

VP	exinf	Extended information
ID	htsk	ID of task locking the mutex
ID	wtsk	ID of tasks waiting to lock the mutex

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mtxid is invalid or cannot be used)
E_NOEXS	Object does not exist (the mutex designated in mtxid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the mutex designated in mtxid, passing in the return parameters the task currently locking the mutex (htsk), tasks waiting to lock the mutex (wtsk), and extended information (exinf).
htsk returns the ID of the task locking the mutex. If no task is locking it, htsk = 0 is returned.
wtsk indicates the ID of a task waiting to lock the mutex. If there are multiple waiting tasks, the ID of the task at the head of the queue is returned. If no tasks are waiting, wtsk = 0 is returned.
If the designated mutex does not exist, error code E_NOEXS is returned.

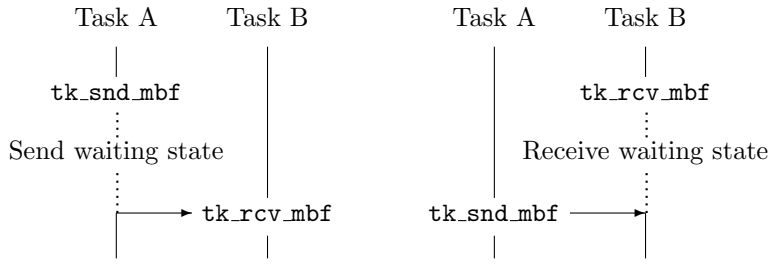
4.5.2 Message Buffer

A message buffer is an object for achieving synchronization and communication by the passing of variable-size messages. Functions are provided for creating and deleting a message buffer, sending and receiving messages using a message buffer, and referencing message buffer status. A message buffer is an object identified by an ID number called a message buffer ID.
A message buffer keeps a queue of messages waiting to be sent (send queue) and a queue of tasks waiting for message receipt (receive queue). It also has a message buffer space for holding sent messages. The message sender (the side making event notification) copies to the message buffer a message it wants to send. If there is insufficient space in the message buffer area, the message is queued for sending until enough space is available. A task waiting to send a message to the message buffer is put in the send queue. On the message receipt side (waiting for event notification), one message is fetched from the message buffer. If the message buffer has no messages, the task enters WAIT state until the next message is sent. A task waiting for receipt from a message buffer is put in the receive queue of that message buffer.
A synchronous message function can be realized by setting the message buffer space size to 0. In that case both the sending task and receiving task wait for a system call to be invoked by each other, and the message is passed when both sides issue system calls.

[Additional Notes]

The message buffer functioning when the size of the message buffer space is set to 0 is explained here using the example in Figure 4.3. In this example Task A and Task B run asynchronously.

- If Task A calls `tk_snd_mbf` first, it goes to WAIT state until Task B calls `tk_rcv_mbf`. In this case Task A is put in the message buffer send queue (a).
- If Task B calls `tk_rcv_mbf` first, on the other hand, Task B goes to WAIT state until Task A calls `tk_snd_mbf`. Task B is put in the message buffer receive queue (b).
- At the point where both Task A has called `tk_snd_mbf` and Task B has called `tk_rcv_mbf`, a message is passed from Task A to Task B; then both tasks go from WAIT state to a run state.



(a) `tk_snd_mbf` called first (b) `tk_rcv_mbf` called first

Figure 4.3: Synchronous Communication by Message Buffer

Tasks waiting to send to a message buffer send messages in their queued order. Suppose Task A wanting to send a 40-byte message to a message buffer, and Task B wanting to send a 10-byte message, are queued in that order. If another task receives a message opening 20 bytes of space in the message buffer, Task B is still required to wait until Task A sends its message.

A message buffer is used to pass variable-size messages by copying them. It is the copying of messages that makes this function different from the mailbox function.
It is assumed that the message buffer will be implemented as a ring buffer.

tk_cre_mbf

Create Message Buffer

[C Language Interface]

```
ID mbfid = tk_cre_mbf ( T_CMBF *pk_cmbf ) ;
```

[Parameters]

T_CMBF*	pk_cmbf	Information about the message buffer to be created

pk_cmbf detail:

VP	exinf	Extended information
ATR	mbfatr	Message buffer attributes
INT	bufsz	Message buffer size (in bytes)
INT	maxmsz	Maximum message size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	mbfid	Message buffer ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block or ring buffer area cannot be allocated)
E_LIMIT	Number of message buffers exceeds the system limit
E_RSATR	Reserved attribute (mbfatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cmbf is invalid, or bufsz or maxmsz is negative or invalid)

[Description]

Creates a message buffer, assigning to it a message buffer ID.
This system call allocates a control block to the created message buffer. Based on the information designated in bufsz, it allocates a ring buffer area for message queue use (for messages waiting to be received).
A message buffer is an object for managing the sending and receiving of variable-size messages. If differs from a mailbox (mbx) in that the contents of the variable-size messages are copied when the message is sent and received. It also has a function for putting the sending task in WAIT state when the buffer is full.
exinf can be used freely by the user to set miscellaneous information about the created message buffer. The information set in this parameter can be referenced by tk_ref_mbf. If a larger area is needed for indicating user information, or if the information may need to be changed after the message buffer is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.

mbfatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of mbfatr is as follows.

```
mbfatr:= (TA_TFIFO || TA_TPRI) | [TA_NODISWAI]
```

TA_TFIFO	Tasks waiting to send are queued in FIFO order
TA_TPRI	Tasks waiting to send are queued in priority order
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

The queuing order of tasks waiting for a message to be sent when the buffer is full can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting. Messages themselves are queued in FIFO order only. Tasks waiting for message receipt from a message buffer are likewise queued in FIFO order only.

```
#define TA_TFIFO    0x00000000  /* manage task queue by FIFO     */
#define TA_TPRI     0x00000001  /* manage task queue by priority */
#define TA_NODISWAI 0x00000080  /* reject wait disabling         */
```

[Additional Notes]

When there are multiple tasks waiting to send messages, the order in which their messages are sent when buffer space becomes available is always in their queued order. If, for example, a Task A wanting to send a 30-byte message is queued with a Task B wanting to send a 10-byte message, in the order A-B, even if 20 bytes of message buffer space becomes available, Task B never sends its message before Task A.
The ring buffer in which messages are queued also contains information for managing each message. For this reason the total size of queued messages will ordinarily not be identical to the ring buffer size designated in bufsz. Normally the total message size will be smaller than bufsz. In this sense bufsz does not strictly represent the total message capacity.
It is possible to create a message buffer with bufsz = 0. In this case communication using the message buffer is completely synchronous between the sending and receiving tasks. That is, if either tk_snd_mbf or tk_rcv_mbf is executed ahead of the other, the task executing the first system call goes to WAIT state. When the other system call is executed, the message is passed (copied), then both tasks resume running.
In the case of a bufsz = 0 message buffer, the specific functioning is as follows.

- In Figure 4.4, Task A and Task B operate asynchronously. If Task A arrives at point (1) first and executes tk_snd_mbf(mbfid), Task A goes to send wait state until Task B arrives at point (2). If tk_ref_tsk is issued for Task A in this state, tskwait=TTW_SMBF is returned. If, on the other hand, Task B gets to point (2) first and calls tk_rcv_mbf(mbfid), Task B goes to receive wait state until Task A gets to point (1). If tk_ref_tsk is issued for Task B in this state, tskwait=TTW_RMBF is returned.
- At the point where both Task A has executed tk_snd_mbf(mbfid) and Task B has executed tk_rcv_mbf(mbfid), a message is passed from Task A to Task B, their wait states are released and both tasks resume running.

tk_del_mbf

Delete Message Buffer

[C Language Interface]

```
ER ercd = tk_del_mbf ( ID mbfid ) ;
```

[Parameters]

ID	mbfid	Message buffer ID

[Return Parameters]

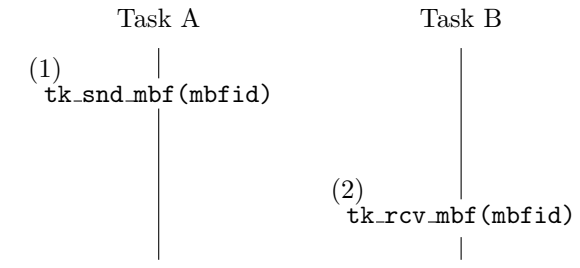
ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the message buffer designated in mbfid does not exist)

[Description]

Deletes the message buffer designated in mbfid.
Issuing this system call releases the corresponding message buffer and control block memory space, as well as the message buffer space.
This system call completes normally even if there were tasks queued in the message buffer for message receipt or message sending, but error code E_DLT is returned to the tasks in WAIT state. If there are messages left in the message buffer when it is deleted, the message buffer is deleted anyway. No error code is returned and the messages are discarded.



Message send wait (TTW_SMBF) if wait entered at (1)
Message receive wait (TTW_RMBF) if wait entered at (2)

Figure 4.4: Synchronous Communication Using Message Buffer of bufsz = 0

tk_snd_mbf

Send Message to Message Buffer

[C Language Interface]

```
ER ercd = tk_snd_mbf ( ID mbfid, VP msg, INT msgsz, TMO tmout ) ;
```

[Parameters]

ID	mbfid	Message buffer ID
INT	msgsz	Send message size (in bytes)
VP	msg	Start address of send message packet
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the message buffer designated in mbfid does not exist)
E_PAR	Parameter error (msgsz ≤ 0, msgsz $>$ maxmsz,value that cannot be used in msg, or tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (message buffer was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Sends the message at the address designated in msg to the message buffer designated in mbfid. The message size is indicated in msgsz. This system call copies msgsz bytes starting from msg to the message queue of message buffer mbfid. The message queue is implemented as a ring buffer.
If msgsz is larger than the maxmsz designated with tk_cre_mbf, error code E_PAR is returned.
If there is not enough available buffer space to accommodate message msg in the message queue, the task issuing this system call goes to send wait state and is queued waiting for buffer space to become available (send queue). Waiting tasks are queued in either FIFO or priority order, depending on the designation made with tk_cre_mbf.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (before there is sufficient buffer space), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).

When `TMO_POL` = 0 is set in `tmout`, this means 0 was designated as the timeout value, and `E_TMOUT` is returned without entering WAIT state if there is not enough buffer space.
When `TMO_FEVR` = (−1) is set in `tmout`, this means infinity was designated as the timeout value, and the task continues to wait for buffer space to become available, without timing out. A message of size 0 cannot be sent. When `msgsz` ≤ 0 is designated, error code `E_PAR` is returned.
When this system call is invoked from a task-independent portion or in dispatch disabled state, error code `E_CTX` is returned; but in the case of `tmout` = `TMO_POL`, there may be implementations where execution from a task-independent portion or in dispatch disabled state is possible.

tk_rcv_mbf

Receive Message from Message Buffer

[C Language Interface]

```
INT msgsz = tk_rcv_mbf ( ID mbfid, VP msg, TMO tmout ) ;
```

[Parameters]

ID	mbfid	Message buffer ID
VP	msg	Start address of receive message packet
TMO	tmout	Timeout designation

[Return Parameters]

INT	msgsz	Received message size
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the message buffer designated in mbfid does not exist)
E_PAR	Parameter error (value that cannot be used in msg, or tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (message buffer was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Receives a message from the message buffer designated in mbfid, putting it in the location designated in msg.
This system call copies the contents of the first queued message in the message buffer designated in mbfid, and copies it to an area of msgsz bytes starting at address msg.
If no message has been sent to the message buffer designated in mbfid (the message queue is empty), the task issuing this system call goes to WAIT state and is put in the receive queue of the message buffer to wait for message arrival. Tasks in the receive queue are ordered by FIFO only.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (before a message arrives), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if there is no message.
When TMO_FEVR = (−1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for message arrival without timing out.

tk_ref_mbf

Get Message Buffer Status

[C Language Interface]

```
ER ercd = tk_ref_mbf ( ID mbfid, T_RMBF *pk_rmbf ) ;
```

[Parameters]

ID	mbfid	Message buffer ID
T_RMBF*	pk_rmbf	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rmbf detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
ID	stsk	Send task information
INT	msgsz	Size of the next message to be received (in bytes)
INT	frbufsz	Free buffer size (in bytes)
INT	maxmsz	Maximum message size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mbfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the message buffer designated in mbfid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the message buffer designated in mbfid, passing in the return parameters sending task information (stsk), the size of the next message to be received (msgsz), free buffer size (frbufsz), tmaximum message size (maxmsz), waiting task information (wtsk), and extended information (exinf). wtsk indicates the ID of a task waiting for receipt from the message buffer. The ID of a task waiting to send to the message buffer is indicated in stsk. If multiple tasks are waiting in the message buffer queues, the ID of the task at the head of the queue is returned. If no tasks are waiting, 0 is returned. If the designated message buffer does not exist, error code E_NOEXS is returned.
The size of the message at the head of the queue (the next message to be received) is returned in msgsz. If there are no queued messages, msgsz = 0 is returned. A message of size 0 cannot be sent. At least one of msgsz = 0 and wtsk = 0 is always true for this system call. frbufsz indicates the free space in the ring buffer of which the message queue consists. This value indicates the approximate size of messages than can be sent. maxmsz returns the maximum message size as designated with tk_cre_mbf.

4.5.3 Rendezvous Port

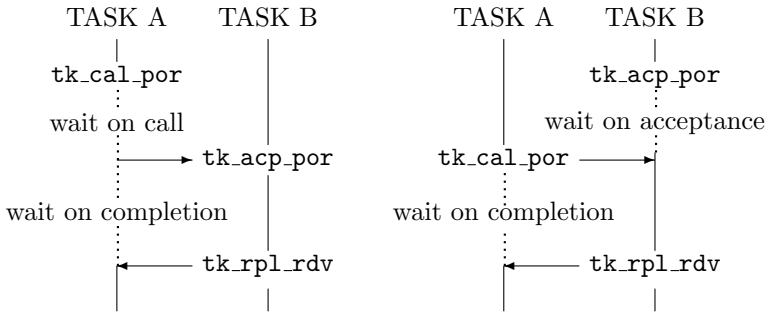
Rendezvous is a function for synchronization and communication between tasks, supporting the procedures for making processing requests by one task to another and for returning the processing result to the requesting task. The object for which both of these tasks wait is called a rendezvous port. The rendezvous function is typically used to realize task communication in a client/server model, but can also support more flexible synchronization and communication models.
Functions are provided for creating and deleting a rendezvous port, issuing a processing request to a rendezvous port (call rendezvous), accepting a processing request from a rendezvous port (accept rendezvous), returning the processing result (reply rendezvous), forwarding an accepted processing request to another rendezvous port (forward rendezvous to other port), and referencing rendezvous port status and rendezvous status. A rendezvous port is identified by an ID number called a rendezvous port ID.
A task issuing a processing request to a rendezvous port (the client-side task) calls a rendezvous, designating a message (called a call message) with information about the rendezvous port, the rendezvous conditions, and the processing being requested. The task accepting a processing request on a rendezvous port (the server-side task) accepts the rendezvous, designating the rendezvous port and rendezvous conditions.
The rendezvous conditions are indicated in a bit pattern. If the bitwise logical AND of the bit patterns on both sides (the rendezvous conditions bit pattern of the task calling a rendezvous for a rendezvous port and the rendezvous conditions bit pattern of the accepting task) is not 0, the rendezvous is established. The state of the task calling the rendezvous is WAIT on rendezvous call until the rendezvous is established. The state of the task accepting a rendezvous is WAIT on rendezvous acceptance until the rendezvous is established.
When a rendezvous is established, a call message is passed from the task that called the rendezvous to the accepting task. The state of the task calling the rendezvous goes to WAIT for rendezvous completion until the requested processing is completed. The task accepting the rendezvous is released from WAIT state and it performs the requested processing. Upon completion of the requested processing, the task accepting the rendezvous passes the result of the processing in a reply message to the calling task and ends the rendezvous. At this point the WAIT state of the task that called the rendezvous is released.
A rendezvous port has separate queues for tasks waiting on rendezvous call (call queue) and tasks waiting on rendezvous acceptance (accept queue). Note, however, that after a rendezvous is established, both tasks that formed the rendezvous are detached from the rendezvous port. In other words, a rendezvous port does not have a queue for tasks waiting for rendezvous completion. Nor does it keep information about the task performing the requested processing.
T-Kernel assigns an object number to identify each rendezvous when more than one is established at the same time. The rendezvous object number is called the rendezvous number. The method of assigning rendezvous numbers is implementation-dependent, but at a minimum information must be included for designating the task that called the rendezvous. Numbers must also be uniquely assigned to the extent possible; for example, even if the same task makes multiple rendezvous calls, the first rendezvous and second rendezvous must have different rendezvous numbers assigned.

[Additional Notes]

Rendezvous is a synchronization and communication function introduced in the ADA programming language, based on Communicating Sequential Processes (CSP). In ADA, however, the rendezvous function is part of the language specification and therefore has a different role than in T-Kernel, which is a real-time kernel specification. The rendezvous ports provided by the real-time kernel are OS primitives by which an ADA rendezvous capability is implemented. Since the ADA rendezvous function differs from that in the T-Kernel specification in a number of ways, the T-Kernel-specification rendezvous functions cannot necessarily be used to implement the ADA rendezvous.

Rendezvous operation is explained here using the example in Figure 4.5. In this figure Task A and Task B are running asynchronously.

- If Task A first calls `tk_cal_por`, Task A goes to WAIT state until Task B calls `tk_acp_por`. The state of Task A at this time is WAIT on rendezvous call (a).
- If, on the other hand, Task B first calls `tk_acp_por`, Task B goes to WAIT state until Task A calls `tk_cal_por`. The stat of Task B at this time is WAIT on rendezvous acceptance (b).
- A rendezvous is established when both Task A has called `tk_cal_por` and Task B has called `tk_acp_por`. At this time Task A remains in WAIT state while the WAIT state of Task B is released. The state of Task A is WAIT for rendezvous completion.
- The Task A WAIT state is released when Task B calls `tk_rpl_rdv`. Thereafter both tasks enter a run state.



(a) `tk_cal_por` called first (b) `tk_acp_por` called first

Figure 4.5: Rendezvous Operation

As an example of a specific method for assigning rendezvous object numbers, the ID number of the task calling the rendezvous can go in the low bits of the rendezvous number, with the high bits used for a sequential number.

[Rationale for the Specification]

While it is true that the rendezvous functionality can be achieved through a combination of other synchronization and communication functions, better efficiency and ease of programming are achieved by having a dedicated function for cases where the communication involves an acknowledgment. One advantage of the rendezvous function is that since both tasks wait until message passing is completed, no memory space needs to be allocated for storing messages.
The reason for assigning unique rendezvous numbers even when the same task does the calling is as follows. It is possible that a task, after establishing a rendezvous and going to WAIT state for its completion, will have its WAIT state released due to timeout or forcible release by another task, then again call a rendezvous and have that rendezvous established. If the same number were assigned to both the first and second rendezvous, attempting to terminate the first rendezvous would end up terminating the second rendezvous. If separate numbers are assigned to the two rendezvous and the task in WAIT state for rendezvous completion is made to remember the number of the rendezvous for which it is waiting, error will be returned when the attempt is made to terminate the first rendezvous.

tk_cre_por

Create Port for Rendezvous

[C Language Interface]

```
ID porid = tk_cre_por ( T_CPOR *pk_cpor ) ;
```

[Parameters]

T_CPOR*	pk_cpor	Information about the rendezvous port to be created

pk_cpor detail:

VP	exinf	Extended information
ATR	poratr	Rendezvous port attributes
INT	maxcmsz	Maximum call message size (in bytes)
INT	maxrmsz	Maximum reply message size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	porid	Port ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Number of rendezvous ports exceeds the system limit
E_RSATR	Reserved attribute (poratr is invalid or cannot be used)
E_PAR	Parameter error (pk_cpor is invalid; maxcmsz or maxrmsz is negative or invalid)

[Description]

Creates a rendezvous port, assigning to it a rendezvous port ID number.
This specification allocates a control block to the created rendezvous port. A rendezvous port is an object used as an OS primitive for implementing a rendezvous capability.
exinf can be used freely by the user to set miscellaneous information about the created rendezvous port. The information set in this parameter can be referenced by tk_ref_por. If a larger area is needed for indicating user information, or if the information may need to be changed after the rendezvous port is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
poratr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of poratr is as follows.

```
poratr:= (TA_TFIFO || TA_TPRI) | [TA_NODISWAI]
```


TA_TFIFO	Tasks waiting on call are queued in FIFO order
TA_TPRI	Tasks waiting on call are queued in priority order
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

TA_TFIFO and TA_TPRI attributes designate the queuing order of tasks waiting on a rendezvous call. Tasks waiting on rendezvous acceptance are queued in FIFO order only.

```
#define TA_TFIFO    0x00000000      /* manage task queue by FIFO     */
#define TA_TPRI     0x00000001      /* manage task queue by priority */
#define TA_NODISWAI 0x00000080      /* reject wait disabling         */
```


tk_del_por

Delete Port for Rendezvous

[C Language Interface]

```
ER ercd = tk_del_por ( ID porid ) ;
```

[Parameters]

ID	porid	Rendezvous port ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (porid is invalid or cannot be used)
E_NOEXS	Object does not exist (the rendezvous port designated in porid does not exist)

[Description]

Deletes the rendezvous port designated in porid.
Issuing this system call releases the ID number and control block space allocated to the rendezvous port. This system call completes normally even if there are tasks waiting on rendezvous acceptance (tk_acp_por) or rendezvous port call (tk_cal_por) at the designated rendezvous port, but error code E_DLT is returned to the tasks in WAIT state.
Deletion of a rendezvous port by tk_del_por does not affect tasks for which rendezvous is already established. In this case, nothing is reported to the task accepting the rendezvous (not in WAIT state), and the state of the task calling the rendezvous (WAIT for rendezvous completion) remains unchanged. When the task accepting the rendezvous issues tk_rpl_rdv, that system call will execute normally even if the port on which the rendezvous was established has been deleted.

tk_cal_por

Call Port for Rendezvous

[C Language Interface]

```
INT rmsgsz = tk_cal_por ( ID porid, UINT calptn, VP msg, INT cmsgsz, TMO tmout ) ;
```

[Parameters]

ID	porid	Rendezvous port ID
UINT	calptn	Call bit pattern (indicating conditions of the caller)
VP	msg	Message packet address
INT	cmsgsz	Call message size (in bytes)
TMO	tmout	Timeout designation

[Return Parameters]

INT	rmsgsz	Reply message size (in bytes)
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (porid is invalid or cannot be used)
E_NOEXS	Object does not exist (the rendezvous port designated in porid does not exist)
E_PAR	Parameter error (cmsgsz < 0, cmsgsz $>$ maxcmsz, calptn $= 0$, value that cannot be used in msg, tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (the rendezvous port was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Issues a rendezvous call for a rendezvous port.
The specific operation of tk_cal_por is as follows. A rendezvous is established if there is a task waiting to accept a rendezvous at the port designated in porid and rendezvous conditions between that task and the task issuing this call overlap. In this case, the task waiting to accept the rendezvous enters READY state while the state of the task issuing tk_cal_por is WAIT for rendezvous completion. The task waiting for rendezvous completion is released from WAIT state when the other (accepting) task executes tk_rpl_rdv. The tk_cal_por system call completes at this time.
If there is no task waiting to accept a rendezvous at the port designated in porid, or if there is a task but conditions for establishing a rendezvous are not satisfied, the task issuing tk_cal_por is placed at the end of the call queue of that port and enters WAIT state on rendezvous call. The order of tasks in the call queue is either FIFO or priority order, depending on the designation made when calling tk_cre_por.

The decision on rendezvous establishment is made by checking conditions in the bit patterns acpptn of the accepting task and calptn of the calling task. A rendezvous is established if the bitwise logical AND of these two bit patterns is not 0. Parameter error E_PAR is returned if calptn is 0, since no rendezvous can be established in that case.
When a rendezvous is established, the calling task can send a message (a call message) to the accepting task. The size of the call message is designated in cmsgsz. In this operation cmsgsz bytes starting at address msg as designated by the calling task when calling tk_cal_por are copied to address msg as designated by the accepting task when calling tk_acp_por.
Similarly, when the rendezvous completes, the accepting task may send a message (reply message) to the calling task. In this operation, the contents of a reply message designated by the accepting task when calling tk_rpl_rdv are copied to address msg as designated by the calling task when calling tk_cal_por. The size of the reply message rmsgsz is set in a tk_cal_por return parameter. The original contents of the message area passed in msg by tk_cal_por end up being overwritten by the reply message received when tk_rpl_rdv executes.
Note that it is possible message contents will be destroyed when a rendezvous is forwarded, since an area no larger than maxrmsz starting from the address msg as designated with tk_cal_por is used as a buffer. It is therefore necessary to reserve a memory space of at least maxrmsz starting from msg, regardless of the expected size of the reply message, whenever there is any possibility that a rendezvous requested by tk_cal_por might be forwarded (See the description of tk_fwd_por for details).
Error code E_PAR is returned when cmsgsz exceeds the size maxcmsz designated with tk_cre_por. This error checking is made before a task enters WAIT state on rendezvous call; and if error is detected, the task executing tk_cal_por does not enter WAIT state.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (rendezvous is not established), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state if there is no task waiting on a rendezvous at the rendezvous port, or if the rendezvous conditions are not met. When TMO_FEVR = (−1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for a rendezvous to be established without timing out. In any case, the tmout designation indicates the time allowed for a rendezvous to be established, and does not apply to the time from rendezvous establishment to rendezvous completion.

tk_acp_por

Accept Port for Rendezvous

[C Language Interface]

```
INT cmsgsz = tk_acp_por ( ID porid, UINT acpptn, RNO *p_rdvno, VP msg, TMO tmout ) ;
```

[Parameters]

ID	porid	Rendezvous port ID
UINT	acpptn	Accept bit pattern (indicating conditions for acceptance)
VP	msg	Message packet address
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code
RNO	rdvno	Rendezvous number
INT	cmsgsz	Call message size (in bytes)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (porid is invalid or cannot be used, or porid is a rendezvous port of another node)
E_NOEXS	Object does not exist (the rendezvous port designated in porid does not exist)
E_PAR	Parameter error (acpptn = 0, value that cannot be used in msg, or tmout ≤ (−2))
E_DLT	The object being waited for was deleted (the rendezvous port was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Accepts a rendezvous on a rendezvous port.
The specific operation of tk_acp_por is as follows. A rendezvous is established if there is a task queued for a rendezvous call at the port designated in porid and if rendezvous conditions of that task and the task issuing this call overlap. In this case, the task queued for a rendezvous call is removed from the queue, and its state changes from WAIT on rendezvous call to WAIT for rendezvous completion. The task issuing tk_acp_por continues executing.
If there is no task waiting to call a rendezvous at the port designated in porid, or if there is a task but conditions for establishing a rendezvous are not satisfied, the task issuing tk_acp_por will enter WAIT state on rendezvous acceptance for that port. No error results if there is already another task in WAIT state on rendezvous acceptance at this time; the task issuing tk_acp_por is placed in the accept queue. It is possible to conduct multiple rendezvous operations on the same port at the same time. Accordingly, no error results even if the next rendezvous is carried out while another task is still

conducting a rendezvous (before tk_rpl_rdv is called for a previously established rendezvous) at the port designated in porid.
The decision on rendezvous establishment is made by checking conditions in the bit patterns acpptn of the accepting task and calptn of the calling task. A rendezvous is established if the bitwise logical AND of these two bit patterns is not 0. If the first task does not satisfy these conditions, each subsequent task in the call queue is checked in succession. If calptn and acpptn are assigned the same non-zero value, rendezvous is established unconditionally. Parameter error E_PAR is returned if acpptn is 0, since no rendezvous can be established in that case. All processing before a rendezvous is established is fully symmetrical on the calling and accepting ends.
When a rendezvous is established, the calling task can send a message (a call message) to the accepting task. The contents of the message designated by the calling task are copied to an area starting from msg designated by the accepting task when tk_acp_por is called. The call message size cmsgsz is passed in a return parameter of tk_acp_por.
A task accepting rendezvous can establish more than one rendezvous at a time. That is, a task that has accepted one rendezvous using tk_acp_por may execute tk_acp_por again before executing tk_rpl_rdv on the first rendezvous. The port designated for the second tk_acp_por call at this time may be the same port as the first rendezvous or a different one. It is even possible for a task already conducting a rendezvous on a given port to execute tk_acp_por again on the same port and conduct multiple rendezvous on the same port at the same time. Of course, the calling tasks will be different in each case.
The return parameter rdvno passed by tk_acp_por is information used to distinguish different rendezvous when more than one has been established at a given time. It is used as a return parameter by tk_rpl_rdv when a rendezvous completes. It is also passed as a parameter to tk_fwd_por when forwarding a rendezvous. Although the exact contents of rdvno are implementation-dependent, it is expected to include information designating the calling task on the other end of the rendezvous.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (rendezvous is not established), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state if there is no task waiting for a rendezvous call at the rendezvous port, or if the rendezvous conditions are not met.
When TMO_FEVR = (−1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for a rendezvous to be established without timing out.

```
select
    when condition_A
        accept entry_A do ... end;
or
    when condition_B
        accept entry_B do ... end;
or
    when condition_C
        accept entry_C do ... end;
end select;
```

Figure 4.6: Sample ADA-like Program Using select Statement

[Additional Notes]

The ability to queue tasks accepting rendezvous is useful when multiple servers perform the same processing concurrently. This capability also takes advantage of the task-independent nature of ports.
If a task accepting a rendezvous terminates abnormally for some reason before completing its rendezvous (before issuing `tk_rpl_rdv`), the task calling for the rendezvous by issuing `tk_cal_por` will continue waiting indefinitely for rendezvous completion without being released. To avoid such a situation, tasks accepting rendezvous should execute a `tk_rpl_rdv` or `tk_rel_wai` call when they terminate abnormally, as well as notifying the task calling for the rendezvous that the rendezvous ended in error.
`rdvno` contains information designating the calling task in the rendezvous, but unique numbers should be assigned to the extent possible. Even if different rendezvous are conducted between the same tasks, a different `rdvno` value should be assigned to the first and second rendezvous to avoid problems like the following.

- Rather than `entry_A`, `entry_B`, and `entry_C` each corresponding to one rendezvous port, the entire select statement corresponds to one rendezvous port.
- `entry_A`, `entry_B`, and `entry_C` correspond to `calptn` and `acpptn` bits `2^0`, `2^1`, and `2^2`.
- A select statement in a typical ADA program looks like the following.

```
ptn := 0;
if condition_A then ptn := ptn + 2^0 endif;
if condition_B then ptn := ptn + 2^1 endif;
if condition_C then ptn := ptn + 2^2 endif;
tk_acp_por(acpptn := ptn);
```

- If the program contains in addition to the select statement a simple `entry_A` accept with no select,

```
tk_acp_por(acpptn := 2^0);
```

  can be executed. If it is desired to have `entry_A`, `entry_B`, and `entry_C` wait unconditionally by OR logic,

```
tk_acp_por(acpptn := 2^2+2^1+2^0);
```

  can be executed.

- If the call on the rendezvous calling side is for `entry_A`,

```
tk_cal_por(calptn := 2^0);
```

  can be executed; and if the call is for `entry_C`,

```
tk_cal_por(calptn := 2^2);
```

  can be executed.

Figure 4.7: Using Rendezvous to Implement ADA select Function

If a task that called `tk_cal_por` and is waiting for rendezvous completion has its WAIT state released by `tk_rel_wai` or by `tk_ter_tsk` + `tk_sta_tsk` or the like, conceivably it may execute `tk_cal_por` a second time, resulting in establishment of a rendezvous. If the same `rdvno` value is assigned to the first rendezvous and the subsequent one, then if `tk_rpl_rdv` is executed for the first rendezvous it will end up terminating the second one. By assigning `rdvno` numbers uniquely and having the task in WAIT state for rendezvous completion remember the number of the expected `rdvno`, it will be possible to detect the error when `tk_rpl_rdv` is called for the first rendezvous.
One possible method of assigning `rdvno` numbers is to put the ID number of the task calling the rendezvous in the low bits of `rdvno`, using the high bits for a sequential number.

The capability of setting rendezvous conditions in `calptn` and `acpptn` can be applied to implement a rendezvous selective acceptance function like the ADA select function. A specific processing approach equivalent to an ADA select statement (Figure 4.6) is shown in Figure 4.7.
The ADA select function is provided only on the accepting end, but it is also possible to implement a select function on the calling end by designating multiple bits in `calptn`.

[Rationale for the Specification]

The reason for specifying separate system calls `tk_cal_por` and `tk_acp_por` even though the conditions for establishing a rendezvous mirror each other on the calling and accepting sides is because processing required after a rendezvous is established differs for the tasks on each side. That is, whereas the calling task enters WAIT state after the rendezvous is established, the accepting task enters READY state.

tk_fwd_por

Forward Rendezvous to Other Port

[C Language Interface]

```
ER ercd = tk_fwd_por ( ID porid, UINT calptn, RNO rdvno, VP msg, INT cmsgsz ) ;
```

[Parameters]

ID	porid	Rendezvous port ID
UINT	calptn	Call bit pattern (indicating conditions of the caller)
RNO	rdvno	Rendezvous number before forwarding
VP	msg	Message packet address
INT	cmsgsz	Call message size (in bytes)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (porid is invalid or cannot be used, or porid is a rendezvous port of another node)
E_NOEXS	Object does not exist (the rendezvous port designated in porid does not exist)
E_PAR	Parameter error (cmsgsz < 0, cmsgsz $>$ maxcmsz after forwarding, cmsgsz $>$ maxrmsz before forwarding, calptn $= 0$, or value that cannot be used in msg)
E_OBJ	Invalid object state (rdvno is invalid, or maxrmsz (after forwarding) $>$ maxrmsz (before forwarding))
E_CTX	Context error (issued from task-independent portion (implementation-dependent error))
E_DISWAI	Wait released by wait disabled state

[Description]

Forwards an accepted rendezvous to another rendezvous port.
The task issuing this system call (here "Task X") must have accepted the rendezvous designated in porid; i.e., this system call can be issued only after executing tk_acp_por. In the discussion that follows, the rendezvous calling task is "Task Y", and the rendezvous number passed in a return parameter by tk_acp_por is rdvno. After tk_fwd_por is issued in this situation, the rendezvous between Task X and Task Y is released, and all processing thereafter is the same as if Task Y had called for a rendezvous on another port (rendezvous port B) passed to this system call in porid.
The specific operations of tk_fwd_por are as follows.

1. The rendezvous designated in rdvno is released.
2. Task Y goes to WAIT state on rendezvous call for the rendezvous port designated in porid. The bit conditions representing the call select conditions in this case are not those given in the calptn designated by Task Y when it called tk_cal_por, but those in the calptn designated by Task X

when it called tk_fwd_por. The state of Task Y goes from WAIT for rendezvous completion back to WAIT on rendezvous call.

3. Then if a rendezvous for the rendezvous port designated in porid is accepted, a rendezvous is established between the accepting task and Task Y. Naturally, if there is a task already waiting to accept a rendezvous on the rendezvous port designated in porid and the rendezvous conditions are met, executing tk_fwd_por will immediately cause a rendezvous to be established.
   Here too, as with calptn, the message sent to the accepting task when the rendezvous is established is that designated in tk_fwd_por by Task X, not that designated in tk_cal_por by Task Y.

4. After the new rendezvous has completed, the reply message returned to the calling task by tk_rpl_rdv is copied to the area designated in the msg parameter passed to tk_cal_por by Task Y, not to the area designated in the msg parameter passed to tk_fwd_por by Task X.

Essentially the following situation:

```
Executing tk_fwd_por (porid=portB, calptn=ptnB, msg=mesB)
after tk_cal_por (porid=portA, calptn=ptnA, msg=mesA)
```

is the same as the following:

```
Executing tk_cal_por (porid=portB, calptn=ptnB, msg=mesB).
```

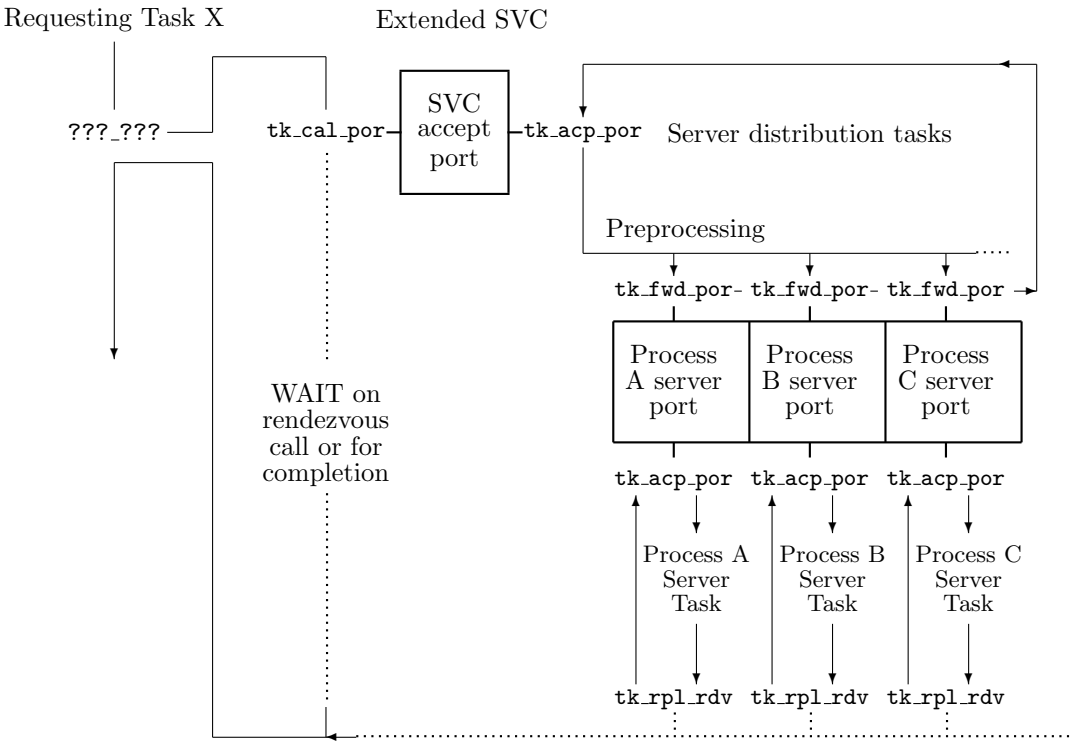
Note that it is not necessary to log the history of rendezvous forwarding.
If tk_ref_tsk is executed for a task that has returned to WAIT on rendezvous call due to tk_fwd_por execution, the value returned in tskwait is TTW_CAL. Here wid is the ID of the rendezvous port to which the rendezvous was forwarded.
tk_fwd_por execution completes immediately; in no case does this system call go to a WAIT state. A task issuing tk_fwd_por loses any relationship to the rendezvous port on which the forwarded rendezvous was established, the forwarding destination (the port designated in porid), and the tasks conducting rendezvous on these ports.
Error code E_PAR is returned if cmsgsz is larger than maxcmsz of the rendezvous port after forwarding. This error is checked before the rendezvous is forwarded. If this error occurs, the rendezvous is not forwarded and the rendezvous designated in rdvno is not released.
The send message designated with tk_fwd_por is copied to another memory space (such as the message area designated with tk_cal_por) when tk_fwd_por is executed. Accordingly, even if the contents of the message area designated in the msg parameter passed to tk_fwd_por are changed before the forwarded rendezvous is established, the forwarded rendezvous will not be affected.
When a rendezvous is forwarded by tk_fwd_por, maxrmsz of the rendezvous port after forwarding (designated in porid) must be no larger than maxrmsz of the rendezvous port on which the rendezvous was established before forwarding. If maxrmsz of the rendezvous port after forwarding is larger than maxrmsz of the rendezvous port before forwarding, this means the destination rendezvous port was not suitable, and error code E_OBJ is returned. The task calling the rendezvous readies a reply message receiving area based on the maxrmsz of the rendezvous port before forwarding. If the maximum size for the reply message increases when the rendezvous is forwarded, this may indicate that an unexpectedly large reply message is being returned to the calling rendezvous port, which would cause problems. For this reason a rendezvous cannot be forwarded to a rendezvous port having a larger maxrmsz.
Similarly, cmsgsz indicating the size of the message sent by tk_fwd_por must be no larger than maxrmsz of the rendezvous port on which the rendezvous was established before forwarding. This is because it is assumed that the message area designated with tk_cal_por will be used as a buffer in implementing tk_fwd_por. If cmsgsz is larger than maxrmsz of the rendezvous port before forwarding, error code E_PAR is returned(See Additional Note for details).

It is not necessary to issue tk_fwd_por and tk_rpl_rdv from a task-independent portion, but it is possible to issue these system calls from dispatch disabled or interrupts disabled state. This capability can be used to perform processing that is inseparable from tk_fwd_por or tk_rpl_rdv. Whether or not error checking is made for issuing of these system calls from a task-independent portion is implementation-dependent.
When as a result of tk_fwd_por Task Y that was in WAIT state for rendezvous completion reverts to WAIT on rendezvous call, the timeout until rendezvous establishment is always treated as Wait forever (TMO_FEVR).
The rendezvous port being forwarded to may be the same port used for the previous rendezvous (the rendezvous port on which the rendezvous designated in rdvno was established). In this case, tk_fwd_por cancels the previously accepted rendezvous. Even in this case, however, the call message and calptn parameters are changed to those passed to tk_fwd_por by the accepting task, not those passed to tk_cal_por by the calling task.
It is possible to forward a rendezvous that has already been forwarded.

[Additional Notes]

A server task operation using tk_fwd_por is illustrated in Figure 4.8.
Generally tk_fwd_por is executed by server distribution tasks (tasks for distributing server-accepted processing to other tasks) as shown in Figure 4.8. Accordingly, a server distribution task that has executed tk_fwd_por must go on to processing for acceptance of the next request regardless of whether the forwarded rendezvous is established or not. The tk_fwd_por message area in this case is used for processing the next request, making it necessary to ensure that changes to the contents of this message area will not affect the previously forwarded rendezvous. For this reason, after tk_fwd_por is executed, it must be possible to modify the contents of the message area indicated in msg passed to tk_fwd_por even before the forwarded rendezvous is established.
In order to fulfill this requirement, in implementation it is allowed to use the message area designated with tk_cal_por as a buffer. That is, in the tk_fwd_por processing, it is permissible to copy the call messages designated with tk_fwd_por to the message area indicated in msg when tk_cal_por was called, and for the task calling tk_fwd_por to change the contents of the message area. When a rendezvous is established, the message placed in the tk_cal_por message area is passed to the accepting task, regardless of whether the rendezvous is one that was forwarded from another port.
The following specifications are made to allow this sort of implementation to be used.

- If there is a possibility that a rendezvous requested by tk_cal_por may be forwarded, a memory space of at least maxrmsz bytes must be allocated starting from msg (passed to tk_cal_por), regardless of the expected reply message size.
- The send message size cmsgsz passed to tk_fwd_por must be no larger than maxrmsz of the rendezvous port before forwarding.
- If a rendezvous is forwarded using tk_fwd_por, maxrmsz of the destination port rendezvous must not be larger than maxrmsz of the port before forwarding.



- Bold outlines indicate rendezvous ports (rendezvous entries)
- While it is possible to use `tk_cal_por` in place of `tk_fwd_por`, this results in rendezvous nesting. Assuming it is acceptable for requesting Task X to resume execution after the processing of server tasks A to C is completed, use of `tk_fwd_por` does away with the need for rendezvous nesting and results in more efficient operations.

Figure 4.8: Server Task Operation Using `tk_fwd_por`

[Rationale for the Specification]

The `tk_fwd_por` specification is designed not to require logging a history of rendezvous forwarding, so as to reduce the number of states that must be kept track of in the system as a whole. Applications that require such a log to be kept can use nested pairs of `tk_cal_por` and `tk_acp_por` rather than using `tk_fwd_por`.

tk_rpl_rdv

Reply Rendezvous

[C Language Interface]

```
ER ercd = tk_rpl_rdv ( RNO rdvno, VP msg, INT rmsgsz ) ;
```

[Parameters]

RNO	rdvno	Rendezvous number
VP	msg	Reply message packet address
INT	rmsgsz	Reply message size (in bytes)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (rmsgsz < 0, rmsgsz $>$ maxrmsz, or value that cannot be used in msg)
E_OBJ	Invalid object state (rdvno is invalid)
E_CTX	Context error (issued from task-independent portion (implementation-dependent error))

[Description]

Returns a reply to the calling task in the rendezvous, ending the rendezvous.
The task issuing this system call (here "Task X") must be engaged in a rendezvous; that is, this system call can be issued only after executing tk_acp_por. In the discussion that follows, the rendezvous calling task is "Task Y", and the rendezvous number passed in a return parameter by tk_acp_por is rdvno. When tk_rpl_rdv is executed in this situation, the rendezvous state between Task X and Task Y is released, and the Task Y state goes from WAIT for rendezvous completion back to READY state.
When a rendezvous is ended by tk_rpl_rdv, accepting Task X can send a reply message to calling Task Y. The contents of the message designated by the accepting task are copied to the memory space designated in msg passed by Task Y to tk_cal_por. The size of the reply message rmsgsz is passed as a tk_cal_por return parameter.
Error code E_PAR is returned if rmsgsz is larger than maxrmsz designated with tk_cre_por. When this error is detected, the rendezvous is not ended and the task that called tk_cal_por remains in WAIT state for rendezvous completion.
It is not necessary to issue tk_fwd_por and tk_rpl_rdv from a task-independent portion, but it is possible to issue these system calls from dispatch disabled or interrupts disabled state. This capability can be used to perform processing that is inseparable from tk_fwd_por or tk_rpl_rdv. Whether or not error checking is made for issuing of these system calls from a task-independent portion is implementation-dependent.

[Additional Notes]

If a task calling a rendezvous aborts for some reason before completion of the rendezvous (before `tk_rpl_rdv` is executed), the accepting task has no direct way of knowing of the abort. In such a case, error code `E_OBJ` is returned to the rendezvous accepting task when it executes `tk_rpl_rdv`.
After a rendezvous is established, tasks are in principle detached from the rendezvous port and have no need to reference information about each other. However, since the value of `maxrmsz`, used when checking the length of the reply message sent using `tk_rpl_rdv`, is dependent on the rendezvous port, the task in rendezvous must record this information somewhere. One possible implementation would be to put this information in the TCB of the calling task after it goes to WAIT state, or in another area that can be referenced from the TCB, such as a stack area.

[Rationale for the Specification]

The parameter `rdvno` is passed to `tk_rpl_rdv` and `tk_fwd_por` as information for distinguishing one established rendezvous from another, but the rendezvous port ID (`porid`) used when establishing a rendezvous is not designated. This is based on the design principle that tasks are no longer related to rendezvous ports after a rendezvous has been established.
Error code `E_OBJ` rather than `E_PAR` is returned for an invalid `rdvno`. This is because `rdvno` itself is an object indicating the task that called the rendezvous.

tk_ref_por

Reference Port Status

[C Language Interface]

```
ER ercd = tk_ref_por ( ID porid, T_RPOR *pk_rpor ) ;
```

[Parameters]

ID	porid	Rendezvous port ID
T_RPOR*	pk_rpor	Start address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rpor detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
ID	atsk	Accept task information
INT	maxcmsz	Maximum call message size (in bytes)
INT	maxrmsz	Maximum reply message size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (porid is invalid or cannot be used)
E_NOEXS	Object does not exist (the rendezvous port designated in porid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the rendezvous port designated in porid, passing in return parameters information about the accepting task (atsk), information about a task waiting on a rendezvous call (wtsk), maximum message sizes (maxcmsz, maxrmsz), and extended information (exinf).
wtsk indicates the ID of a task in WAIT state on rendezvous call at the rendezvous port. If there is no task waiting on rendezvous call, wtsk = 0 is returned. atsk indicates the ID of a task in WAIT state on rendezvous acceptance at the rendezvous port. If there is no task waiting for rendezvous acceptance, atsk = 0 is returned. If there are multiple tasks waiting on rendezvous call or acceptance at this rendezvous port, the ID of the task at the head of the call queue and accept queue is returned.
If the designated rendezvous port does not exist, error code E_NOEXS is returned.

[Additional Notes]

This system call cannot be used to get information about tasks involved in a currently established rendezvous.

4.6 Memory Pool Management Functions

Memory pool management functions provide software-based management of memory pools and memory block allocation.
There are fixed-size memory pools and variable-size memory pools, which are considered separate objects and require separate sets of system calls for their operation. Memory blocks allocated from a fixed-size memory pool are all of one fixed size, whereas memory blocks from a variable-size memory pool can be of various sizes.
The memory managed by the memory pool management functions is all in system space; there is no T-Kernel function for managing task space memory.

4.6.1 Fixed-size Memory Pool

A fixed-size memory pool is an object used for dynamic management of fixed-size memory blocks. Functions are provided for creating and deleting a fixed-size memory pool, getting and returning memory blocks in a fixed-size memory pool, and referencing the status of a fixed-size memory pool. A fixed-size memory pool is an object identified by an ID number called a fixed-size memory pool ID.
A fixed-size memory pool has a memory space used as the fixed-size memory pool (called a fixed-size memory pool area or simply memory pool area), and a queue for tasks waiting for memory block allocation. A task wanting to allocate a memory block from a fixed-size memory pool that lacks sufficient available memory space goes to WAIT state for fixed-size memory block until memory blocks are returned to the pool. A task in this state is put in the task queue of the fixed-size memory pool.

[Additional Notes]

When memory blocks of various sizes are needed from fixed-size memory pools, it is necessary to provide multiple memory pools of different sizes.

tk_cre_mpf

Create Fixed-size Memory Pool

[C Language Interface]

```
ID mpfid = tk_cre_mpf ( T_CMPF *pk_cmpf ) ;
```

[Parameters]

T_CMPF*	pk_cmpf	Information about the memory pool to be created

pk_cmpf detail:

VP	exinf	Extended information
ATR	mpfatr	Memory pool attributes
INT	mpfcnt	Memory pool block count
INT	blfsz	Memory block size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	mpfid	Fixed-size memory pool ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block or memory pool area cannot be allocated)
E_LIMIT	Number of fixed-size memory pools exceeds the system limit
E_RSATR	Reserved attribute (mpfatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cmpf is invalid; mpfsz or blfsz is negative or invalid)

[Description]

Creates a fixed-size memory pool, assigning to it a fixed-size memory pool ID.
This system call allocates a memory space for use as a memory pool based on the information designated in parameters mpfcnt and blfsz, and assigns a control block to the memory pool. A memory block of size blfsz can be allocated from the created memory pool by calling the tk_get_mpf system call.
exinf can be used freely by the user to set miscellaneous information about the created memory pool. The information set in this parameter can be referenced by tk_ref_mpf. If a larger area is needed for indicating user information, or if the information may need to be changed after the memory pool is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
mpfatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of mpfatr is as follows.


```
mpfatr:= (TA_TFIFO || TA_TPRI) | [TA_NODISWAI]
       | (TA_RNG0 || TA_RNG1 || TA_RNG2 || TA_RNG3)
```

TA_TFIFO	Tasks waiting for memory allocation are queued in FIFO order
TA_TPRI	Tasks waiting for memory allocation are queued in priority order
TA_RNG*n*	Memory access privilege is set to protection level *n*
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

```
#define TA_TFIFO     0x00000000  /* manage task queue by FIFO     */
#define TA_TPRI      0x00000001  /* manage task queue by priority */
#define TA_NODISWAI  0x00000080  /* reject wait disabling         */
#define TA_RNG0      0x00000000  /* protection level 0            */
#define TA_RNG1      0x00000100  /* protection level 1            */
#define TA_RNG2      0x00000200  /* protection level 2            */
#define TA_RNG3      0x00000300  /* protection level 3            */
```

The queuing order of tasks waiting for memory block allocation from a memory pool can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting.
TA_RNG*n* is designated to limit the protection levels at which memory can be accessed. Only tasks running at the same or higher protection level than the one designated can access the allocated memory. If a task running at a lower protection level attempts access, a CPU protection fault exception is raised. For example, memory allocated from a memory pool designated as TA_RNG1 can be accessed by tasks running at levels TA_RNG0 or TA_RNG1, but not by tasks running at levels TA_RNG2 or TA_RNG3.
The created memory pool is in resident memory in system space. There is no T-Kernel function for creating a memory pool in task space.

[Additional Notes]

In the case of a fixed-size memory pool, separate memory pools must be provided for different block sizes. That is, if various memory block sizes are required, memory pools must be created for each block size.
For the sake of portability, the TA_RNG*n* attribute must be accepted even by a system without an MMU. It is possible, for example, to treat all TA_RNG*n* designations as equivalent to TA_RNG0; but error must not be returned.

tk_del_mpf

Delete Fixed-size Memory Pool

[C Language Interface]

```
ER ercd = tk_del_mpf ( ID mpfid ) ;
```

[Parameters]

ID	mpfid	Fixed-size memory pool ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mpfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the fixed-size memory pool designated in mpfid does not exist)

[Description]

Deletes the fixed-size memory pool designated in mpfid.
No check or notification is made as to whether there are tasks using memory allocated from this memory pool. The system call completes normally even if not all blocks have been returned to the pool.
Issuing this system call releases the memory pool ID number, the control block memory space and the memory pool space itself.
This system call completes normally even if there are tasks waiting for memory block allocation from the deleted memory pool, but error code E_DLT is returned to the tasks in WAIT state.

tk_get_blf

Get Fixed-size Memory Block

[C Language Interface]

```
ER ercd = tk_get_mpf ( ID mpfid, VP *p_blf, TMO tmout ) ;
```

[Parameters]

ID	mpfid	Fixed-size memory pool ID
TMO	tmout	Timeout designation

[Return Parameters]

ER	ercd	Error code
VP	blf	Memory block start address

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mpfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the fixed-size memory pool designated in mpfid does not exist)
E_PAR	Parameter error (tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (the memory pool was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Gets a memory block from the fixed-size memory pool designated in mpfid. The start address of the allocated memory block is returned in blf. The size of the allocated memory block is the value designated in the blfsz parameter when the fixed-size memory pool was created.
The allocated memory is not cleared to zero, and the memory block contents are indeterminate.
If a block cannot be allocated from the designated memory pool, the task that issued tk_get_blf is put in the queue of tasks waiting for memory allocation from that memory pool, and waits until memory can be allocated.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (memory space does not become available), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if memory cannot be allocated.
When TMO_FEVR = (-1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for memory allocation without timing out.

The queuing order of tasks waiting for memory block allocation is either FIFO or task priority order, depending on the memory pool attribute.

tk_rel_mpf

Release Fixed-size Memory Block

[C Language Interface]

```
ER ercd = tk_rel_mpf ( ID mpfid, VP blf ) ;
```

[Parameters]

ID	mpfid	Fixed-size memory pool ID
VP	blf	Memory block start address

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mpfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the fixed-size memory pool designated in mpfid does not exist)
E_PAR	Parameter error (blf is invalid, or block returned to wrong memory pool)

[Description]

Returns the memory block designated in blf to the fixed-size memory pool designated in mpfid.
Executing tk_rel_mpf may enable memory block acquisition by another task waiting to allocate memory from the memory pool designated in mpfid, releasing the WAIT state of that task.
When a memory block is returned to a fixed-size memory pool, it must be the same fixed-size memory pool from which the block was allocated. If an attempt to return a memory block to a different memory pool is detected, error code E_PAR is returned. Whether this error detection is made or not is implementation-dependent.

tk_ref_mpf

Reference Fixed-size Memory Pool Status

[**C Language Interface**]

```
ER ercd = tk_ref_mpf ( ID mpfid, T_RMPF *pk_rmpf ) ;
```

[**Parameters**]

ID	mpfid	Fixed-size memory pool ID
T_RMPF*	pk_rmpf	Address of packet for returning status information

[**Return Parameters**]

ER	ercd	Error code

pk_rmpf detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
INT	frbcnt	Free block count

(Other implementation-dependent parameters may be added beyond this point.)

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (mpfid is invalid or cannot be used)
E_NOEXS	Object does not exist (the fixed-size memory pool designated in mpfid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[**Description**]

References the status of the fixed-size memory pool designated in mpfid, passing in return parameters the current free block count frbcnt, waiting task information (wtsk), and extended information (exinf). wtsk indicates the ID of a task waiting for memory block allocation from this fixed-size memory pool. If multiple tasks are waiting for the fixed-size memory pool, the ID of the task at the head of the queue is returned. If there are no waiting tasks, wtsk = 0 is returned.
If the fixed-size memory pool designated with tk_ref_mpf does not exist, error code E_NOEXS is returned. At least one of frbcnt = 0 and wtsk = 0 is always true for this system call.

[**Additional Notes**]

Whereas frsz returned by tk_ref_mpl gives the total free memory size in bytes, frbcnt returns the number of unused memory blocks.

4.6.2 Variable-size Memory Pool

A variable-size memory pool is an object for dynamically managing memory blocks of any size. Functions are provided for creating and deleting a variable-size memory pool, allocating and returning memory blocks in a variable-size memory pool, and referencing the status of a variable-size memory pool. A variable-size memory pool is an object identified by an ID number called a variable-size memory pool ID.
A variable-size memory pool has a memory space used as the variable-size memory pool (called a variable-size memory pool area or simply memory pool area), and a queue for tasks waiting for memory block allocation. A task wanting to allocate a memory block from a variable-size memory pool that lacks sufficient available memory space goes to WAIT state for variable-size memory block until memory blocks are returned to the pool. A task in this state is put in the task queue of the variable-size memory pool.

[Additional Notes]

When tasks are waiting for memory block allocation from a variable-size memory pool, they are served in queued order. If, for example, Task A requesting a 400-byte memory block from a variable-size memory pool is queued along with Task B requesting a 100-byte block, in A-B order, then even if 200 bytes of space are free, Task B is made to wait until Task A has acquired the requested memory block.

tk_cre_mpl

Create Variable-size Memory Pool

[C Language Interface]

```
ID mplid = tk_cre_mpl ( T_CMPL *pk_cmpl ) ;
```

[Parameters]

T_CMPL*	pk_cmpl	Information about the variable-size memory pool to be created

pk_cmpf detail:

VP	exinf	Extended information
ATR	mplatr	Memory pool attributes
INT	mplsz	Memory pool size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	mplid	Variable-size memory pool ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block or memory pool area cannot be allocated)
E_LIMIT	Number of variable-size memory pools exceeds the system limit
E_RSATR	Reserved attribute (mplatr is invalid or cannot be used)
E_PAR	Parameter error (pk_cmpl is invalid, or mplsz is negative or invalid)

[Description]

Creates a variable-size memory pool, assigning to it a variable-size memory pool ID.
This system call allocates a memory space for use as a memory pool, based on the information in parameter mplsz, and allocates a control block to the created memory pool.
exinf can be used freely by the user to set miscellaneous information about the created memory pool. The information set in this parameter can be referenced by tk_ref_mpl. If a larger area is needed for indicating user information, or if the information may need to be changed after the memory pool is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
mplatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of mplatr is as follows.

```
mplatr:= (TA_TFIFO || TA_TPRI) | [TA_NODISWAI]
       | (TA_RNG0 || TA_RNG1 || TA_RNG2 || TA_RNG3)
```


TA_TFIFO	Tasks waiting for memory allocation are queued in FIFO order
TA_TPRI	Tasks waiting for memory allocation are queued in priority order
TA_RNG*n*	Memory access privilege is set to protection level *n*
TA_NODISWAI	Wait disabling by tk_dis_wai is prohibited

```
#define TA_TFIFO    0x00000000  /* manage task queue by FIFO     */
#define TA_TPRI     0x00000001  /* manage task queue by priority */
#define TA_NODISWAI 0x00000080  /* reject wait disabling         */
#define TA_RNG0     0x00000000  /* protection level 0            */
#define TA_RNG1     0x00000100  /* protection level 1            */
#define TA_RNG2     0x00000200  /* protection level 2            */
#define TA_RNG3     0x00000300  /* protection level 3            */
```

The queuing order of tasks waiting to acquire memory from a memory pool can be designated in TA_TFIFO or TA_TPRI. If the attribute is TA_TFIFO, tasks are ordered by FIFO, whereas TA_TPRI designates queuing of tasks in order of their priority setting.
When tasks are queued waiting for memory allocation, memory is allocated in the order of queuing. Even if other tasks in the queue are requesting smaller amounts of memory than the task at the head of the queue, they do not acquire memory blocks before the first task. If, for example, Task A requesting a 400-byte memory block from a variable-size memory pool is queued along with Task B requesting a 100-byte block, in A-B order, then even if 200 bytes of space are free, Task B is made to wait until Task A has acquired the requested memory block.
TA_RNG*n* is designated to limit the protection levels at which memory can be accessed. Only tasks running at the same or higher protection level than the one designated can access the allocated memory. If a task running at a lower protection level attempts access, a CPU protection fault exception is raised. For example, memory allocated from a memory pool designated as TA_RNG1 can be accessed by tasks running at levels TA_RNG0 or TA_RNG1, but not by tasks running at levels TA_RNG2 or TA_RNG3.
The created memory pool is in resident memory in system space. There is no T-Kernel function for creating a memory pool in task space.

[Additional Notes]

If the task at the head of the queue waiting for memory allocation has its WAIT state forcibly released, or if a different task becomes the first in the queue as a result of a change in task priority, memory allocation is attempted to that task. If memory can be allocated, the WAIT state of that task is released. In this way it is possible under some circumstances for memory allocation to take place and task WAIT state to be released even when memory is not released by tk_rel_mpl.
For the sake of portability, the TA_RNG*n* attribute must be accepted even by a system without an MMU. It is possible, for example, to treat all TA_RNG*n* designations as equivalent to TA_RNG0; but error must not be returned.

[Rationale for the Specification]

The capability of creating multiple memory pools can be used for memory allocation as needed for error handling or in emergencies, etc.

tk_del_mpl

Delete Variable-size Memory Pool

[C Language Interface]

```
ER ercd = tk_del_mpl ( ID mplid ) ;
```

[Parameters]

ID	mplid	Variable-size memory pool ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mplid is invalid or cannot be used)
E_NOEXS	Object does not exist (the variable-size memory pool designated in mplid does not exist)

[Description]

Deletes the variable-size memory pool designated in mplid.
No check or notification is made as to whether there are tasks using memory allocated from this memory pool. The system call completes normally even if not all blocks have been returned to the pool.
Issuing this system call releases the memory pool ID number, the control block memory space and the memory pool space itself.
This system call completes normally even if there are tasks waiting for memory block allocation from the deleted memory pool, but error code E_DLT is returned to the tasks in WAIT state.

tk_get_blk

Get Variable-size Memory Block

[C Language Interface]

```
ER ercd = tk_get_mpl ( ID mplid, W blksz, VP *p_blk, TMO tmout ) ;
```

[Parameters]

ID	mplid	Variable-size memory pool ID
INT	blksz	Memory block size (in bytes)
TMO	tmout	Timeout

[Return Parameters]

ER	ercd	Error code
VP	blk	Block start address

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mplid is invalid or cannot be used)
E_NOEXS	Object does not exist (the variable-size memory pool designated in mplid does not exist)
E_PAR	Parameter error (tmout $\leq (-2)$)
E_DLT	The object being waited for was deleted (the memory pool was deleted while waiting)
E_RLWAI	Wait state released (tk_rel_wai received in wait state)
E_DISWAI	Wait released by wait disabled state
E_TMOUT	Polling failed or timeout
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[Description]

Gets a memory block of size blksz (bytes) from the variable-size memory pool designated in mplid. The start address of the allocated memory block is returned in blk.
The allocated memory is not cleared to zero, and the memory block contents are indeterminate.
If memory cannot be allocated, the task issuing this system call enters WAIT state.
A maximum wait time (timeout) can be set in tmout. If the tmout time elapses before the wait release condition is met (memory space does not become available), the system call terminates, returning timeout error code E_TMOUT.
Only positive values can be set in tmout. The time base for tmout (time unit) is the same as that for system time (= 1 ms).
When TMO_POL = 0 is set in tmout, this means 0 was designated as the timeout value, and E_TMOUT is returned without entering WAIT state even if memory cannot be allocated.
When TMO_FEVR = (-1) is set in tmout, this means infinity was designated as the timeout value, and the task continues to wait for memory allocation without timing out.
The queuing order of tasks waiting for memory block allocation is either FIFO or task priority order, depending on the memory pool attribute.

tk_rel_mpl

Release Variable-size Memory Block

[C Language Interface]

```
ER ercd = tk_rel_mpl ( ID mplid, VP blk ) ;
```

[Parameters]

ID	mplid	Variable-size memory pool ID
VP	blf	Memory block start address

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mplid is invalid or cannot be used)
E_NOEXS	Object does not exist (the variable-size memory pool designated in mplid does not exist)
E_PAR	Parameter error (blk is invalid, or block returned to wrong memory pool)

[Description]

Returns the memory block designated in blk to the variable-size memory pool designated in mplid. Executing tk_rel_mpl may enable memory block acquisition by another task waiting to allocate memory from the memory pool designated in mplid, releasing the WAIT state of that task.
When a memory block is returned to a variable-size memory pool, it must be the same variable-size memory pool from which the block was allocated. If an attempt to return a memory block to a different memory pool is detected, error code E_PAR is returned. Whether this error detection is made or not is implementation-dependent.

[Additional Notes]

When memory is returned to a variable-size memory pool in which multiple tasks are queued, multiple tasks may be released at the same time depending on the amount of memory returned and their requested memory size. The task precedence among tasks of the same priority after their WAIT state is released in such a case is the order in which they were queued.

tk_ref_mpl

Reference Variable-size Memory Pool Status

[C Language Interface]

```
ER ercd = tk_ref_mpl ( ID mplid, T_RMPL *pk_rmpl ) ;
```

[Parameters]

ID	mplid	Variable-size memory pool ID
T_RMPL*	pk_rmpl	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rmpl detail:

VP	exinf	Extended information
ID	wtsk	Waiting task information
INT	frsz	Free memory size (in bytes)
INT	maxsz	Maximum memory space size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (mplid is invalid or cannot be used)
E_NOEXS	Object does not exist (the variable-size memory pool designated in mplid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the variable-size memory pool designated in mplid, passing in return parameters the total size of free space frsz, the maximum size of memory immediately available maxsz, waiting task information (wtsk), and extended information (exinf).
wtsk indicates the ID of a task waiting for memory block allocation from this variable-size memory pool. If multiple tasks are waiting for the variable-size memory pool, the ID of the task at the head of the queue is returned. If there are no waiting tasks, wtsk = 0 is returned.
If the variable-size memory pool designated with tk_ref_mpl does not exist, error code E_NOEXS is returned.

4.7 Time Management Functions

Time management functions are for performing time-dependent processing. They include functions for system time management, cyclic handlers, and alarm handlers.
The general name used here for cyclic handlers and alarm handlers is time event handlers.

4.7.1 System Time Management

System time management functions are for manipulating system time. Functions are provided for system clock setting and reference, and for referencing system operating time.

tk_set_tim

Set Time

[C Language Interface]

```
ER ercd = tk_set_tim ( SYSTIM *pk_tim ) ;
```

[Parameters]

SYSTIM*	pk_tim	Address of current time packet

pk_tim detail:

SYSTIM	systim	Current system time

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (pk_tim is invalid, or time setting is invalid)

[Description]

Sets the system clock to the value designated in systim.
System time is expressed as cumulative milliseconds from 0:00:00 (GMT), January 1, 1985.

[Additional Notes]

The relative time designated in RELTIM or TMO does not change even if the system clock is changed by calling tk_set_tim during system operation. For example, if a timeout is set to elapse in 60 seconds and the system clock is advanced by 60 seconds by tk_set_tim while waiting for the timeout, the timeout occurs not immediately but 60 seconds after it was set. Instead, tk_set_tim changes the system time at which the timeout occurs.

tk_get_tim

Get Time

[C Language Interface]

```
ER ercd = tk_get_tim ( SYSTIM *pk_tim ) ;
```

[Parameters]

SYSTIM*	pk_tim	Address of current time packet

[Return Parameters]

ER	ercd	Error code

pk_tim detail:

SYSTIM	systim	Current system time

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (pk_tim is invalid)

[Description]

Reads the current value of the system clock and returns in it systim.
System time is expressed as cumulative milliseconds from 0:00:00 (GMT), January 1, 1985.

tk_get_otm

Get System Operating Time

[C Language Interface]

```
ER ercd = tk_get_otm ( SYSTIM *pk_tim ) ;
```

[Parameters]

SYSTIM*	pk_tim	Address of packet returning operating time

pk_tim detail:

SYSTIM	opetim	System operating time

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (pk_tim is invalid)

[Description]

Gets the system operating time (up time).
System operating time, unlike system time, indicates the length of time elapsed linearly since the system was started. It is not affected by clock settings made by tk_set_tim.
System operating time must have the same precision as system time.

4.7.2 Cyclic Handler

A cyclic handler is a time event handler started at regular intervals. Cyclic handler functions are provided for creating and deleting a cyclic handler, activating and deactivating a cyclic handler operation, and referencing cyclic handler status. A cyclic handler is an object identified by an ID number called a cyclic handler ID.

The time interval at which a cyclic handler is started (cycle time) and the cycle phase are designated for each cyclic handler when it is created. When a cyclic handler operation is requested, T-Kernel determines the time at which the cyclic handler should next be started based on the cycle time and cycle phase set for it. When a cyclic handler is created, the time when it is to be started next is the time of its creation plus the cycle phase. When the time comes to start a cyclic handler, exinf, containing extended information about the cyclic handler, is passed to it as a starting parameter. The time when the cyclic handler is started plus its cycle time becomes the next start time. Sometimes when a cyclic handler is activated, the next start time will be newly set.

In principle the cycle phase of a cyclic handler is no longer than its cycle time. The behavior if the cycle phase is made longer than the cycle time is implementation-dependent.

A cyclic handler has two activation states, active and inactive. While a cyclic handler is inactive, it is not started even when its start time arrives, although calculation of the next start time does take place. When a system call for activating a cyclic handler is called (`tk_sta_cyc`), the cyclic handler goes to active state, and the next start time is decided if necessary. When a system call for deactivating a cyclic handler is called (`tk_stp_cyc`), the cyclic handler goes to inactive state. Whether a cyclic handler upon creation is active or inactive is decided by a cyclic handler attribute.

The cycle phase of a cyclic handler is a relative time designating the first time the cyclic handler is to be started, in relation to the time when the system call creating it was invoked. The cycle time of a cyclic handler is likewise a relative time, designating the next time the cyclic handler is to be started in relation to the time it should have started (not the time it started). For this reason, the intervals between times the cyclic handler is started will individually be shorter than the cycle time in some cases, but their average over a longer time span will match the cycle time.

tk_cre_cyc

Create Cyclic Handler

[C Language Interface]

```
ID cycid = tk_cre_cyc ( T_CCYC *pk_ccyc ) ;
```

[Parameters]

T_CCYC*	pk_ccyc	Address of cyclic handler definition packet

pk_ccyc detail:

VP	exinf	Extended information
ATR	cycatr	Cyclic handler attributes
FP	cychdr	Cyclic handler address
RELTIM	cyctim	Cycle time
RELTIM	cycphs	Cycle phase

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ID	cycid	Cyclic handler ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Number of cyclic handlers exceeds the system limit
E_RSATR	Reserved attribute (cycatr is invalid or cannot be used)
E_PAR	Parameter error (pk_ccyc, cychdr, cyctim, or cycphs is invalid or cannot be used)

[Description]

Creates a cyclic handler, assigning to it a cyclic handler ID. A cyclic handler is a handler running at designated intervals as a task-independent portion.
exinf can be used freely by the user to set miscellaneous information about the created cyclic handler. The information set in this parameter can be referenced by tk_ref_cyc. If a larger area is needed for indicating user information, or if the information may need to be changed after the cyclic handler is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
cycatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of cycatr is as follows.

```
cycatr := (TA_ASM || TA_HLNG) | [TA_STA] | [TA_PHS]
```


TA_ASM	The handler is written in assembly language
TA_HLNG	The handler is written in high-level language
TA_STA	Activate immediately upon cyclic handler creation
TA_PHS	Save the cycle phase

```
#define TA_ASM  0x00000000  /* assembly program */
#define TA_HLNG 0x00000001  /* high-level language program */
#define TA_STA  0x00000002  /* activate cyclic handler */
#define TA_PHS  0x00000004  /* save cyclic handler cycle phase */
```

cychdr designates the cyclic handler start address, cyctim the cycle time, and cycphs the cycle phase. When the TA_HLNG attribute is designated, the cyclic handler is started via a high-level language support routine. The high-level language support routine takes care of saving and restoring register values. The cyclic handler terminates by a simple return from a function. The cyclic handler takes the following format when the TA_HLNG attribute is designated.

```
void cychdr( VP exinf )
{
   /*
   Processing
   */
 return; /* Exit cyclic handler*/

 }
```

The cyclic handler format when the TA_ASM attribute is designated is implementation-dependent, but exinf must be passed in a starting parameter.
cycphs indicates the length of time until the cyclic hander is initially started after being created by tk_cre_cyc. Thereafter it is started periodically at the interval set in cyctim. If zero is designated for cycphs, the cyclic handler starts immediately after it is created. Zero cannot be designated for cyctim. The starting of the cyclic handler for the nth time occurs after at least $\texttt{chcphs} + \texttt{chctim} \times (n-1)$ time has elapsed from the cyclic handler creation.
When TA_STA is designated, the cyclic handler goes to active state immediately on creation, and starts at the intervals noted above. If TA_STA is not designated, the cycle time is calculated but the cyclic handler is not actually started.
When TA_PHS is designated, then even if tk_sta_cyc is called activating the cyclic handler, the cycle time is not reset, and the cycle time calculated as above from the time of cyclic handler creation continues to apply. If TA_PHS is not designated, calling tk_sta_cyc resets the cycle time and the cyclic handler is started at cyctim intervals measured from the time tk_sta_cyc was called. Note that the resetting of cycle time by tk_sta_cyc does not affect cycphs. In this case the starting of the cyclic handler for the nth time occurs after at least $\texttt{cyctim} \times n$ has elapsed from the calling of tk_sta_cyc.
Even if a system call is invoked from a cyclic handler and this causes the task in RUN state up to that time to go to another state, with a different task going to RUN state, dispatching (task switching) does not occur while the cyclic handler is running. Completion of execution by the cyclic handler has precedence even if dispatching is necessary; only when the cyclic handler terminates does the dispatch take place. In other words, a dispatch request occurring while a cyclic handler is running is not processed immediately, but is delayed until the cyclic handler terminates. This is called delayed dispatching.
A cyclic handler runs as a task-independent portion. As such, it is not possible to call in a cyclic handler a system call that can enter WAIT state, or one that is intended for the invoking task.

[Additional Notes]

Once a cyclic handler is defined, it continues to run at the designated cycles either until `tk_stp_cyc` is called to deactivate it or until it is deleted. There is no designation of number of cycles in `tk_cre_cyc`. When multiple time event handlers or interrupt handlers operate at the same time, it is an implementation-dependent matter whether to have them run serially (after one handler exits, another starts) or nested (one handler operation is suspended, another runs, and when that one finishes the previous one resumes). In either case, since time event handlers and interrupt handlers run as task-independent portion, the principle of delayed dispatching applies.

tk_del_cyc

Delete Cyclic Handler

[C Language Interface]

```
ER ercd = tk_del_cyc ( ID cycid ) ;
```

[Parameters]

ID	cycid	Cyclic handler ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (cycid is invalid or cannot be used)
E_NOEXS	Object does not exist (the cyclic handler designated in cycid does not exist)

[Description]

Deletes a cyclic handler.

tk_sta_cyc

Start Cyclic Handler

[C Language Interface]

```
ER ercd = tk_sta_cyc ( ID cycid ) ;
```

[Parameters]

ID	cycid	Cyclic handler ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (cycid is invalid or cannot be used)
E_NOEXS	Object does not exist (the cyclic handler designated in cycid does not exist)

[Description]

Activates a cyclic handler, putting it in active state.
If the TA_PHS attribute was designated, the cycle time of the cyclic handler is not reset when the cyclic handler goes to active state. If it was already in active state when this system call was executed, it continues unchanged in active state.
If the TA_PHS attribute was not designated, the cycle time is reset when the cyclic handler goes to active state. If it was already in active state, it continues in active state but its cycle time is reset. In this case, the next time the cyclic handler starts is after cyctim has elapsed.

tk_stp_cyc

Stop Cyclic Handler

[C Language Interface]

```
ER ercd = tk_stp_cyc ( ID cycid ) ;
```

[Parameters]

ID	cycid	Cyclic handler ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (cycid is invalid or cannot be used)
E_NOEXS	Object does not exist (the cyclic handler designated in cycid does not exist)

[Description]

Deactivates a cyclic handler, putting it in inactive state. It the cyclic handler was already in inactive state, this system call has no effect (no operation).

tk_ref_cyc

Reference Cyclic Handler Status

[**C Language Interface**]

```
ER ercd = tk_ref_cyc ( ID cycid, T_RCYC *pk_rcyc ) ;
```

[**Parameters**]

ID	cycid	Cyclic handler ID
T_RCYC*	pk_rcyc	Address of packet for returning status information

[**Return Parameters**]

ER	ercd	Error code

pk_rcyc detail:

VP	exinf	Extended information
RELTIM	lfttim	Time remaining until the next start time
UINT	cycstat	Cyclic handler activation state

(Other implementation-dependent parameters may be added beyond this point.)

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (cycid is invalid or cannot be used)
E_NOEXS	Object does not exist (the cyclic handler designated in cycid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[**Description**]

References the status of the cyclic handler designated in cycid, passing in return parameters the cyclic handler activation state cycstat, the time remaining until the next start lfttim, and extended information exinf.
The following information is returned in cycstat.

```
cycstat:= (TCYC_STP | TCYC_STA)
```

TCYC_STP	The cyclic handler is inactive
TCYC_STA	The cyclic handler is active

```
#define TCYC_STP    0x00    /* cyclic handler is inactive */
#define TCYC_STA    0x01    /* cyclic handler is active   */
```

If the cyclic handler designated in cycid does not exist, error code E_NOEXS is returned.

4.7.3 Alarm Handler

An alarm handler is a time event handler that starts at a designated time. Functions are provided for creating and deleting an alarm handler, activating and deactivating the alarm handler, and referencing the alarm handler status. An alarm handler is an object identified by an ID number called an alarm handler ID.
The time at which an alarm handler starts (called the alarm time) can be set independently for each alarm handler. When the alarm time arrives, exinf, containing extended information about the alarm handler, is passed to it as a starting parameter.
After an alarm handler is created, initially it has no alarm time set and is in inactive state. The alarm time is set when the alarm handler is activated by calling `tk_sta_alm`, as relative time from the time that system call is executed. When `tk_stp_alm` is called deactivating the alarm handler, the alarm time setting is canceled. Likewise, when an alarm time arrives and the alarm handler runs, the alarm time is canceled and the alarm handler becomes inactive.

tk_cre_alm

Create Alarm Handler

[C Language Interface]

```
ID almid = tk_cre_alm ( T_CALM *pk_calm ) ;
```

[Parameters]

T_CALM*	pk_calm	Address of alarm handler definition packet

pk_calm detail:

VP	exinf	Extended information
ATR	almatr	Alarm handler attributes
FP	almhdr	Alarm handler address

[Return Parameters]

ID	almid	Alarm handler ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_LIMIT	Number of alarm handlers exceeds the system limit
E_RSATR	Reserved attribute (almatr is invalid or cannot be used)
E_PAR	Parameter error (almno, pk_calm, or almhdr is invalid or cannot be used)

[Description]

Creates an alarm handler, assigning to it an alarm handler ID. An alarm handler is a handler running at the designated time as a task-independent portion.
exinf can be used freely by the user to set miscellaneous information about the created alarm handler. The information set in this parameter can be referenced by tk_ref_alm. If a larger area is needed for indicating user information, or if the information may need to be changed after the alarm handler is created, this can be done by allocating separate memory for this purpose and putting the memory packet address in exinf. The OS pays no attention to the contents of exinf.
almatr indicates system attributes in its low bits and implementation-dependent information in the high bits. Designation in the system attributes part of almatr is as follows.

```
almatr := (TA_ASM || TA_HLNG)
```

TA_ASM	The handler is written in assembly language
TA_HLNG	The handler is written in high-level language

```
#define TA_ASM  0x00000000  /* assembly program */
#define TA_HLNG 0x00000001  /* high-level language program */
```


`almhdr` designates the alarm handler start address.
When the `TA_HLNG` attribute is designated, the alarm handler is started via a high-level language support routine. The high-level language support routine takes care of saving and restoring register values. The alarm handler terminates by a simple return from a function. The alarm handler takes the following format when the `TA_HLNG` attribute is designated.

```
void almhdr( VP exinf )
{
   /*
   Processing
   */

   return; /* exit alarm handler */
}
```

The alarm handler format when the `TA_ASM` attribute is designated is implementation-dependent, but exinf must be passed in a starting parameter.
Even if a system call is invoked from an alarm handler and this causes the task in RUN state up to that time to go to another state, with a different task going to RUN state, dispatching (task switching) does not occur while the alarm handler is running. Completion of execution by the alarm handler has precedence even if dispatching is necessary; only when the alarm handler terminates does the dispatch take place. In other words, a dispatch request occurring while an alarm handler is running is not processed immediately, but is delayed until the alarm handler terminates. This is called delayed dispatching.
An alarm handler runs as a task-independent portion. As such, it is not possible to call in an alarm handler a system call that can enter WAIT state, or one that is intended for the invoking task.

[Additional Notes]

When multiple time event handlers or interrupt handlers operate at the same time, it is an implementation-dependent matter whether to have them run serially (after one handler exits, another starts) or nested (one handler operation is suspended, another runs, and when that one finishes the previous one resumes). In either case, since time event handlers and interrupt handlers run as task-independent portion, the principle of delayed dispatching applies.

tk_del_alm

Delete Alarm Handler

[C Language Interface]

```
ER ercd = tk_del_alm ( ID almid ) ;
```

[Parameters]

ID	almid	Alarm handler ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (almid is invalid or cannot be used)
E_NOEXS	Object does not exist (the alarm handler designated in almid does not exist)

[Description]

Deletes an alarm handler.

tk_sta_alm

Start Alarm Handler

[C Language Interface]

```
ER ercd = tk_sta_alm ( ID almid, RELTIM almtim ) ;
```

[Parameters]

ID	almid	Alarm handler ID
RELTIM	almtim	Alarm handler start time (alarm time)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (almid is invalid or cannot be used)
E_NOEXS	Object does not exist (the alarm handler designated in almid does not exist)

[Description]

Sets the alarm time of the alarm handler designated in almid to the time given in almtim, putting the alarm handler in active state. almtim is designated as relative time from the time of calling tk_sta_alm. After the time designated in almtim has elapsed, the alarm handler starts. If the alarm handler is already active when this system call is invoked, the existing almtim setting is canceled and the alarm handler is activated anew with the alarm time designated here.
If almtim = 0 is set, the alarm handler starts as soon as it is activated.

tk_stp_alm

Stop Alarm Handler

[C Language Interface]

```
ER ercd = tk_stp_alm ( ID almid ) ;
```

[Parameters]

ID	almid	Alarm handler ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (almid is invalid or cannot be used)
E_NOEXS	Object does not exist (the alarm handler designated in almid does not exist)

[Description]

Cancels the alarm time of the alarm handler designated in almid, putting it in inactive state. If it was already in inactive state, this system call has no effect (no operation).

tk_ref_alm

Reference Alarm Handler Status

[C Language Interface]

```
ER ercd = tk_ref_alm ( ID almid, T_RALM *pk_ralm ) ;
```

[Parameters]

ID	almid	Alarm handler ID
T_RALM*	pk_ralm	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_ralm detail:

VP	exinf	Extended information
RELTIM	lfttim	Time remaining until the handler starts
UINT	almstat	Alarm handler activation state

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (almid is invalid or cannot be used)
E_NOEXS	Object does not exist (the alarm handler designated in almid does not exist)
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

References the status of the alarm handler designated in almno, passing in return parameters the time remaining until the handler starts lfttim, and extended information exinf.
The following information is returned in almstat.

```
almstat:= (TALM_STP | TALM_STA)
```

TALM_STP	Thg alarm handler is inactive
TALM_STA	The alarm handler is active

```
#define TALM_STP    0x00    /* alarm handler is inactive */
#define TALM_STA    0x01    /* alarm handler is active   */
```

If the alarm handler is active (TALM_STA), lfttim returns the relative time until the alarm handler is scheduled to start. This value is within the range almtim $\geq$ lfttim ≥ 0 designated with tk_sta_alm. Since lfttim is decremented with each timer interrupt, lfttim $= 0$ means the alarm handler will start at the next timer interrupt. If the alarm handler is inactive (TALM_STP), lfttim is indeterminate.
If the alarm handler designated with tk_ref_alm in almid does not exist, error code E_NOEXS is returned.

4.8 Interrupt Management Functions

Interrupt management functions are for defining and manipulating handlers for external interrupts and CPU exceptions.
An interrupt handler runs as a task-independent portion. System calls can be invoked in a task-independent portion in the same way as in a task portion, but the following restriction applies to system call issuing in a task-independent portion.

- A system call that implicitly designates the invoking task, or one that may put the invoking task in WAIT state cannot be issued. Error code `E_CTX` is returned in such cases.

During task-independent portion execution, task switching (dispatching) does not occur. If system call processing results in a dispatch request, the dispatch is delayed until processing leaves the task-independent portion. This is called delayed dispatching.

tk_def_int

Define Interrupt Handler

[C Language Interface]

```
ER ercd = tk_def_int ( UINT dintno, T_DINT *pk_dint ) ;
```

[Parameters]

UINT	dintno	Interrupt definition number
T_DINT*	pk_dint	Packet of interrupt handler definition information

pk_dint detail:

ATR	intatr	Interrupt handler attributes
FP	inthdr	Interrupt handler address

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_RSATR	Reserved attribute (intatr is invalid or cannot be used)
E_PAR	Parameter error (dintno, pk_dint, or inthdr is invalid or cannot be used)

[Description]

Defines an interrupt handler for interrupt definition number dintno, and enables use of the interrupt handler. Here "interrupts" include both external interrupts from a device and CPU exceptions.
This system call maps the interrupt definition number indicated in dintno to the interrupt handler address and attributes.
The specific significance of dintno is defined separately for each implementation, but generally it means an interrupt vector number.
intatr indicates system attributes in its low bits, with the high bits used for implementation-dependent attributes. The system attributes part of intatr is designated in the following format.

```
intatr := (TA_ASM || TA_HLNG)
```

TA_ASM	The handler is written in assembly language
TA_HLNG	The handler is written in high-level language

```
#define TA_ASM  0x00000000  /* assembly program */
#define TA_HLNG 0x00000001  /* high-level language program */
```


When the TA_ASM attribute is designated, in principle the OS is not involved in interrupt handler starting. When an interrupt is raised, the interrupt handling function in the CPU hardware (depending on the implementation, processing by T-Monitor may be included) directly starts the interrupt handler defined by this system call. Accordingly, processing for saving and restoring registers used by the interrupt handler is necessary at the beginning and end of the interrupt handler. An interrupt handler is terminated by execution of the tk_ret_int system call or by the CPU interrupt return instruction (or equivalent means).
Provision of a means for return from an interrupt handler without using tk_ret_int and without OS intervention is mandatory. Note that if tk_ret_int is not used, delayed dispatching is not necessary. Support for return from an interrupt handler using tk_ret_int is mandatory, and in this case delayed dispatching is necessary.
When the TA_HLNG attribute is designated, the interrupt handler is started via a high-level language support routine. The high-level language support routine takes care of saving and restoring register values. The interrupt handler terminates by a simple return from a function. The interrupt handler takes the following format when the TA_HLNG attribute is designated.

```
void inthdr( UINT dintno )
{
   /*
   Processing
   */
    return; /* exit interrupt handler */
}
```

The parameter dintno passed to an interrupt handler is a number identifying the interrupt that was raised, and is the same as that designated with tk_def_int. Depending on the implementation, other information about the interrupt may be passed in addition to dintno. If such information is used, it must be defined for each implementation in a second parameter or subsequent parameters passed to the interrupt handler.
If the TA_HLNG attribute is designated, it is assumed that the CPU interrupt flag will be set to interrupts disabled state from the time the interrupt is raised until the interrupt handler is called. In other words, as soon as an interrupt is raised, the state goes to multiple interrupts disabled, and this state remains when the interrupt handler is called. If multiple interrupts are enabled, the interrupt handler must include processing that enables interrupts by manipulating the CPU interrupt flag.
Also in the case of the TA_HLNG attribute, upon entry into the interrupt handler, system call issuing must be possible. Note, however, that assuming standard provision of the functionality described above, extensions are allowable such as adding a function for entering an interrupt handler with multiple interrupts enabled.
When the TA_ASM attribute is designated, the state upon entry into the interrupt handler is defined for each implementation. Such matters as the stack and register status upon interrupt handler entry, whether system calls can be made, the method of invoking system calls, and the method of returning from the interrupt handler without OS intervention must all be defined explicitly.
In the case of the TA_ASM attribute, depending on the implementation there may be cases where interrupt handler execution is not considered to be a task-independent portion. In such a case the following points need to be noted carefully.

- If interrupts are enabled, there is a possibility that task dispatching will occur.
- When a system call is invoked, it will be processed as having been called from a task portion or quasi-task portion.

If a method is provided for performing some kind of operation in an interrupt handler to have it detected as task-independent portion, that method must be indicated for each implementation.
Whether the `TA_HLNG` or `TA_ASM` attribute is designated, upon entry into an interrupt handler, the logical space at the time the interrupt occurred is retained. No processing takes place upon return from the interrupt handler for restoring the logical space to its state at the time the interrupt was raised. Switching logical spaces inside the interrupt handler is not prohibited, but the OS is not aware of the effects of logical space switching.
Even if a system call is invoked from an interrupt handler and this causes the task in RUN state up to that time to go to another state, with a different task going to RUN state, dispatching (task switching) does not occur while the interrupt handler is running. Completion of execution by the interrupt handler has precedence even if dispatching is necessary; only when the interrupt handler terminates does the dispatch take place. In other words, a dispatch request occurring while an interrupt handler is running is not processed immediately, but is delayed until the interrupt handler terminates. This is called delayed dispatching.
An interrupt handler runs as a task-independent portion. As such, it is not possible to call in an interrupt handler a system call that can enter WAIT state, or one that is intended for the invoking task.
When `pk_dint` = NULL is set, a previously defined interrupt handler is canceled. When the handler for an interrupt is canceled, the default handler defined by T-Monitor is used.
It is possible to redefine an interrupt handler for an interrupt number already having a defined handler. It is not necessary first to cancel the definition for that number. Defining a new handler for a `dintno` already having an interrupt handler defined does not return error.

[Additional Notes]

The various specifications governing the `TA_ASM` attribute are mainly concerned with achieving an interrupt hook. For example, when an exception is raised due to illegal address access, ordinarily an interrupt handler defined in a higher-level program detects this and performs the error processing; but in the case of debugging, in place of error processing by a higher-level program, a T-Monitor interrupt handler does the processing and starts a debugger. In this case the interrupt handler defined by the higher-level program hooks the T-Monitor interrupt handler. After that, depending on the situation, either interrupt handling is passed off to T-Monitor or the other program does the processing on its own.

tk_ret_int

Return from Interrupt Handler

[C Language Interface]

```
void tk_ret_int ( ) ;
```

- Although this system call is defined in the form of a C language interface, it will not be called in this format if a high-level language support routine is used.

[Parameters]

None.

[Return Parameters]

- Does not return to the context issuing the system call.

[Error Codes]

- The following kind of error may be detected, but no return is made to the context issuing the system call even if the error is detected. For this reason the error code cannot be passed directly as a system call return parameter. The behavior if error is detected is implementation-dependent.

E_CTX	Context error (issued from other than an interrupt handler (implementation-dependent error))

[Description]

Exits an interrupt handler.
System calls invoked from an interrupt handler do not result in dispatching while the handler is running; instead, the dispatching is delayed until tk_ret_int is called ending the interrupt handler processing (delayed dispatching). Accordingly, tk_ret_int results in the processing of all dispatch requests made while the interrupt handler was running.
tk_ret_int is invoked only if the interrupt handler was defined designating the TA_ASM attribute. In the case of a TA_HLNG attribute interrupt handler, the functionality equivalent to tk_ret_int is executed implicitly in the high-level language support routine, so tk_ret_int is not (must not be) called explicitly.
As a rule, the OS is not involved in the starting of a TA_ASM attribute interrupt handler. When an interrupt is raised, the defined interrupt handler is started directly by the CPU hardware interrupt processing function. The saving and restoring of registers used by the interrupt handler must therefore be taken care of in the interrupt handler.
For the same reason, the stack and register states at the time tk_ret_int is issued must be the same as those at the time of entry into the interrupt handler. Because of this, in some cases function codes cannot be used in tk_ret_int, in which case tk_ret_int can be implemented using a trap instruction of another vector separate from that used for other system calls.

[Additional Notes]

`tk_ret_int` is a system call that does not return to the context from which it was called. Even if an error code is returned when an error of some kind is detected, normally no error checking is performed in the context from which the system call was invoked, leaving the possibility that the program will hang. For this reason these system calls do not return even if error is detected.
Using an assembly-language return (`REIT`) instruction instead of `tk_ret_int` to exit the interrupt handler is possible if it is clear no dispatching will take place on return from the handler (the same task is guaranteed to continue executing), or if there is no need for dispatching to take place.
Depending on the CPU architecture and method of configuring the OS, it may be possible to perform delayed dispatching even when an interrupt handler exits using an assembly-language `REIT` instruction. In such cases it is allowable for the assembly-language `REIT` instruction to be interpreted as if it were a `tk_ret_int` system call.
Performing of `E_CTX` error checking when `tk_ret_int` is called from a time event handler is implementation-dependent. Depending on the implementation, control may return from a different type of handler.

4.9 System Management Functions

System management functions are functions for changing and referencing system states. Functions are provided for rotating task precedence in a queue, getting the ID of the task in RUN state, disabling and enabling task dispatching, referencing context and system states, setting low-power mode, and referencing the T-Kernel version.

tk_rot_rdq

Rotate Ready Queue

[C Language Interface]

```
ER ercd = tk_rot_rdq ( PRI tskpri ) ;
```

[Parameters]

PRI	tskpri	Task priority

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (tskpri is invalid)

[Description]

Rotates the precedence among tasks having the priority designated in tskpri.
This system call changes the precedence of tasks in RUN or READY state having the designated priority, so that the task with the highest precedence among those tasks is given the lowest precedence.
By setting tskpri = TPRI_RUN = 0, this system call rotates the precedence of tasks having the priority level of the task currently in RUN state. When tk_rot_rdq is called from an ordinary task, it rotates the precedence of tasks having the same priority as the invoking task. When calling from a cyclic handler or other task-independent portion, it is also possible to call tk_rot_rdq (tskpri = TPRI_RUN).

[Additional Notes]

If there are no tasks in a run state having the designated priority, or only one such task, the system call completes normally with no operation (no error code is returned).
When this system call is issued in dispatch enabled state, designating as the priority either TPRI_RUN or the current priority of the invoking task, the precedence of the invoking task will be the lowest among tasks of the same priority. In this way the system call can be used to relinquish execution privilege.
In dispatch disabled state, the task with highest precedence among tasks of the same priority is not always the currently executing task. The precedence of the invoking task will therefore not always become the lowest among tasks having the same priority when the above method is used in dispatch disabled state.
Examples of tk_rot_rdq execution are given in Figure 4.9 and Figure 4.10. When this system call is issued in the state shown in Figure 4.9 designating tskpri = 2, the new precedence order becomes that in Figure 4.10, and Task C becomes the executing task.

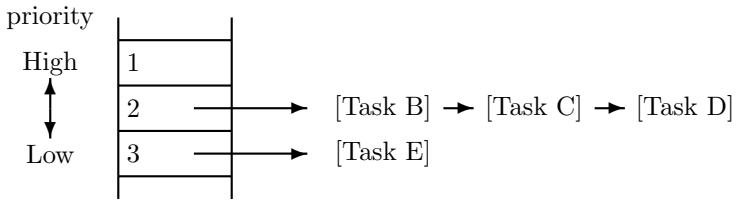
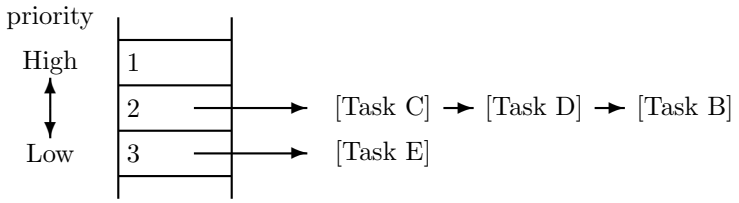


Figure 4.9: Precedence Before Issuing `tk_rot_rdq`



- Task C executes next.

Figure 4.10: Precedence After Issuing `tk_rot_rdq` (`tskpri` = 2)

tk_get_tid

Get Task Identifier

[C Language Interface]

```
ID tskid = tk_get_tid ( ) ;
```

[Parameters]

None

[Return Parameters]

`ID`	`tskid`	ID of the task in RUN state

[Error Codes]

None

[Description]

Gets the ID number of the task currently in RUN state. Unless the task-independent portion is executing, the current RUN state task will be the invoking task.
If there is no task currently in RUN state, 0 is returned.

[Additional Notes]

The task ID returned by `tk_get_tid` is identical to runtskid returned by `tk_ref_sys`.

tk_dis_dsp

Disable Dispatch

[C Language Interface]

```
ER ercd = tk_dis_dsp ( ) ;
```

[Parameters]

None

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_CTX	Context error (issued from task-independent portion)

[Description]

Disables task dispatching. Dispatch disabled state remains in effect until tk_ena_dsp is called enabling task dispatching. While dispatching is disabled, the invoking task does not change from RUN state to READY state or to WAIT state. External interrupts, however, are still enabled, so even in dispatch disabled state an interrupt handler can be started. In dispatch disabled state, the running task can be preempted by an interrupt handler, but not by another task.
The specific operations during dispatch disabled state are as follows.

- Even if a system call issued from an interrupt handler or by the task that called tk_dis_dsp results in a task going to READY state with a higher priority than the task that called tk_dis_dsp, that task will not be dispatched. Dispatching of the higher-priority task is delayed until dispatch disabled state ends.
- If the task that called tk_dis_dsp issues a system call that may cause the invoking task to be put in WAIT state (e.g., tk_slp_tsk or tk_wai_sem), error code E_CTX is returned.
- When system status is referenced by tk_ref_sys, TSS_DDSP is returned in sysstat.

If tk_dis_dsp is called for a task already in dispatch disabled state, that state continues with no error code returned. No matter how many times tk_dis_dsp is called, calling tk_ena_dsp just one time is enough to enable dispatching again. The operation when the pair of system calls tk_dis_dsp and tk_ena_dsp are nested must therefore be managed by the user as necessary.

[Additional Notes]

A task in RUN state cannot go to DORMANT state or NON-EXISTENT state while dispatching is disabled. If `tk_ext_tsk` or `tk_exd_tsk` is called for a task in RUN state while interrupts or dispatching is disabled, error code `E_CTX` is detected. Since, however, `tk_ext_tsk` and `tk_exd_tsk` are system calls that do not return to their original context, such errors are not passed in return parameters by these system calls.
Use of dispatch disabled state for mutual exclusion control among tasks is possible only if the system does not have a multiprocessor configuration.

tk_ena_dsp

Enable Dispatch

[C Language Interface]

```
ER ercd = tk_ena_dsp ( ) ;
```

[Parameters]

None

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_CTX	Context error (issued from task-independent portion)

[Description]

Enables task dispatching.
This system call cancels the disabling of dispatching by the tk_dis_dsp system call.
If tk_ena_dsp is called for a task not in dispatch disabled state, the dispatch enabled state continues and no error code is returned.

tk_ref_sys

Reference System Status

[C Language Interface]

```
ER ercd = tk_ref_sys ( T_RSYS *pk_rsys ) ;
```

[Parameters]

T_RSYS*	pk_rsys	Address of packet for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rsys detail:

INT	sysstat	System status
ID	runtskid	ID of task currently in RUN state
ID	schedtskid	ID of task scheduled to run next

(Other implementation-dependent parameters may be added beyond this point.)

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

Gets the current system execution status, passing in return parameters such information as the dispatch disabled state and whether a task-independent portion is executing.
The following values are returned in sysstat.

```
sysstat := ( TSS_TSK  | [TSS_DDSP] | [TSS_DINT] )
        || ( TSS_QTSK | [TSS_DDSP] | [TSS_DINT] )
        || ( TSS_INDP )
```

TSS_TSK	Task portion executing
TSS_DDSP	Dispatch disabled
TSS_DINT	Interrupts disabled
TSS_INDP	Task-independent portion executing
TSS_QTSK	Quasi-task portion executing

```
#define TSS_TSK     0   /* Task portion executing              */
#define TSS_DDSP    1   /* Dispatch disabled                   */
#define TSS_DINT    2   /* Interrupts disabled                 */
#define TSS_INDP    4   /* Task-independent portion executing  */
#define TSS_QTSK    8   /* Quasi-task portion executing        */
```


The ID of the task currently in RUN state is returned in runtskid, while schedtskid indicates the ID of the next task scheduled to go to RUN state. Normally `runtskid` = `schedtskid`, but this is not necessarily true if, for example, a higher-priority task was wakened during dispatch disabled state. If there is no such task, 0 is returned.
It must be possible to invoke this system call from an interrupt handler or time event handler.

[Additional Notes]

Depending on the OS implementation, the information returned by `tk_ref_sys` is not necessarily guaranteed to be accurate at all times.

tk_set_pow

Set Low-Power Mode

[C Language Interface]

```
ER ercd = tk_set_pow ( UINT powmode ) ;
```

[Parameters]

UINT	powmod	Low-power mode

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (value that cannot be used in powmode)
E_QOVR	Low-power mode disable count overflow
E_OBJ	TPW_ENALOWPOW was requested with low-power mode disable count at 0

[Description]

The following two power-saving functions are supported.

- **Switching to low-power mode when the system is idle**
  When there are no tasks to be executed, the system switches to a low-power mode provided in hardware. Low-power mode is a function for reducing power use during very short intervals, such as from one timer interrupt to the next. This is accomplished, for example, by lowering the CPU clock frequency. It does not require complicated mode-switching in software but is implemented mainly using hardware functionality.
- **Automatic power-off**
  When the operator performs no operations for a certain length of time, the system automatically cuts the power and goes to suspended state. If there is a start request (interrupt, etc.) from a peripheral device or if the operator turns on the power, the system resumes from the state when the power was cut. In the case of a power supply problem such as low battery, the system likewise cuts the power and goes to suspended state.

  In suspended state, the power is cut to peripheral devices and circuits as well as to the CPU, but the main memory contents are retained.

tk_set_pow sets the low-power mode.

```
powmode:= ( TPW_DOSUSPEND || TPW_DISLOWPOW || TPW_ENALOWPOW )
```

TPW_DOSUSPEND	Suspended state
TPW_DISLOWPOW	Switching to low-power mode disabled
TPW_ENALOWPOW	Switching to low-power mode enabled (default)


```
#define TPW_DOSUSPEND   1   Suspended state
#define TPW_DISLOWPOW   2   Switching to low-power mode disabled
#define TPW_ENALOWPOW   3   Switching to low-power mode enabled (default)
```

- TPW_DOSUSPEND
  Execution of all tasks and handlers is stopped, peripheral circuits (timers, interrupt controllers, etc.) are stopped, and the power is cut (suspended). (off_pow is called.)

  When power is turned back on, peripheral circuits are restarted, execution of all tasks and handlers is resumed, operations resume from the point before power was cut, and the system call returns.

  If for some reason the resume processing fails, normal startup processing (for reset) is performed and the system boots fresh.

- TPW_DISLOWPOW
  Switching to low-power mode in the dispatcher is disabled. (low_pow is not called.)

- TPW_ENALOWPOW
  Switching to low-power mode in the dispatcher is enabled. (low_pow is called). The default at system startup is low-power mode enabled (TPW_ENALOWPOW).

Each time TPW_DISLOWPOW is designated, the request count is taken. Low-power mode is enabled only when TPW_ENALOWPOW is requested for as many times as TPW_DISLOWPOW was requested. The maximum request count is implementation-dependent, but a count of at least 255 times must be possible.

[Additional Notes]

off_pow and low_pow are T-Kernel/SM functions. See 5.6 for details.
T-Kernel does not detect power supply problems or other factors for suspending the system. Actual suspension requires suspend processing in each of the peripheral devices (device drivers). The system is suspended not by calling tk_set_pow directly but by use of the T-Kernel/SM suspend function.

tk_ref_ver

Reference Version Information

[C Language Interface]

```
ER ercd = tk_ref_ver ( T_RVER *pk_rver ) ;
```

[Parameters]

T_RVER*	pk_rver	Start address of version information packet

[Return Parameters]

ER	ercd	Error code

pk_rver detail:

UH	maker	T-Kernel maker code
UH	prid	T-Kernel ID
UH	spver	Specification version
UH	prver	T-Kernel version
UH	prno[4]	T-Kernel products management information

[Error Codes]

E_OK	Normal completion
E_PAR	Parameter error (the return parameter packet address cannot be used)

[Description]

Gets information about the T-Kernel version in use, returning that information in the packet designated in pk_rver. The following information can be obtained.
maker is the maker code of the T-Kernel implementing vendor. The maker field has the format shown in Figure 4.11. Maker codes are assigned by the TRON Association.

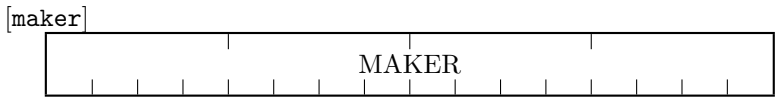


Figure 4.11: maker Field Format

prid is a number indicating the T-Kernel type. The prid format is shown in Figure 4.12.
Assignment of values to prid is left up to the vendor implementing T-Kernel. Note, however, that this is the only number distinguishing product types, and that vendors should give careful thought to how

they assign these numbers, doing so in a systematic way. In that way the combination of maker code and `prid` becomes a unique identifier of the T-Kernel type.

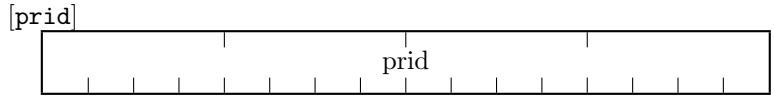


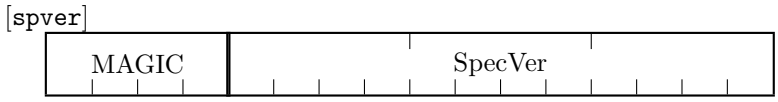
Figure 4.12: `prid` Field Format

The upper 4 bits of spver give the TRON specification series. The low 12 bits indicate the T-Kernel specification version implemented. The format of spver is shown in Figure 4.13.
If, for example, a product conforms to the T-Kernel specification Ver 1.02.xx, spver is as follows.

`MAGIC`	= 0x7	(T-Kernel)
`SpecVerS`	= 0x102	(Ver 1.02)
`spver`	= 0x7102	

If a product implements the T-Kernel specification draft version Ver 1.B0.xx, spver is as follows.

`MAGIC`	= 0x7	(T-Kernel)
`SpecVerS`	= 0x1B0	(Ver 1.B0)
`spver`	= 0x71B0	



MAGIC: A number identifying the TRON specification series

0x0	TRON common (TAD, etc.)
0x1	ITRON1, ITRON2
0x2	BTRON
0x3	CTRON
0x4	reserved
0x5	μITRON
0x6	μBTRON
0x7 T-Kernel	

SpecVer: The version of the TRON specification on which the product is based. This is given as a three-digit packed-format BCD code. In the case of a draft version, the letter A, B, or C may appear in the second digit. In this case the corresponding hexadecimal form of A, B, or C is inserted.

Figure 4.13: `spver` Field Format

`prver` is the version number of the T-Kernel implementation. The specific values assigned to prver are left to the T-Kernel implementing vendor to decide.

`prno` is a return parameter for use in indicating T-Kernel product management information, product number or the like. The specific meaning of values set in `prno` is left to the T-Kernel implementing vendor to decide.

[Additional Notes]

The format of the packet and structure members for getting version information is mostly uniform across the various TRON specifications, but the CPU information and variation descriptors are not specified. The value obtained by `tk_ref_ver` in `SpecVer` is the first three digits of the specification version number. The numbers after that indicate minor revisions such as those issued to correct misprints and the like, and are not obtained by `tk_ref_ver`. For the purpose of matching to the specification contents, the first three numbers of the specification version are sufficient.
An OS implementing a draft version may have A, B, or C as the second number of `SpecVer`. It must be noted that in such cases the specification order of release may not correspond exactly to higher and lower `SpecVer` values. For example, specifications may be released in the following order:

$$\text{Ver } 1.A1 \rightarrow \text{Ver } 1.A2 \rightarrow \text{Ver } 1.B1 \rightarrow \text{Ver } 1.C1 \rightarrow \text{Ver } 1.00 \rightarrow \text{Ver } 1.01 \rightarrow \cdots$$

In this example, when going from Ver 1.Cx to Ver 1.00, `SpecVer` goes from a higher to a lower value.

4.10 Subsystem Management Functions

Subsystems consist of extended SVC handlers, break functions, startup functions, cleanup functions, event functions, and resource control blocks. SVC handlers (Figure4.14).
An extended SVC handler accepts requests from applications and other programs as an application programming interface (API) for a subsystem.
A break function, a startup function, a cleanup function, and an event function accept requests from OS.

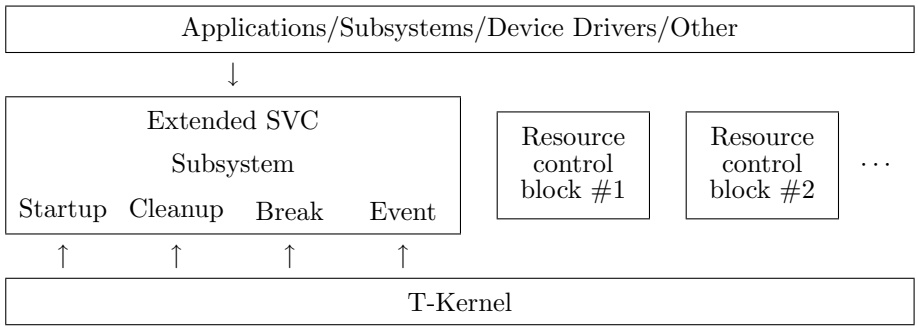


Figure 4.14: T-Kernel Subsystems

tk_def_ssy

Define Subsystem

[C Language Interface]

```
ER ercd = tk_def_ssy ( ID ssid, T_DSSY *pk_dssy ) ;
```

[Parameters]

ID	ssid	Subsystem ID
T_DSSY*	pk_dssy	Subsystem definition information

pk_dssy detail:

ATR	ssyatr	Subsystem attributes
PRI	ssypri	Subsystem priority
FP	svchdr	Extended SVC handler address
FP	breakfn	Break function address
FP	startupfn	Startup function address
FP	cleanupfn	Cleanup function address
FP	eventfn	Event handling function address
INT	resblksz	Resource control block size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (ssid is invalid or cannot be used)
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)
E_RSATR	Reserved attribute (svcatr is invalid or cannot be used)
E_PAR	Parameter error (pk_dssy is invalid or cannot be used)
E_OBJ	ssid is already defined (when pk_dssy $\neq$ NULL)
E_NOEXS	ssid is not defined(when pk_dssy = NULL)

[Description]

Defines subsystem ssid.
One subsystem ID must be assigned to one subsystem without overlapping with other subsystems. The OS does not have a function for assigning these automatically.
Subsystem IDs 1 to 9 are reserved for T-Kernel use. 10 to 255 are numbers used by middleware, etc. The maximum usable subsystem ID value is implementation-dependent and may be lower than 255 in some implementations.

ssyatr indicates system attributes in its low bits and implementation-dependent attributes in the high bits. The system attributes in ssyatr are not assigned in this version, and no system attributes are used.
ssypri indicates the subsystem priority. The startup function, cleanup function, and event handling function are called in order of priority. The order of calling when priority is the same is undefined. Subsystem priority 1 is the highest priority, with larger numbers indicating lower priorities. The range of priorities that can be designated is implementation-dependent, but it must be possible to assign at least priorities 1 to 16.
NULL can be designated in breakfn, startupfn, cleanupfn, and eventfn, in which case the corresponding function will not be called.
Designating pk_dssy = NULL deletes a subsystem definition. The ssid subsystem resource control block will also be deleted.

- Resource control block

  The resource control block defines groups of resources and manages them by their attributes and other factors. Each resource group is allocated its own memory space of the size designated in resblksz. If resblksz = 0 is designated, no resource control block is allocated; but a resource ID (see tk_cre_res) is assigned even in this case.

  Each task belongs to one resource group or another. When a task makes a request to a subsystem and resources are allocated to that task in the subsystem, the allocation information is stored in the resource control block. The subsystem decides what kinds of resources to register in the resource control block and how they are to be registered.

  The OS is not involved in the contents of the resource control block; it can be used freely by the subsystem. The size designated in resblksz should, however, be as small as possible. If a larger memory block is needed, the subsystem must allocate that memory on its own and register its address in the resource control block.

  A resource control block is resident memory located in shared (system) space.

- Extended SVC handler

  An extended SVC handler accepts requests from applications and other programs as an application programming interface (API) for a subsystem. It can be called in the same way as an ordinary system call, and is normally invoked using a trap instruction or the like.

  The format of an extended SVC handler is as follows.

```
INT svchdr( VP pk_para, FN fncd )
{
    /*
    Branching by fncd
    */

    return retcode; /* exit extended SVC handler */
}
```

  fncd is a function code. The low 8 bits of the instruction code are the subsystem ID. The remaining high bits can be used in any way by the subsystem. Ordinarily they are used as a function code inside the subsystem. A function code must be a positive value, so the most significant bit is always 0.

pk_para points to a packet of parameters passed to this system call. The packet format can be decided by the subsystem. Generally a format like the stack passed to a C language function is used, which in many cases is the same format as a C language structure.

The return code passed by an extended SVC handler is passed to the caller transparently as the function return code. As a rule, negative values are error codes and 0 or positive values are the return code for normal completion. If an extended SVC call fails for some reason, OS error code (negative value) is returned to the caller without invoking the extended SVC handler, so it is best to avoid confusion with these values.

The format by which an extended SVC is called is dependent on the OS implementation. As a subsystem API, however, it must be specified in a C language function format independent of the OS implementation. The subsystem must provide an interface library for converting from the C language function format to the OS-dependent extended SVC calling format.

An extended SVC handler runs as a quasi-task portion. It can be called from a task-independent portion, and in this case the extended SVC handler also runs as a task-independent portion.

- Break function

  A break function is a function called when a task exception is raised for a task while an extended SVC handler is executing.

  When a break function is called, the processing by the extended SVC handler running at the time the task exception was raised must be stopped promptly and control must be returned from the extended SVC handler to its caller. The processing for stopping the processing by the currently running extended SVC handler is called a break function.

  The format of a break function is as follows.

```
void breakfn( ID tskid )
{
   /*
       Stop the running extended SVC handler
   */
}
```

  tskid is the ID of the task where the task exception was raised.

  A break function is called when a task exception is raised by tk_ras_tex. If extended SVC handler calls are nested, then when return is made from an extended SVC handler and the nesting level drops by 1, the extended SVC handler corresponding to the return destination is the one called.

  A break function is called one time only for one extended SVC handler per one task exception.

  If another nested extended SVC call is made while a task exception is raised, no break function is called for the called extended SVC handler.

  A break function runs as a quasi-task portion. Its task context is either that of the task that called tk_ras_tex or that of the task where the task exception was raised (the task running an extended SVC handler). In the former case, the break function runs when tk_ras_tex is called, while in the latter case the break function runs when extended SVC nesting is reduced by one level. This means it is possible that the task executing the break function will be different from the task executing the extended SVC handler. In such a case the break function and extended SVC handler run concurrently as controlled by task scheduling. It is thus conceivable that the extended SVC handler will return to its caller before the break function finished executing, but in that case the extended SVC handler waits at the point right before returning, until the break function

completes. How this wait state maps to the task state transitions is implementation-dependent, but preferably it should remain in READY state (a READY state that does not go to RUN state). The precedence of a task may change while it is waiting for a break function to complete, but how task precedence is treated is implementation-dependent. Similarly, an extended SVC handler cannot call an extended SVC until break function execution completes. In other words, during the time from the raising of a task interrupt until the break function completes, the affected task must stay in the extended SVC handler that was executing at the time of the task exception.

If a break function and extended SVC handler run in different task contexts and the break function task priority is lower than the extended SVC handler task priority, the task priority of the break function is raised to the same priority as the extended SVC handler task only during the time while the break handler is executing. On the other hand, if the break function task priority is the same as or higher than that of the extended SVC handler, the priority does not change. The priority that gets changed is the current priority; the base priority stays the same. The change in priority occurs only right before entry into the break function; any changes after that in the extended SVC handler task priority are not followed up by further changes in priority of the break function task. In no case does a change in the break function priority while a break function is running result in a priority change in the extended SVC handler task. At the same time there is no restriction on priority changes because a break function is running. When the break function completes, the current priority of its task reverts to base priority. If a mutex was locked, however, the priority reverts to that as adjusted by the mutex. (In other words, the ability is provided to adjust the current priority at the entry and exit of the break function only; other than that, the priority is the same as when an ordinary task is running.)

- Startup function

  A startup function is called by issuing the `tk_sta_ssy` system call. It performs resource control block initialization processing.

  The format of a startup function is as follows.

```
void startupfn( ID resid, INT info )
{
   /*
       Resource control block initialization processing
   */
}
```

  `resid` is the ID of the resource group to be initialized, and `info` is a parameter that can be used in any way. Both are passed to `tk_sta_ssy`.

  Even if initialization of the resource control block fails for some reason, the startup function must be terminated normally. If the resource control block could not be initialized, then when an API (extended SVC) that cannot be executed normally as a result is called, error is passed in the return code of that API.

  A startup function runs as a quasi-task portion in the context of the task that called `tk_sta_ssy`.

- Cleanup function

  A cleanup function is called by issuing the `tk_cln_ssy` system call, and performs resource release processing.

  The format of a cleanup function is as follows.

```
void cleanupfn( ID resid, INT info )
```



```
{
   /*
       Resource release processing
   */
}
```

resid is the ID of the resource group subject to resource release, while info is a parameter that can be used freely. Both are parameters passed to tk_cln_ssy.

Even if resource release fails for some reason, the cleanup function must be terminated normally. The error handling, such as logging of errors, can be decided for each subsystem.

After the cleanup function completes its processing, the resource control block is automatically cleared to 0. If no cleanup function was defined (cleanupfn = NULL), the tk_cln_ssy system call clears the resource control block to 0.

A cleanup function runs as a quasi-task portion in the context of the task that called tk_cln_ssy.

- Event handling function

  An event handling function is called by issuing the tk_evt_ssy system call. It processes various requests made to a subsystem. Note that it does not carry the obligation to process all requests for all subsystems. If processing is not required, it can simply return E_OK without performing any operation.

  The format of an event handling function is as follows.

```
ER eventfn( INT evttyp, ID resid, INT info )
{
   /*
       Event processing
   */
   return ercd;
}
```

  evttyp indicates the request type, resid gives the ID of the resource group, and info is a parameter that can be used freely. All these parameters are passed to tk_evt_ssy. If the system call is not invoked for any particular resource group, resid can be set to 0.

  If processing completes normally, E_OK is passed in the return code; otherwise an error code (negative value) is returned.

  The following event types evttyp are defined. See 5.3 for details.

```
#define TSEVT_SUSPEND_BEGIN     1   /* before suspending device   */
#define TSEVT_SUSPEND_DONE      2   /* after suspending device    */
#define TSEVT_RESUME_BEGIN      3   /* before resuming device     */
#define TSEVT_RESUME_DONE       4   /* after resuming device      */
#define TSEVT_DEVICE_REGIST     5   /* device registration notice */
#define TSEVT_DEVICE_DELETE     6   /* device deletion notice     */
```

  An event handling function runs as a quasi-task portion in the context of the task that called tk_evt_ssy.

[Additional Notes]

Extended SVC handlers as well as break functions, startup functions, cleanup functions and event handling functions all have the equivalent of the `TA_HLNG` attribute only. There is no means of designating the `TA_ASM` attribute.
Prior to initialization of a resource control block by a startup function, and after resource release by a cleanup function, the behavior if an extended SVC is called by a task belonging to that resource group is dependent on the subsystem implementation. The OS does not make any attempt to prevent this kind of call. Basically it is necessary to avoid calling an extended SVC before calling a startup function and after calling a cleanup function.
There may be cases where, for some reason or other, a break function, cleanup function or event handling function is called without first calling a startup function. These functions must execute normally even in such a case. A resource control block is cleared to 0 when it is first created and when cleanup processing is executed by `tk_cln_ssy`. Accordingly, even if it was not initialized properly by a startup function, the resource control block can still be assumed to have been cleared to 0.

tk_sta_ssy
tk_cln_ssy

Call Startup Function
Call Cleanup Function

[**C Language Interface**]

```
ER ercd = tk_sta_ssy ( ID ssid, ID resid, INT info ) ;
ER ercd = tk_cln_ssy ( ID ssid, ID resid, INT info ) ;
```

[**Parameters**]

ID	ssid	Subsystem ID
ID	resid	Resource ID
INT	info	Any parameter

[**Return Parameters**]

ER	ercd	Error code

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (ssid or resid is invalid or cannot be used)
E_NOEXS	Object does not exist (the subsystem designated in ssid is not defined)
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)

[**Description**]

Calls the startup function/cleanup function of the subsystem designated in ssid.
A designation of ssid = 0 makes the system call applicable to all currently defined subsystems. In this case the startup/cleanup functions of each subsystem are called in sequence.

tk_sta_ssy: Calls in order starting from the highest subsystem priority.

tk_cln_ssy: Calls in order starting from the lowest subsystem priority.

The order among subsystems having the same priority is not defined.
If there are dependency relationships among different subsystems, the subsystem priority must therefore be set with those relationships in mind. If, for example, subsystem B uses functions in subsystem A, then the priority of subsystem A must be set higher than that of subsystem B.
Even if these system calls are issued for a subsystem with no startup function or cleanup function defined, those functions are simply not called; no error results.
If during startup/cleanup function execution a task exception is raised for the task that called tk_sta_ssy or tk_cln_ssy, the task exception is held until the startup/cleanup function completes its processing.

tk_evt_ssy

Call Event Handling Function

[**C Language Interface**]

```
ER ercd = tk_evt_ssy ( ID ssid, INT evttyp, ID resid, INT info ) ;
```

[**Parameters**]

ID	ssid	Subsystem ID
INT	evttyp	Event request type
ID	resid	Resource ID
INT	info	Any parameter

[**Return Parameters**]

ER	ercd	Error code

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (ssid, resid is invalid or cannot be used)
E_NOEXS	Object does not exist (the subsystem designated in ssid is not defined)
E_CTX	Context error (issued from task-independent portion or in dispatch disabled state)
Other	Error code returned by the event handling function

[**Description**]

Calls the event handling function of the subsystem designated in ssid.
A designation of ssid = 0 makes the system call applicable to all currently defined subsystems. In this case the event handling function of each subsystem is called in sequence.

When evttyp is an odd number: Calls in order starting from the highest subsystem priority.

When evttyp is an even number: Calls in order starting from the lowest subsystem priority.

The order among subsystems having the same priority is not defined.
If this system call is issued for a subsystem with no event handling function defined, the function is simply not called; no error results.
If this system call is not invoked for any particular resource group, resid = 0 is designated.
If the event handling function returns an error, the error code is passed transparently in the system call return code. When ssid = 0 and an event handler returns an error, the event handling functions of all other subsystems continue to be called. In the system call return code, only one error code is returned even if more than one event handling function returned an error. It is not possible to know which subsystem's event handling function returned the error.
If during event handling function execution a task exception is raised for the task that called tk_evt_ssy, the task exception is held until the event handling function completes its processing.

tk_ref_ssy

Reference Subsystem Status

[**C Language Interface**]

```
ER ercd = tk_ref_ssy ( ID ssid, T_RSSY *pk_rssy ) ;
```

[**Parameters**]

ID	ssid	Subsystem ID
T_RSSY*	pk_rssy	Subsystem definition information

[**Return Parameters**]

ER	ercd	Error code

pk_rssy detail:

PRI	ssypri	Subsystem priority
INT	resblksz	Resource control block size (in bytes)

(Other implementation-dependent parameters may be added beyond this point.)

[**Error Codes**]

E_OK	Normal completion
E_ID	Invalid ID number (ssid is invalid or cannot be used)
E_NOEXS	Object does not exist (the subsystem designated in ssid is not defined)
E_PAR	Parameter error (pk_rssy is invalid or cannot be used)

[**Description**]

References information about the status of the subsystem designated in ssid. resblksz returns the size of the resource control block designated with tk_def_ssy. If the subsystem designated in ssid does not exist, E_NOEXS is returned.

tk_cre_res

Create Resource Group

[C Language Interface]

```
ID resid = tk_cre_res ( ) ;
```

[Parameters]

None

[Return Parameters]

ID	resid	Resource ID
	or	Error Code

[Error Codes]

E_OK	Normal completion
E_LIMIT	Number of resource groups exceeds the system limit
E_NOMEM	Insufficient memory (memory for control block cannot be allocated)

[Description]

Creates a new resource group, assigning to it a resource control block and resource ID.
Resource IDs are assigned in common for the entire system. A separate resource control block is created for each subsystem (see Figure 4.15).

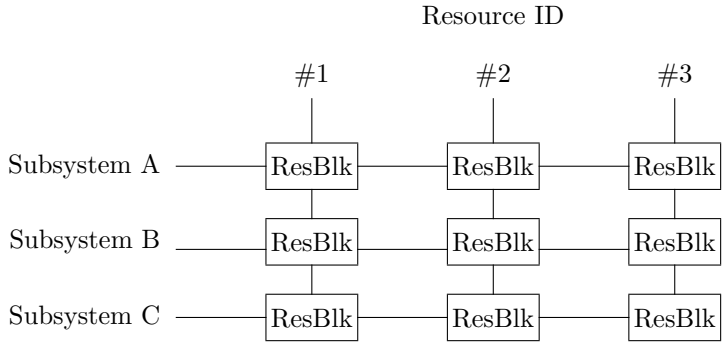


Figure 4.15: Subsystems and Resource Groups

In some cases a new subsystem will be defined when a resource group is already created. Even in such a case, it is necessary to create a resource control block of an already existing resource group for the newly registered subsystem. In other words, there may be cases where resource control block creation must be performed by `tk_def_ssy`. For example, if a new subsystem ID is defined in a situation like that

shown in Figure 4.15, resource control blocks with resource IDs #1, #2, and #3 must automatically be created for the subsystem.

[Additional Notes]

A resource ID is in some cases used also as a logical space ID (`lsid`). Resource IDs should therefore be assigned values that can be used directly as logical space IDs or that can easily be converted for use as logical space IDs.
A system resource group always exists as a special resource group. One system resource group always exists, moreover, from the time the system boots, without waiting for creation by `tk_cre_res`. The system resource group cannot be deleted. Other than the requirement that it must always exist, a system resource group is no different from other resource groups.
Resource control block creation might be implemented in either of the following ways.

(A) At the time of subsystem definition (`tk_def_ssy`), create as many resource control blocks as the maximum number of resource groups, and use `tk_cre_res` simply to assign them.

(B) Use `tk_cre_res` to create as many resource control blocks as there are subsystems and assign them.

Since the specification requires clearing a resource control block to 0 when it is initially created, the timing of this clearing to 0 differs between methods (A) and (B). This difference should not have much of an effect; but since method (A) will have fewer cases of clearing to 0, subsystems must be implemented assuming (A). Method (A) is also recommended for the OS implementation.

tk_del_res

Delete Resource Group

[C Language Interface]

```
ER ercd = tk_del_res ( ID resid ) ;
```

[Parameters]

ID	resid	Resource ID

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (resid is invalid or cannot be used)
E_NOEXS	Object does not exist (the resource designated in resid does not exist)

[Description]

Deletes the resource control blocks of the resource group designated in resid, and releases the resource ID.
The resource control blocks of all subsystems are deleted.

[Additional Notes]

Resources are deleted even if there are still tasks belonging to a resource to be deleted. In principle, resource deletion must be performed after exit and deletion of all tasks belonging to the resources. The behavior is not guaranteed if a resource is deleted while a task belonging to that resource remains and is calling a subsystem (extended SVC). Likewise, the behavior is not guaranteed if a task belonging to a deleted resource calls a subsystem (extended SVC).
The timing for actual resource control block deletion is implementation-dependent. (See tk_cre_res.)
The system resource group cannot be deleted (error code E_ID is returned).

tk_get_res

Get Resource Control Block

[C Language Interface]

```
ER ercd = tk_get_res ( ID resid, ID ssid, VP *p_resblk ) ;
```

[Parameters]

ID	resid	Resource ID
ID	ssid	Subsystem ID

[Return Parameters]

VP	resblk	Resource control block
ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (resid or ssid is invalid or cannot be used)
E_NOEXS	Object does not exist (the resource designated in resid or ssid does not exist)
E_PAR	Parameter error (value that cannot be used in p_resblk)

[Description]

Gets the address of the resource control block of resource group resid for subsystem ssid.

[Additional Notes]

E_OK might be returned even if this system call is issued for a deleted resource ID. Whether or not error (E_NOEXS) is returned in this case is implementation-dependent.

Chapter 5

T-Kernel/SM

Details of the functions provided by T-Kernel System Manager (T-Kernel/SM) are described in this chapter.

5.1 System Memory Management Functions

System memory management functions manage all the memory allocated dynamically by T-Kernel (system memory). This includes memory used internally by T-Kernel as well as task stacks, message buffers, and memory pools.
System memory is managed in memory block units. The block size is normally the page size defined for the MMU. A system that does not use an MMU can set any desired block size, but a size in the range of around 1 KB to 4 KB is recommended. Block size can be learned by calling `tk_ref_smb`.
System memory is allocated in the system space. T-Kernel does not manage task space memory.
System memory management functions are called as extended SVC. They are for use not only in T-Kernel but also in applications, subsystems and device drivers. In the case of T-Kernel internal use, the calling of these functions without going through extended SVC calls is an implementation-dependent option.

5.1.1 System Memory Allocation

- `ER tk_get_smb( VP *addr, INT nblk, UINT attr )`

  Allocates a memory space of a size accommodating the number of contiguous memory blocks designated in `nblk`, and having the attributes designated in `attr`. The start address of the allocated memory space is returned in `addr`.

  ```
  attr := (TA_RNG0 || TA_RNG1 || TA_RNG2 || TA_RNG3) | [TA_NORESIDENT]

  #define TA_NORESIDENT   0x00000010  /* nonresident        */
  #define TA_RNG0         0x00000000  /* protection level 0 */
  #define TA_RNG1         0x00000100  /* protection level 1 */
  #define TA_RNG2         0x00000200  /* protection level 2 */
  #define TA_RNG3         0x00000300  /* protection level 3 */
  ```

  The acquired memory does not belong to a resource group. If memory could not be allocated, `E_NOMEM` is returned.

- `ER tk_rel_smb( VP addr )`

  Releases the memory designated by the start address addr. addr must be the address obtained by `tk_get_smb`.

- `ER tk_ref_smb( T_RSMB *pk_rsmb )`

  Gets information about system memory.

  ```
  typedef struct t_rsmb {
         INT blksz;      /* block size (in bytes)      */
         INT total;      /* total block count          */
         INT free;       /* remaining free block count */
         /* Implementation-dependent information may be added beyond this point.*/
  } T_RSMB;
  ```

  When virtual memory is used, there may be cases where the total block and remaining free block counts cannot be decided unequivocally. In such cases the contents of total and free are implementation-dependent, but preferably they should be values such that `free` ÷ `total` gives a useful estimate of the remaining memory capacity.

5.1.2 Memory Allocation Libraries

Since system memory is allocated in block units, libraries are provided for dividing up those blocks for use.

- `void*  Vmalloc( size_t size )`
- `void*  Vcalloc( size_t nmemb, size_t size )`
- `void*  Vrealloc( void *ptr, size_t size )`
- `void  Vfree( void *ptr )`
- `void*  Kmalloc( size_t size )`
- `void*  Kcalloc( size_t nmemb, size_t size )`
- `void*  Krealloc( void *ptr, size_t size )`
- `void  Kfree( void *ptr )`

  The functions are equivalent to the standard C libraries `malloc`, `calloc`, `realloc`, `free` and so on. `V`— means the function is for nonresident memory and `K`— for resident memory; in both cases the memory is assigned to the `TSVCLimit` protection level.

  These functions cannot be called from a task-independent portion or while dispatching or interrupts are disabled. The behavior if they are called in those situations is undefined. (System failure is a possibility.)

5.2 Address Space Management Functions

Memory access privilege is held as access privilege information for each task. Essentially access privilege information indicates the right to access at the protection level immediately before an extended SVC is called. If, for example, a task is running at protection level 3 when it calls an extended SVC, its access privilege information indicates the right to access at protection level 3. Since the protection level when an extended SVC is executing is protection level 0, in the case of nested calling of an extended SVC from another extended SVC, access privilege information in the extended SVC for which a nested call was made indicates the right to access at protection level 0.
Memory access privilege information is set as follows.

- Immediately after a task is started, its access privilege is that designated when the task was created.
- When an extended SVC is called, the access privilege at the protection level at which it was running at the time of the call is set.
- Upon return from the extended SVC, the access privilege reverts to that at the time the extended SVC was called.
- Executing `SetTaskSpace()` copies the current access privilege of the target task to the invoking task.

5.2.1 Address Space Configuration

- `ER SetTaskSpace( ID tskid )`

  Assigns to the invoking task the task space and access privilege information of the task designated in `tskid`. As a result, both the invoking task and target task have the same task space and access privilege information.

  Note that this copying of task space information applies only at the time the function is called; if thereafter the task designated in `tskid` switches to a different address space and its access privilege changes, the invoking task is not affected by those changes (its address space and access privilege do not change accordingly). If the invoking task is calling an extended SVC, on return from the extended SVC its access privilege reverts to that prior to calling the extended SVC. Its task space, however, does not revert.

  The task ID of the invoking task cannot be designated in `tskid`. However, if `TSK_SELF` is used to designate the invoking task, access privilege is set to the currently running protection level; task space is not switched in this case.

`E_ID`	`tskid` is invalid
`E_NOEXS`	Object does not exist (the task designated in `tskid` does not exist)
`E_OBJ`	Invoking task designated by other than `TSK_SELF`

5.2.2 Address Space Checking

The following functions check whether access is allowed to the designated memory space, based on the current access privilege information. If access cannot be made (no privilege or the memory does not exist), they return error code `E_MACV`.

—`R`	Check for read access privilege.
—`RW`	Check for read and write access privilege.
—`RE`	Check for read and execute access privilege.

- `ER ChkSpaceR( VP addr, INT len )`
- `ER ChkSpaceRW( VP addr, INT len )`
- `ER ChkSpaceRE( VP addr, INT len )`

  Checks access privilege to the memory space of `len` bytes from location `addr`.

- `INT ChkSpaceBstrR( UB *str, INT max )`
- `INT ChkSpaceBstrRW( UB *str, INT max )`

  Checks access privilege to the memory space from `str` up to the string termination (`'\0'`) or up to the number of characters (bytes) designated in `max`, whichever comes first. If `max` = 0 is set, `max` is ignored and privilege is checked up to the string termination.

  If access is allowed, the length of the string (in bytes) is returned. If the string termination occurred up to the string length indicated in `max`, the length to the character before `'\0'` is returned; if `max` characters occurred before the string termination, `max` is returned.

- `INT ChkSpaceTstrR( TC *str, INT max )`
- `INT ChkSpaceTstrRW( TC *str, INT max )`

```
typedef UH  TC;         /* TRON character code */

#define TNULL((TC)0)    /* TRON code string termination */
```

  Checks access privilege to the memory space from `str` up to the TRON Code string termination (`TNULL`) or up to the number of characters (TC count) designated in max, whichever comes first. If `max` = 0 is set, `max` is ignored and privilege is checked up to the string termination.

  If access is allowed, the length of the string (TC count) is returned. If the string termination occurred up to the string length indicated in max, the length to the character before TNULL is returned; if `max` characters occurred before the string termination, `max` is returned.

  `str` must be an even-numbered address.

5.2.3 Lock Address Space

Generally memory is made resident or nonresident a page at a time and is managed in page units. For this reason, in many cases the OS does not check for matching of locked and unlocked spaces. It is the responsibility of the calling side to make sure the same spaces are designated in lock and unlock operations.

- `ER LockSpace( VP addr, INT len )`

  Locks (makes resident) the memory space of `len` bytes from location `addr`.

  `E_MACV` The memory does not exist

- `ER UnlockSpace( VP addr, INT len )`

  Unlocks (makes nonresident) the memory space of len bytes from location addr. If the same space was locked more than once, it is not unlocked until the number of unlock operations equals the number of lock operations.

  Note that it is not possible to unlock just part of a locked space.

5.2.4 Get Physical Address

- `INT CnvPhysicalAddr( VP vaddr, INT len, VP *paddr )`

`vaddr`	Local address
`len`	Memory space size (in bytes)
`paddr`	Returns physical address
return code	Returns size (in bytes) of physical address contiguous space, or error

Gets the physical address corresponding to logical address `vaddr`, returning the result in `paddr`. This function also passes in the return code the size of contiguous space included in `len` bytes from `vaddr`. Accordingly, only the space of the size passed in the return code starting from `paddr` is valid.

The space for which the physical address is obtained must be locked (made resident).

On the assumption of DMA transfer, memory caching is turned off for the space whose physical address is obtained (the memory space starting from `paddr` of the size passed in the return code). When the space is made nonresident (unlocked), caching goes back on.

`E_MACV`	The memory does not exist

5.3 Device Management Functions

5.3.1 Basic Concepts

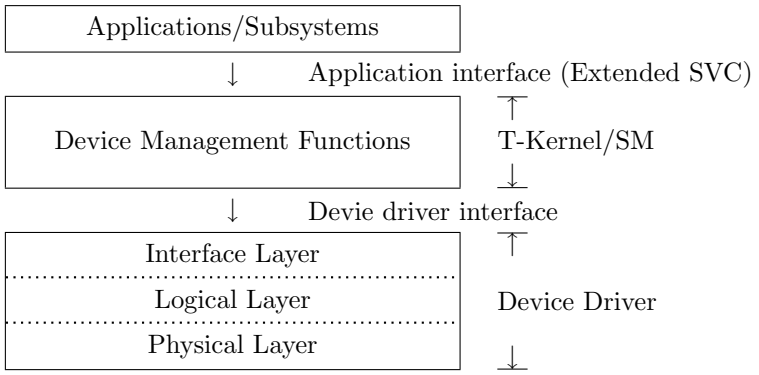


Figure 5.1: Device Management Functions

(1) Device Name (UB* type)

A device name is a string of up to 8 characters consisting of the following elements.

```
#define L_DEVNM 8   /* Device name length */
```

Type Name indicating the device type
Characters a to z and A to Z can be used.

Unit One letter indicating a physical device
Each unit is assigned a letter from a to z in order starting from a.

Subunit One to three digits indicating a logical device
Each subunit is assigned a number from 0 to 254 in order starting from 0.

Device names take the format type + unit + subunit. Some devices may not have a unit or subunit, in which case the corresponding field is omitted.
A name consisting of type + unit is called a physical device name. A name consisting of type + unit + subunit may be called a logical device name to distinguish it from a physical device name. If there is no subunit, the physical device name and logical device name are identical. The term "device name" by itself means the logical device name.
A subunit generally refers to a partition on a hard disk, but can be used to mean other logical devices as well.

Examples:

`hda`	Hard disk (entire disk)
`hda0`	Hard disk (1st partition)
`fda`	Floppy disk
`rsa`	Serial port
`kbpd`	Keyboard/pointing device

(2) Device ID (ID type)

By registering a device (device driver) with T-Kernel/SM, a device ID (> 0) is assigned to the device (physical device name). Device IDs are assigned to each physical device. The device ID of a logical device consists of the device ID assigned to the physical device to which is appended the subunit number + 1 (1 to 255).

`devid`: The device ID assigned at device registration

`devid`	Physical device
`devid` $+ n + 1$	The nth subunit (logical device)

Examples:

`had`	`devid`	Entire hard disk
`hda0`	`devid` $+ 1$	1st partition of hard disk
`hda1`	`devid` $+ 2$	2nd partition of hard disk

(3) Device Attribute (ATR type)

Device attributes are defined as follows, in order to classify devices by their properties.

```
IIII IIII IIII IIII PRxx xxxx KKKK KKKK
```

The high 16 bits are device-dependent attributes defined for each device.
The low 16 bits are standard attributes defined as follows.

```
#define TD_PROTECT      0x8000  /* P: write protection           */
#define TD_REMOVABLE    0x4000  /* R: removable media            */

#define TD_DEVKIND      0x00ff  /* K: device/media kind          */
#define TD_DEVTYPE      0x00f0  /* device type                   */

                                /* device type                   */
#define TDK_UNDEF       0x0000  /* undefined/unknown             */
#define TDK_DISK        0x0010  /* disk device                   */

                                /* disk kind                      */
#define TDK_DISK_UNDEF  0x0010  /* miscellaneous disk             */
#define TDK_DISK_RAM    0x0011  /* RAM disk (used as main memory) */
#define TDK_DISK_ROM    0x0012  /* ROM disk (used as main memory) */
#define TDK_DISK_FLA    0x0013  /* Flash ROM or other silicon disk */
#define TDK_DISK_FD     0x0014  /* floppy disk                    */
#define TDK_DISK_HD     0x0015  /* hard disk                      */
#define TDK_DISK_CDROM  0x0016  /* CD-ROM                         */
```

Currently no device types other than disks are defined. Other devices are assigned to undefined type (`TDK_UNDEF`). Note that device types are defined for the sake of distinguishing devices from the standpoint of the user as necessary, such as when applications must change their processing based on the type of device or media. Devices for which no such distinctions are necessary do not have to have a device type assigned.
See the individual device driver specifications regarding device-dependent attributes.

(4) Device Descriptor (ID type)

A device descriptor (> 0) is an identifier used for accessing a device, assigned by T-Kernel/SM when a device is opened.
A device descriptor belongs to a resource group. Operations using a device descriptor can be performed only by tasks belonging to the same resource group as the device descriptor. Error code (`E_OACV`) is returned for requests from tasks belonging to a different resource group.

(5) Request ID (ID type)

When an IO request is made to a device, a request ID (> 0) is assigned identifying the request. This ID can be used to wait for IO completion.

(6) Data Number (INT type)

Device data is designated by a data number. Data is classified into device-specific data and attribute data as follows.

Device-specific data: Data number ≥ 0

As device-specific data, the data numbers are defined separately for each device.

Examples

Disk	Data number = physical block number
Serial port	Data number = 0 only

Attribute data: Data number < 0

Attribute data designates driver or device state acquisition and setting modes, and special functions, etc.

Data numbers common to devices are defined, but device-dependent attribute data can also be defined. Details are given later.

5.3.2 Application Interface

The functions below are provided as application interface functions, called as extended SVC. These functions cannot be called from a task-independent portion or while dispatch or interrupts are disabled (`E_CTX`).

```
ID  tk_opn_dev( UB *devnm, UINT omode )
ER  tk_cls_dev( ID dd, UINT option )
ID  tk_rea_dev( ID dd, INT start, VP buf, INT size, TMO tmout )
ER  tk_srea_dev( ID dd, INT start, VP buf, INT size, INT *asize )
ID  tk_wri_dev( ID dd, INT start, VP buf, INT size, TMO tmout )
ER  tk_swri_dev( ID dd, INT start, VP buf, INT size, INT *asize )
ID  tk_wai_dev( ID dd, ID reqid, INT *asize, ER *ioerr, TMO tmout )
INT tk_sus_dev( UINT mode )
INT tk_get_dev( ID devid, UB *devnm )
ID  tk_ref_dev( UB *devnm, T_RDEV *rdev )
ID  tk_oref_dev( ID dd, T_RDEV *rdev )
INT tk_lst_dev( T_LDEV *ldev, INT start, INT ndev )
INT tk_evt_dev( ID devid, INT evttyp, VP evtinf )
```


- `ID tk_opn_dev( UB *devnm, UINT omode )`

`devnm`	Device name
`omode`	Open mode
return code	Device descriptor or error

  Opens the device designated in devnm in the mode designated in `omode`, and prepares for device access.

  The device descriptor is passed in the return code.

```
omode := (TD_READ || TD_WRITE || TD_UPDATE) | [TD_EXCL || TD_WEXCL]
       | [TD_NOLOCK]

#define TD_READ     0x0001  /* read only                              */
#define TD_WRITE    0x0002  /* write only                             */
#define TD_UPDATE   0x0003  /* read/write                             */
#define TD_EXCL     0x0100  /* exclusive                              */
#define TD_WEXCL    0x0200  /* exclusive write                        */
#define TD_NOLOCK   0x1000  /* lock (making resident) not necessary */
```

  `TD_READ` Read only

  `TD_WRITE` Write only

  `TD_UPDATE` Sets read and write access mode.
  When `TD_READ` is set, `tk_wri_dev()` cannot be used.
  When `TD_WRITE` is set, `tk_rea_dev()` cannot be used.

  `TD_EXCL` Exclusive

  `TD_WEXCL` Exclusive write
  Sets the exclusive mode.
  When `TD_EXCL` is set, all concurrent opening is prohibited.
  When `TD_WEXCL` is set, concurrent opening in write mode (`TD_WRITE` or `TD_UPDATE`) is prohibited.

Present Open Mode		Concurrent Open Mode					
		No exclusive mode		`TD_WEXCL`		`TD_EXCL`	
		R	W	R	W	R	W
No exclusive mode	R	Yes	Yes	Yes	Yes	No	No
	W	Yes	Yes	No	No	No	No
`TD_WEXCL`	R	Yes	No	Yes	No	No	No
	W	Yes	No	No	No	No	No
`TD_EXCL`	R	No	No	No	No	No	No
	W	No	No	No	No	No	No

  R = `TD_READ`
  W = `TD_WRITE` or `TD_UPDATE`
  Yes = Can be opened
  No = Cannot be opened (`E_BUSY`)

TD_NOLOCK Lock (making resident) not necessary
Indicates that a memory space (buf) designated in IO operations (tk_rea_dev and tk_wri_dev) has already been locked (made resident) on the calling side and does not have to be locked by the device driver. In this case the device driver does not (must not) lock the area. One use of this designation is to perform disk access for page in/page out in a virtual memory system. Generally it does not have to be designated.

The device descriptor belongs to the resource group of the task that opened the device.

When a physical device is opened, the logical devices belonging to it are all treated as having been opened in the same mode, and are processed as exclusive open.

E_BUSY	Device busy (exclusive open)
E_NOEXS	Device does not exist
E_LIMIT	Open count exceeds the limit
Other	Errors returned by device driver

- `ER tk_cls_dev( ID dd, UINT option )`

dd	Device descriptor
option	Close option
return code	Error

Closes device descriptor dd.

If a request is being processed, the processing is aborted and the device is closed.

```
option := [TD_EJECT]

#define TD_EJECT    0x0001      /* eject media */
```

TD_EJECT Eject media
If the same device has not been opened by another task, the media is ejected. In the case of devices that cannot eject their media, the request is ignored.

The subsystem cleanup processing (tk_cln_ssy) closes all the device descriptors belonging to the resource group.

E_ID	dd is invalid or not open
Other	Errors returned by device driver

- `ID tk_rea_dev( ID dd, INT start, VP buf, INT size, TMO tmout )`

dd	Device descriptor
start	Read start location (≥ 0: Device-specific data, < 0: Attribute data)
buf	Buffer location for putting the read data
size	Read size
tmout	Request acceptance timeout (ms)
return code	Request ID or error

Starts reading device-specific data or attribute data from the designated device. This function starts reading only, returning to its caller without waiting for the read operation to finish. The space designated in buf must be retained until the read operation completes. Read completion is waited for by tk_wai_dev.

The time required for read start processing differs with the device; return of control is not necessarily immediate.

In the case of device-specific data, the start and size units are decided for each device. With attribute data, start is an attribute data number and size is in bytes. The attribute data of the data number designated in start is read. Normally size must be at least as large as the size of the attribute data to be read. Reading of multiple attribute data in one operation is not possible. When `size` = 0 is designated, actual reading does not take place but the current size of data that can be read is checked.

Whether or not a new request can be accepted while a read or write operation is in progress depends on the device driver. If a new request cannot be accepted, the request is queued. The timeout for request waiting is set in `tmout`. The `TMO_POL` or `TMO_FEVR` attribute can be designated for tmout. Note that what times out is request acceptance. Once a request has been accepted, this function does not time out.

`E_ID`	`dd` is invalid or not open
`E_OACV`	Open mode is invalid (read not permitted)
`E_LIMIT`	Number of requests exceeds the limit
`E_TMOUT`	Busy processing other requests
`E_ABORT`	Processing aborted
Other	Errors returned by device driver

- `ER tk_srea_dev( ID dd, INT start, VP buf, INT size, INT *asize )`

  Synchronous read. This is equivalent to the following.

```
ER tk_srea_dev( ID dd, INT start, VP buf, INT size, INT *asize )
{
    ER er, ioer;
    er = tk_rea_dev(dd, start, buf, size, TMO_FEVR);
    if ( er > 0 ) {
       er = tk_wai_dev(dd, er, asize, &ioer, TMO_FEVR);
       if ( er > 0 ) er = ioerr;
    }
    return er;
}
```

- `ID tk_wri_dev( ID dd, INT start, VP buf, INT size, TMO tmout )`

`dd`	Device descriptor
`start`	write start location (≥ 0: Device-specific data, < 0: Attribute data)
`buf`	Buffer holding data to be written
`size`	Size of data to be written
`tmout`	Request acceptance timeout (ms)
return code	Request ID or error

Starts writing device-specific data or attribute data to a device. This function starts writing only, returning to its caller without waiting for the write operation to finish. The space designated in buf must be retained until the write operation completes. Write completion is waited for by `tk_wai_dev`.
The time required for write start processing differs with the device; return of control is not necessarily immediate.

In the case of device-specific data, the `start` and size units are decided for each device. With attribute data, `start` is an attribute data number and `size` is in bytes. The attribute data of the data number designated in `start` is written. Normally `size` must be at least as large as the size

of the attribute data to be written. Multiple attribute data cannot be written in one operation. When `size` = 0 is designated, actual writing does not take place but the current size of data that can be written is checked.

Whether or not a new request can be accepted while a read or write operation is in progress depends on the device driver. If a new request cannot be accepted, the request is queued. The timeout for request waiting is set in `tmout`. The `TMO_POL` or `TMO_FEVR` attribute can be designated for tmout. Note that what times out is request acceptance. Once a request has been accepted, this function does not time out.

`E_ID`	`dd` is invalid or not open
`E_OACV`	Open mode is invalid (write not permitted)
`E_RONLY`	Read-only device
`E_LIMIT`	Number of requests exceeds the limit
`E_TMOUT`	Busy processing other requests
`E_ABORT`	Processing aborted
Other	Errors returned by device driver

- `ER tk_swri_dev( ID dd, INT start, VP buf, INT size, INT *asize )`

  Synchronous write. This is equivalent to the following.

```
ER tk_swri_dev( ID dd, INT start, VP buf, INT size, INT *asize )
{
    ER er, ioer;
    er = tk_wri_dev(dd, start, buf, size, TMO_FEVR);
    if ( er > 0 ) {
        er = tk_wai_dev(dd, er, asize, &ioer, TMO_FEVR);
        if ( er > 0 ) er = ioer;
    }
    return er;
}
```

- `ID tk_wai_dev( ID dd, ID reqid, INT *asize, ER *ioer, TMO tmout )`

`dd`	Device descriptor
`reqid`	Request ID
`asize`	Returns the read/write data size
`ioer`	Returns IO error
`tmout`	Timeout (ms)
return code	Completed request ID or error

Waits for completion of request reqid for device `dd`.

If `reqid` = 0 is set, this function waits for completion of any pending request to `dd`.

This function waits for completion only of requests currently processing when the function is called. A request issued after `tk_wai_dev` was called is not waited for.

When multiple requests are being processed concurrently, the order of their completion is not necessarily the same as the order of request but is dependent on the device driver. Processing is, however, guaranteed to be performed in a sequence such that the result is consistent with the order of requesting. When processing a read operation from a disk, for example, the sequence might be changed as follows.

Block number request sequence	1	4	3	2	5
Block number processing sequence	1	2	3	4	5

Disk access can be made more efficient by changing the sequence as above with the aim of reducing seek time and spin wait time.

The timeout for waiting for completion is set in tmout. The TMO_POL or TMO_FEVR attribute can be designated for tmout. If a timeout error is returned (E_TMOUT), tk_wai_dev must be called again to wait for completion, since the request processing is ongoing.

When reqid > 0 and tmout = TMO_FEVR are both set, the processing must be completed without timing out.

If the requested processing results in error (IO error, etc.) ioer is stored rather than a return code. The return code is used for errors when the request wait itself was not handled properly. When error is passed in the return code, ioer has no meaning. Note also that if error is passed in the return code, tk_wai_dev must be called again to wait for completion, since the request processing is ongoing.

If a task exception is raised during completion waiting by tk_wai_dev, the request in reqid is aborted and processing is completed. The result of aborting the requested processing is dependent on the device driver. When reqid = 0 was set, however, requests are not aborted but are treated as timeout. In this case E_ABORT rather than E_TMOUT is returned.

It is not possible for multiple tasks to wait for completion of the same request ID at the same time. If there is a task waiting for request completion with reqid = 0 set, another task cannot wait for completion for the same device descriptor. Similarly, if there is a task waiting for request completion with reqid > 0 set, another task cannot wait for completion designating reqid = 0.

E_ID	dd is invalid or not open reqid is invalid or not a request for dd
E_OBJ	Another task is already waiting for request reqid
E_NOEXS	No requests are being processed (only when reqid = 0)
E_TMOUT	Timeout (processing continues)
E_ABORT	Processing aborted
Other	Errors returned by device driver

- `INT tk_sus_dev( UINT mode )`

mode	Mode
return code	Suspend disable request count or error

Performs the processing designated in mode, then passes the resulting suspend disable request count in the return code.

```
mode := ( (TD_SUSPEND | [TD_FORCE]) || TD_DISSUS || TD_ENASUS || TD_CHECK)

#define TD_SUSPEND  0x0001  /* suspend                          */
#define TD_DISSUS   0x0002  /* disable suspension               */
#define TD_ENASUS   0x0003  /* enable suspension                */
#define TD_CHECK    0x0004  /* get suspend disable request count */
#define TD_FORCE    0x8000  /* forcibly suspend                 */
```

TD_SUSPEND Suspend
: If suspending is enabled, suspends processing. If suspending is disabled, returns E_BUSY.

TD_SUSPEND|TD_FORCE Forcibly suspend
: Suspends even in suspend disabled state.

TD_DISSUS Disable suspension
: Disables suspension.

TD_ENASUS Enable suspension
Enables suspension.
If the enable request count is above the disable count for the resource group, no operation is performed.

TD_CHECK Get suspend disable count
Gets only the number of times suspend disable has been requested.

Suspension is performed in the following steps.

1. Processing prior to start of suspension in each subsystem
   `tk_evt_ssy(0, TSEVT_SUSPEND_BEGIN, 0, 0)`
2. Suspension processing in non-disk devices
3. Suspension processing in disk devices
4. Processing after completion of suspension in each subsystem
   `tk_evt_ssy(0, TSEVT_SUSPEND_DONE, 0, 0)`
5. SUSPEND state entered
   `tk_set_pow(TPW_DOSUSPEND)`

Resumption from SUSPEND state is performed in the following steps.

1. Return from SUSPEND state Return from `tk_set_pow(TPW_DOSUSPEND)`
2. Processing prior to start of resumption in each subsystem
   `tk_evt_ssy(0, TSEVT_RESUME_BEGIN, 0, 0)`
3. Resumption processing in disk devices
4. Resumption processing in non-disk devices
5. Processing after completion of resumption in each subsystem
   `tk_evt_ssy(0, TSEVT_RESUME_DONE, 0, 0)`

The number of suspend disable requests is counted. Suspension is enabled only if the same number of suspend enable requests is made. At system boot, the suspend disable count is 0 and suspension is enabled. There is only one suspend disable request count kept per system, but the system keeps track of the resource group making the request. It is not possible to clear suspend disable requests made in another resource group. When the cleanup function runs in a resource group, all the suspend requests made in that group are cleared and the suspend disable request count is reduced accordingly. The maximum suspend disable request count is implementation-dependent, but must be at least 255. When the upper limit is exceeded, `E_QOVR` is returned.

`E_BUSY` Suspend already disabled

`E_QOVR` Suspend disable request count limit exceeded

- `ID tk_get_dev( ID devid, UB *devnm )`

`devid`	Device ID
`devnm`	Device name storage location
return code	Device ID of physical device or error

Gets the device name of the device designated in `devid` and puts the result in `devnm`.

`devid` is the device ID of either a physical device or a logical device. If `devid` is a physical device, the physical device name is put in `devnm`. If `devid` is a logical device, the logical device name is put in `devnm`. `devnm` requires a space of `L_DEVNM` + 1 bytes or larger.

The device ID of the physical device to which device `devid` belongs is passed in the return code.

`E_NOEXS` The device designated in `devid` does not exist

- `ID tk_ref_dev( UB *devnm, T_RDEV *rdev )`
- `ID tk_oref_dev( ID dd, T_RDEV *rdev )`

`devnm`	Device name
`dd`	Device descriptor
`rdev`	Device information
return code	Device ID or error

```
typedef struct t_rdev {
    ATR devatr; /* device attributes */
    INT blksz;  /* block size of device-specific data (-1: unknown) */
    INT nsub;   /* subunit count */
    INT subno;  /* 0: physical device: 1 to nsub: subunit number+1 */
    /* Implementation-dependent information may be added beyond this point.*/
} T_RDEV;
```

Gets device information about the device designated in `devnm` or `dd` and puts the result in `rdev`.

If `rdev` = NULL is set, the device information is not stored. `nsub` indicates the number of physical device subunits belonging to the device designated in `devnm` or `dd`.

The device ID of the device designated in `devnm` is passed in the return code. `E_NOEXS` The device designated in `devnm` does not exist.

- `INT tk_lst_dev( T_LDEV *ldev, INT start, INT ndev )`

`ldev`	Location of registered device information (array)
`start`	Starting number
`ndev`	Number to acquire
return code	Remaining device registration count or error

```
typedef struct t_ldev {
    ATR devatr;         /* device attributes                              */
    INT blksz;          /* device-specific data block size (-1: unknown) */
    INT nsub;           /* subunits                                       */
    UB  devnm[L_DEVNM]; /* physical device name                           */
    /* Implementation-dependent information may be added beyond this point.*/
} T_LDEV;
```

Gets information about registered devices.

Registered devices are managed per physical device. The registered device information is therefore also obtained per physical device.

When the number of registered devices is N, number are assigned serially to devices from 0 to $N-1$. Starting from the number designated in start in accord with this scheme, the number of registrations designated in `ndev` is acquired and put in `ldev`. The space designated in `ldev` must be large enough to hold `ndev` registration information. The number of remaining registrations after `start` ($N -$ `start`) is passed in the return code. If the number of registrations from `start` is fewer than `ndev`, all remaining registrations are stored. A value passed in return code less than or equal to `ndev` means all remaining registrations were obtained. Note that this numbering changes as devices are registered and deleted. For this reason, accurate information may not always be obtained if the acquisition is carried out over multiple operations.

`E_NOEXS`	start exceeds the number of registered devices

- `INT tk_evt_dev( ID devid, INT evttyp, VP evtinf )`

`devid`	Event destination device ID
`evttyp`	Driver request event type
`evtinf`	Information for each event type
return code	Return code from device driver or error

  Sends a driver request event to the device (device driver) designated in `devid`.

  The following driver request events are defined.

```
#define TDV_CARDEVT 1   /* PC Card event (see Card Manager) */
#define TDV_USBEVT  2   /* USB event (see USB Manager)      */
```

  The functioning of driver request events and the contents of `evtinf` are defined for each event type.

`E_NOEXS`	The device designated in `devid` does not exist
`E_PAR`	Internal device manager events (`evttyp` < 0) cannot be designated

5.3.3 Device Registration

The following device registration information is defined in registering a device.
Device registration is performed for each physical device.

```
typedef struct t_ddev {
        VP  exinf;      /* extended information                              */
        ATR drvatr;     /* driver attributes                                 */
        ATR devatr;     /* device attributes                                 */
        INT nsub;       /* subunits                                          */
        INT blksz;      /* block size of device-specific data (-1: unknown)  */
        FP  openfn;     /* open count                                        */
        FP  closefn;    /* close count                                       */
        FP  execfn;     /* processing start function                         */
        FP  waitfn;     /* completion wait function                          */
        FP  abortfn;    /* abort processing function                         */
        FP  eventfn;    /* event function                                    */
        /* Implementation-dependent information may be added beyond this point. */
} T\_DDEV;
```

`exinf` is used to store any desired information. The value is passed to the processing functions. Device management pays no attention to the contents.
`drvatr` sets device driver attribute information. The low bits indicate system attributes, and the high bits are used for implementation-dependent attributes. The implementation-dependent attribute portion is used, for example, to indicate validity flags when implementation-dependent data is added to `T_DDEV`.

```
drvatr := [TDA_OPENREQ]

#define TDA_OPENREQ 0x0001  /* open/close each time */
```

`TDA_OPENREQ`

When a device is opened multiple times, normally `openfn` is called the first time it is opened and closefn the last time it is closed.

If `TDA_OPENREQ` is designated, then `openfn`/`closefn` will be called for all open/close operations even in case of multiple openings.

Device attributes are designated in devatr. The details of device attribute setting are as noted above. The number of subunits is set in nsub. If there are no subunits, 0 is designated.
blksz sets the block size of device-specific data in bytes. In the case of a disk device, this is the physical block size. It is set to 1 byte for a serial port, etc. For a device with no device-specific data it is set to 0. For an unformatted disk or other device whose block size is unknown, −1 is set.
If blksz $\leq$ 0, device-specific data cannot be accessed. When device-specific data is accessed by tk_rea_dev or tk_wri_dev, size $\times$ blksz must be the size of the area being accessed, that is, the size of buf.
openfn, closefn, execfn, waitfn, abortfn, and eventfn set the entry address of processing functions. Details of the processing functions are discussed later.

- ID tk_def_dev(UB *devnm, T_DDEV *ddev, T_IDEV *idev)

devnm	Physical device name
ddev	Device registration information
idev	Returns device initialization information
return code	Device ID or error

  Registers a device with the device name set in devnm.

  If a device with device name devnm is already registered, the registration is updated with new information, in which case the device ID does not change.

  When ddev = NULL is designated, device devnm registration is deleted.

  The device initialization information is returned in idev.

  This includes information set by default when the device driver is started, and can be used as necessary.

  When idev = NULL is set, device initialization information is not stored.

```
typedef struct t_idev {
    ID  evtmbfid;   /* event notification message buffer ID */
    /* Implementation-dependent information may be added beyond this point.*/
} T_IDEV;
```

  evtmbfid designates the system default message buffer ID for event notification. If there is no system default event notification message buffer, 0 is set.

  Notification like the following is made to each subsystem when a device is registered or deleted. devid is the device ID of the physical device registered or deleted.

Device registration or update:	tk_evt_ssy(0, TSEVT_DEVICE_REGIST, 0, devid)
Device deletion:	tk_evt_ssy(0, TSEVT_DEVICE_DELETE, 0, devid)

E_LIMIT	Number of registrations exceeds the system limit
E_NOEXS	The device designated in devnm does not exist (when ddev = NULL)

- ER tk_ref_idv(T_IDEV *idev)

idev	Returns device initialization information
return code	Error

  Gets device initialization information.

  The contents are the same as the information obtained by tk_dev_def().

5.3.4 Device Driver Interface

The device driver interface consists of processing functions designated when registering a device. These functions are called by device management and run as a quasi-task portion. They must be reentrant. The mutually exclusive calling of these processing functions is not guaranteed. If, for example, there are simultaneous requests from multiple devices for the same device, different tasks might call the same processing function at the same time. The device driver must apply mutual exclusion control in such cases as necessary.
IO requests to a device driver are made by means of the following request packet mapped to a request ID.

```
typedef struct t_devreq {
        struct   t_devreq *next;  /* I: Link to request packet (NULL: termination) */
        VP       exinf;           /* X: Extended information                       */
        ID       devid;           /* I: Target device ID                           */
        INT      cmd:4;           /* I: Request command                            */
        BOOL     abort:1;         /* I: TRUE if abort request                      */
        BOOL     nolock:1;        /* I: TRUE if lock (making resident) not needed  */
        INT      rsv:26;          /* I: reserved (always 0)                        */
        T_TSKSPC tskspc;          /* I: Task space of requesting task              */
        INT      start;           /* I: Starting data number                       */
        INT      size;            /* I: Request size                               */
        VP       buf;             /* I: IO buffer address                          */
        INT      asize;           /* O: Size of result                             */
        ER       error;           /* O: Error result                               */
        /* Implementation-dependent information may be added beyond this point.    */
} T_DEVREQ;
```

I indicates an input parameter and O an output parameter. Input parameters must not be changed by the device driver. Parameters other than input parameters (I) are initially cleared to 0 by device management. After that, device management does not modify them.
`next` is used to link the request packet. In addition to use for keeping track of request packets in device management, it is used also by the completion wait function (`waitfn`) and abort function (`abortfn`).
`exinf` can be used freely by the device driver. Device management does not pay attention to the contents.
The device ID of the device to which the request is issued is designated in `devid`.
The request command is designated in `cmd` as follows.

```
cmd := (TDC_READ || TDC_WRITE)

#define TDC_READ    1   /* read request  */
#define TDC_WRITE   2   /* write request */
```

If abort processing is to be carried out, abort is set to TRUE right before calling the abort function (`abortfn`). abort is a flag indicating whether abort processing was requested, and does not indicate that processing was aborted.
In some cases `abort` is set to TRUE even when the abort function (`abortfn`) is not called. Abort processing is performed when a request with abort set to TRUE is actually passed to the device driver.
`nolock` indicates that the memory space designated in buf has already been locked (made resident) and does not need to be locked by the device driver. In this case the device driver must not lock the memory space. (`nolock` is designated when there is a possibility of wrong operation if the device driver performs a lock. Accordingly, when `nolock` = TRUE, the device driver must not lock the space.)

tskspc sets the task space of the requesting task. Since processing functions are called in the context of the requesting task, tskspc is the same as the task space of the processing function. If, however, the actual IO processing (read/write in the space designated in buf) is performed by a separate task in the device driver, it is necessary to switch the task space of the task performing the IO processing to the task space of the requesting task.
The start and size parameters designated with tk_rea_dev or tk_wri_dev are set transparently in start and size here.
The buf parameter designated with tk_rea_dev or tk_wri_dev is set in buf here.
The memory space designated in buf may be nonresident in some cases or task space in others. Care must therefore be taken regarding the following points.

- Nonresident memory cannot be accessed from a task-independent portion or while dispatching or interrupts are disabled.
- Task space memory cannot be accessed from another task space.

For these reasons, switching of task space or making memory space resident must be performed as necessary. Special attention is needed when access is made by an interrupt handler. Generally it is best not to access buf directly from an interrupt handler.
Before accessing the buf memory space, the validity of buf must be checked using an address space check function (ChkSpace—, described later below).
The device driver sets in asize the value returned in asize by tk_wai_dev.
The device driver sets in error the error code passed by tk_wai_dev in its return code. E_OK indicates a normal result.

- Open Function: `ER openfn( ID devid, UINT omode, VP exinf )`

devid	Device ID of the device to open
omode	Open mode (same as tk_opn_dev)
exinf	Extended information set at device registration
return code	Error

  The open function openfn is called when tk_opn_dev is invoked.

  The function openfn performs processing to enable use of a device. Details of the processing are device-dependent; if no processing is needed, it does nothing. The device driver does not need to remember whether a device is open or not, nor is it necessary to treat as error the calling of another processing function simply because the device was not opened (openfn had not been called). If another processing function is called for a device that is not open, the necessary processing can be performed so long as there is no problem in device driver operation.

  When openfn is used to perform device initialization or the like, in principle no processing should be performed that causes a WAIT state. The processing and return from openfn must be as prompt as possible. In the case of a device such as a serial port for which it is necessary to set the communication mode, for example, the device can be initialized when the communication mode is set by tk_wri_dev. There is no need for openfn to initialize the device.

  When the same device is opened multiple times, normally this function is called only for the first time. If, however, the driver attribute TDA_OPENREQ is designated in device registration, this function is called each time the device is opened.

  The openfn function does not need to perform any processing with regard to multiple opening or open mode, which are handled by device management. Likewise, omode is simply passed as reference information; no processing relating to omode is required.

- Close Function: `ER closefn( ID devid, UINT option, VP exinf )`

`devid`	Device ID of the device to close
`option`	Close option (same as tk_cls_dev)
`exinf`	Extended information set at device registration
return code	Error

The close function `closefn` is called when `tk_cls_dev` is invoked.

The `closefn` function performs processing to end use of a device. Details of the processing are device-dependent; if no processing is needed, it does nothing.

If the device is capable of ejecting media and `TD_EJECT` is set in option, media ejection is performed.

When `closefn` is used to perform device shutdown processing or media ejection, in principle no processing should be performed that causes a WAIT state. The processing and return from `closefn` must be as prompt as possible. If media ejection takes time, it is permissible to return from `closefn` without waiting for the ejection to complete.

When the same device is opened multiple times, normally this function is called only the last time it is closed. If, however, the driver attribute `TDA_OPENREQ` is designated in device registration, this function is called each time the device is closed. In this case `TDA_EJECT` is designated in option only for the last time.

The `closefn` function does not need to perform any processing with regard to multiple opening or open mode, which are handled by device management.

- Processing Start Function: `ER execfn( T_DEVREQ *devreq, TMO tmout, VP exinf )`

`devreq`	Request packet
`tmout`	Request acceptance timeout (ms)
`exinf`	Extended information set at device registration
return code	Error

The `execfn` function is called when `tk_rea_dev` or `tk_wri_dev` is invoked, and starts the processing requested in devreq. This function starts the requested processing only, returning to its caller without waiting for the processing to complete. The time required to start processing depends on the device driver; this function does not necessarily complete immediately.

When new processing cannot be accepted, this function goes to WAIT state for request acceptance. If the new request cannot be accepted within the time designated in tmout, the function times out. The attribute `TMO_POL` or `TMO_FEVR` can be designated in tmout. If the function times out, `E_TMOUT` is passed in the `execfn` return code. Timeout applies to the request acceptance, not to the processing after acceptance.

When error is passed in the `execfn` return code, the request is considered not to have been accepted and the request packet is discarded.

If processing is aborted before the request is accepted (before the requested processing starts), `E_ABORT` is passed in the `execfn` return code and the request packet is discarded. If the abort occurs after the processing has been accepted, `E_OK` is returned for this function. The request packet is not discarded until waitfn is executed and processing completes.

When abort occurs, the important thing is to return from `execfn` as quickly as possible. If processing will end soon anyway without aborting, it is not necessary to abort.

- Completion Wait Function: `INT waitfn( T_DEVREQ *devreq, INT nreq, TMO tmout, VP exinf )`

devreq	Request packet list
nreq	Request packet count
tmout	Timeout designation (ms)
exinf	Extended information set at device registration
return code	Completed request packet number or error

The waitfn function is called when tk_wai_dev is invoked.

devreq is a list of request packets in a chain linked by devreq->next. This function waits for completion of any of the nreq request packets starting from devreq. The final next is not necessarily NULL, so the nreq designation must always be followed. The number of the completed request packet (which one after devreq) is passed in the return code. The first one is numbered 0 and the last one is numbered nreq − 1. Here completion means any of normal completion, abnormal (error) termination, or abort.

The time to wait until completion is set in tmout. TMO_POL or TMO_FEVR can be designated as the tmout attribute. If the wait times out, the requested processing continues. The waitfn return code in case of timeout is E_TMOUT. The request packet error parameter does not change. Note that if return from waitfn occurs while the requested processing continues, error must be returned in the waitfn return code; but the processing must be completed even when error is passed in the return code, and a value other than error must not be returned if processing is ongoing. As long as error is not passed in the waitfn return code, the request is considered to be pending and no request packet is discarded. When the number of a request packet whose processing was completed is passed in the waitfn return code, the processing of that request is considered to be completed and that request packet is discarded.

IO error and other device-related errors are stored in the request packet error parameter. Error is passed in the waitfn return code when completion waiting did not take place properly. The waitfn return code is set in the tk_wai_dev return code, whereas the request packet error value is returned in ioer.

Abort processing differs depending on whether the wait is for completion of a single request (nreq = 1) or multiple requests (nreq > 1). When completion of a single request is being waited for, the request currently processing is aborted. When waiting for completion of multiple requests, only the wait is aborted (wait release), not the requested processing itself. When a wait for multiple requests is aborted (wait release), E_ABORT is passed in the waitfn return code.

During a wait for request completion, an abort request may be set in the abort parameter of a request packet. In such a case, if it is a single request, the request abort processing must be performed. If the wait is for multiple requests it is also preferable that abort processing be executed, but it is also possible to ignore the abort flag.

When abort occurs, the important thing is to return from waitfn as quickly as possible. If processing will end soon anyway without aborting, it is not necessary to abort.

As a rule, E_ABORT is returned in the request packet error parameter when processing is aborted; but a different error code may be returned as appropriate based on the device properties. It is also permissible to return E_OK on the basis that the processing right up to the abort is valid. If processing completes normally to the end, E_OK is returned even if there was an abort request.

- Abort Function: ER abortfn(ID tskid, T_DEVREQ *devreq, INT nreq, VP exinf)

tskid	Task ID of the task executing execfn or waitfn
devreq	Request packet list
nreq	Request packet count
exinf	Extended information set at device registration
return code	Error

The function abortfn causes execfn or waitfn to return promptly when the designated request is being executed. Normally this means the request being processed is aborted. If, however, the processing can be completed soon without aborting, it may not have to be aborted. The important thing is to return as quickly as possible from execfn or waitfn.

tskid indicates the task executing the request designated in devreq. In other words, it is the task executing execfn or waitfn. devreq and nreq are the same as the parameters that were passed to execfn or waitfn. In the case of execfn, nreq is always 1.

abortfn is called by a different task from the one executing execfn or waitfn. Since both tasks run concurrently, mutual exclusion control must be performed as necessary. It is possible that the abortfn function will be called immediately before calling execfn or waitfn, or during return from these functions. Measures must be taken to ensure proper operation in such cases. Before abortfn is called, the abort flag in the request packet whose processing is to be aborted is set to TRUE, enabling execfn or waitfn to know whether there is going to be an abort request. Note also that abortfn can make use of tk_dis_wai for any object.

When waitfn is executing for multiple requests (nreq > 1), this is treated as a special case differing as follows from other cases.

- Only the completion wait is aborted (wait release), not the requested processing.
- The abort flag is not set in the request packet (remains as abort = FALSE).

Aborting a request when execfn and waitfn are not executing is done not by calling abortfn but by setting the request packet abort flag. If execfn is called when the abort flag is set, the request is not accepted. If waitfn is called, abort processing is the same as that when abortfn is called.

If a request for which processing was started by execfn is aborted before waitfn was called to wait for its completion, the completion of the aborted processing is notified when waitfn is called. Even though processing was aborted, the request itself is not discarded until its completion has been confirmed by waitfn.

abortfn starts abort processing only, returning promptly without waiting for the abort to complete.

abortfn is called in the following cases.

- When a break function is executing after a task exception and the task that raised the exception requests abort processing, abortfn is used to abort the request being processed by that task.
- When a device is being closed by tk_cls_dev and by subsystem cleanup processing, and a device descriptor was processing a request, abortfn is used to abort the request being processed by that device descriptor.

- Event Handling Function: `INT eventfn( INT evttyp, VP evtinf, VP exinf )`

evttyp	Driver request event type
evtinf	Information for each event type
exinf	Extended information set at device registration
return code	Return code defined for each event type or error

The following driver request event types are defined. Those with positive values are called by tk_evt_dev, and those with negative values are called inside device management.


```
#define TDV_SUSPEND (-1)    /* suspend                          */
#define TDV_RESUME  (-2)    /* resume                           */
#define TDV_CARDEVT   1     /* PC Card event (see Card Manager */
#define TDV_USBEVT    2     /* USB event (see USB Manager)     */
p
```

The processing performed by an event function is defined for each event type. Suspend and resume processing are discussed later below.

When a device event is called by `tk_evt_dev`, the eventfn return code is set transparently as the `tk_evt_dev` return code.

Requests to event functions must be accepted even if another request is processing and must be processed as quickly as possible.

5.3.5 Attribute Data

Attribute data is classified broadly into the following three kinds of data.

- **Common attributes**
  Attributes defined in common for all devices (device drivers).
- **Device kind attributes**
  Attributes defined in common for devices (device drivers) of the same kind.
- **Device-specific attributes**
  Attributes defined independently for each device (device driver).

For the device kind attributes and device-specific attributes, see the specifications for each device. Only the common attributes are defined here.
Common attributes are assigned attribute data numbers in the range from −1 to −99. While common attribute data numbers are the same for all devices, not all devices necessarily support all common attributes. If an unsupported data number is designated, error code `E_PAR` is returned.

```
#define TDN_EVENT       (-1)    /* RW: event notification message buffer ID */
#define TDN_DISKINFO    (-2)    /* R: disk information                      */
#define TDN_DISPSPEC    (-3)    /* R: display device specification          */
```

RW: read (`tk_rea_dev`)/write (`tk_wri_dev`) enabled
R: read (`tk_rea_dev`) only

`TDN_EVENT`: Event Notification Message Buffer ID

Data type: `ID`

The `ID` of the message buffer used for device event notification. Since the system default message buffer `ID` is passed in device registration, that `ID` is set as the initial setting when a driver is started.

If 0 is set, device events are not notified.

Device event notification is discussed later below.

`TDN_DISKINFO`: Disk Information

Data type: `DiskInfo`


```
typedef enum {
        DiskFmt_STD     = 0,    /* standard (HD, etc.) */
        DiskFmt_2DD     = 1,    /* 2DD 720KB           */
        DiskFmt_2HD     = 2,    /* 2HD 1.44MB          */
        DiskFmt_CDROM   = 4,    /* CD-ROM 640MB        */
} DiskFormat;

typedef struct {
        DiskFormat  format;         /* format              */
        UW          protect:1;      /* protected status    */
        UW          removable:1;    /* removable           */
        UW          rsv:30;         /* reserved (always 0) */
        W           blocksize;      /* block size in bytes */
        W           blockcount;     /* total block count   */
} DiskInfo;
```

See the disk driver specification for details.

TDN_DISPSPEC: Display Device Specification

Data type: DEV_SPEC

```
typedef struct {
H   attr;       /* device attributes           */
H   planes;     /* number of planes            */
H   pixbits;    /* pixel bits (boundary/valid) */
H   hpixels;    /* horizontal pixels           */
H   vpixels;    /* vertical pixels             */
H   hres;       /* horizontal resolution       */
H   vres;       /* vertical resolution         */
H   color[4];   /* color information           */
H   resv[6];    /* reserved                    */
} DEV_SPEC;
```

See the screen driver specification for details.

5.3.6 Device Event Notification

A device driver sends events occurring in devices to the event notification message buffer (TDN_EVENT) as device event notification. The system default event notification message buffer is designated at the time of device registration, but can be changed later. The system default event notification message buffer is defined in TDEvtMbfSz in system configuration information.
The following event types are defined.

```
typedef enum tdevttyp {
        TDE_unknown     = 0,        /* undefined                */
        TDE_MOUNT       = 0x01,     /* media mounted            */
        TDE_EJECT       = 0x02,     /* media ejected            */
        TDE_ILLMOUNT    = 0x03,     /* media illegally mounted  */
        TDE_ILLEJECT    = 0x04,     /* media illegally ejected  */
        TDE_REMOUNT     = 0x05,     /* media remounted          */
        TDE_CARDBATLOW  = 0x06,     /* card battery alarm       */
```



```
        TDE_CARDBATFAIL = 0x07,    /* card battery failure       */
        TDE_REQEJECT    = 0x08,    /* media eject request        */
        TDE_PDBUT       = 0x11,    /* PD button state change     */
        TDE_PDMOVE      = 0x12,    /* PD move                    */
        TDE_PDSTATE     = 0x13,    /* PD state change            */
        TDE_PDEXT       = 0x14,    /* PD extended event          */
        TDE_KEYDOWN     = 0x21,    /* key down                   */
        TDE_KEYUP       = 0x22,    /* key up                     */
        TDE_KEYMETA     = 0x23,    /* meta key state change      */
        TDE_POWEROFF    = 0x31,    /* power switch off           */
        TDE_POWERLOW    = 0x32,    /* low power alarm            */
        TDE_POWERFAIL   = 0x33,    /* power failure              */
        TDE_POWERSUS    = 0x34,    /* auto suspend               */
        TDE_POWERUPTM   = 0x35,    /* clock update               */
        TDE_CKPWON      = 0x41     /* auto power on notification */
} TDEvtTyp;
```

Device events are notified in the following format. The contents of event notification and size differ with each event type.

```
typedef struct t_devevt {
       TDEvtTyp    evttyp;     /* event type */
       /* Information specific to each event type is appended here. */
} T_DEVEVT;
```

The format of device event notification with device ID is as follows.

```
typedef struct t_devevt_id {
       TDEvtTyp    evttyp;     /* event type */
       ID          devid;      /* device ID */
       /* Information specific to each event type is appended here. */
} T_DEVEVT_ID;
```

See the device driver specifications for event details.
Measures must be taken so that if event notification cannot be sent because the message buffer is full, the lack of notification will not adversely affect operation on the receiving end. One option is to hold the notification until space becomes available in the message buffer, but in that case other device driver processing should not, as a rule, be allowed to fall behind as a result. Processing on the receiving end should be designed to the extent possible to avoid message buffer overflow.

5.3.7 Device Suspend/Resume Processing

Device drivers suspend and resume device operations in response to the issuing of suspend/resume (`TDV_SUSPEND`/`TDV_RESUME`) events to the event handling function (`eventfn`). Suspend and resume events are issued only to physical devices.

`TDV_SUSPEND`: Suspend Device

`evttyp` = `TDV_SUSPEND`
`evtinf` = NULL (none)

Suspension processing takes place in the following steps.

(A) If there is a request being processed at the time, the device driver waits for it to complete, pauses it or aborts. Which of these options to take depends on the device driver implementation. Since the suspension must be effected as quickly as possible, however, pause or abort should be chosen if completion of the request will take time. Suspend events can be issued only for physical devices, but the same processing is applied to all logical devices included in the physical device.

Pause: Processing is suspended, then continues after the device resumes operation.

Abort: Processing is aborted just as when the abort function (`abortfn`) is executed, and is not continued after the device resumes operation.

(B) New requests other than a resume event are not accepted.

(C) The device power is cut and other suspension processing is performed.

Abort should be avoided if at all possible because of its effects on applications. It should be used only in such cases as long input waits from a serial port, or when interruption would be difficult. Normally it is best to wait for completion of a request or, if possible, choose pause (suspension and resumption).

Requests arriving at the device driver in suspend state are made to wait until operation resumes, after which acceptance processing is performed. If the request does not involve access to the device, however, or otherwise can be processed even during suspension, a request may be accepted without waiting for resumption.

`TDV_RESUME`**:** Resume Device

`evttyp` = `TDV_RESUME`
`evtinf` = NULL (none)

Resumption processing takes place as follows.

(A) The device power is turned back on, the device states are restored and other device resumption processing is performed.

(B) Paused processing is resumed.

(C) Request acceptance is resumed.

5.3.8 Special Properties of Disk Devices

A disk device has a special role to play in a virtual memory system. In order to realize virtual memory, the OS must call the disk driver for transferring data between memory and disk.
The need for the OS to perform data transfer with a disk arises when access is made to nonresident memory and the memory contents must be read from the disk (page in). The OS calls the disk driver in this case.
If nonresident memory is accessed in the disk driver, the OS must likewise call the disk driver. In such a case, if the disk driver treats the access to nonresident memory as a wait for page in, it is possible that the OS will again request disk access. Even then, the disk driver must be able to execute the later OS request.
A similar case may arise in suspension processing. When access is made to nonresident memory during suspension processing and a disk driver is called, if that disk driver is already suspended, page in will not be possible. To avoid such a situation, suspension processing should suspend other devices before disk devices. If there are multiple disk devices, however, the order of their suspension is indeterminate. For this reason, during suspension processing a disk driver must not access nonresident memory.

Because of the above limitations, a disk driver must not use (`access`) nonresident memory. It is possible, however, that the IO buffer (`buf`) space designated with `tk_rea_dev` or `tk_wri_dev` will be nonresident memory, since this is a memory location designated by the caller. In the case of IO buffers, therefore, it is necessary to make the memory space resident (see `LockSpace`) at the time of IO access.

5.4 Interrupt Management Functions

Interrupt handling is largely hardware-dependent, differing with each system, and therefore difficult to standardize. The following are given as standard specifications, but it may not be possible to follow these exactly on all systems. Implementors should strive to comply with these specifications to the extent possible; but where implementation is not feasible, full compliance is not mandatory. If functions not in the standard specifications are added, however, the function names must be different from those given here. In any case, `DI()`, `EI()`, and `isDI()` must be implemented in accord with the standard specifications.
Interrupt management functions are provided as library functions or C language macros. These can be called from a task-independent portion and while dispatching and interrupts are disabled.

5.4.1 CPU Interrupt Control

These functions are for CPU external interrupt flag control.
Generally they do not perform any operation on the interrupt controller.
`DI()` and `EI()` are C language macros.

- `DI( UINT intsts )`

  `intsts` CPU interrupt status (details are implementation-dependent)
  This is not a pointer.

  Disables all external interrupts.

  The status prior to disabling interrupts is stored in `intsts`.

- `EI( UINT intsts )`

  `intsts` CPU interrupt status (details are implementation-dependent)

  Enables all external interrupts.

  More precisely, this macro restores the status in `intsts`. That is, the interrupt status reverts to what it was before interrupts were disabled by `DI()`. If there were interrupts disabled at the time `DI()` was executed, those interrupts are not enabled by `EI()`. All interrupts can be enabled, however, by designating 0 in `intsts`.

  `intsts` must be either the values stored in it by `DI()` or 0. If any other value is designated, the behavior is not guaranteed.

- `BOOL isDI( UINT intsts )`

  `intsts` CPU interrupt status (details are implementation-dependent)

  Return code:
  TRUE (not 0): Interrupts disabled
  FALSE: Interrupts enabled

  Gets the status of external interrupt disabling stored in `intsts`.

  Interrupts disabled status is the status in which T-Kernel/OS determines that interrupts are disabled.

  `intsts` must by the value stored by `DI()`. If any other value is designated, the behavior is not guaranteed.

  Sample usage:


```
void foo()
{
    UINT    intsts;

    DI(intsts);

    if ( isDI(intsts) ) {
        /* Interrupts were already disabled at the time this function was called.*/
    } else {
        /* Interrupts were enabled at the time this function was called.         */
    }

    EI(intsts);

}
```

5.4.2 Control of Interrupt Controller

These functions control the interrupt controller.
Generally they do not perform any operation with respect to the CPU interrupt flag.

```
typedef UINT    INTVEC;     /* interrupt vector */
```

The specific details of the interrupt vectors (`INTVEC`) are implementation-dependent. Preferably, however, they should be the same numbers as the interrupt definition numbers designated with `tk_def_int`, or should allow for simple conversion to and from those numbers.

- `UINT DINTNO( INTVEC intvec )`

  Converts an interrupt vector to the corresponding interrupt definition number.

- `void EnableInt( INTVEC intvec )`

- `void EnableInt( INTVEC intvec, INT level )`

  Enables the interrupt designated in `intvec`.

  In a system that allows interrupt priority level to be designated, the level parameter can be used to designate the interrupt priority level. The precise meaning of level is implementation-dependent.

  Both methods with and without the level designation must be provided.

- `void DisableInt( INTVEC intvec )`

  Disables the interrupt designated in `intvec`.

  Generally, interrupts raised while interrupts are disabled are made pending, and are raised after interrupts are enabled by `EnableInt()`. `ClearInt()` must be used if it is desired to clear interrupts occurring in interrupts disabled state.

- `void ClearInt( INTVEC intvec )`

  Clears any interrupts raised for `intvec`.

- `void EndOfInt( INTVEC intvec )`

  Issues `EOI` (End Of Interrupt) to the interrupt controller `intvec` must be an interrupt for which `EOI` can be issued. Generally this must be executed at the end of an interrupt handler.

- `BOOL CheckInt( INTVEC intvec )`

  Checks whether interrupt intvec has been raised.

  If interrupt intvec has been raised, it returns TRUE (value other than 0), else FALSE.

5.5 IO Port Access Support Functions

IO port access support functions are provided as library functions or C language macros. These can be called from a task-independent portion or while dispatching and interrupts are disabled.

5.5.1 IO Port Access

In a system with separate IO space and memory space, an IO port access function accesses IO space. In a system with memory-mapped IO only, an IO port access function accesses memory space. Using these functions will improve software portability and readability even in a memory-mapped IO system.

—`_w` Word (32-bit) units
—`_h` Half-word (16-bit) units
—`_b` Byte (8-bit) units

- `void out_w( INT port, UW data )`
- `void out_h( INT port, UH data )`
- `void out_b( INT port, UB data )`

  `port` IO port address data Data to be written

  Writes data to an IO port.

- `UW in_w( INT port )`
- `UH in_h( INT port )`
- `UB in_b( INT port )` port IO port address return code Data to be read

  Reads data from an IO port.

5.5.2 Microwait

- `void WaitUsec( UINT usec )`
- `void WaitNsec( UINT nsec )`

  `usec` Wait time (microseconds)
  `nsec` Wait time (nanoseconds)

  Performs a microwait for the designated interval.

  These waits occur in an ordinary busy loop, and as such are easily influenced by the runtime environment, such as execution in RAM, execution in ROM, memory cache on or off, etc. These wait times are therefore not very accurate.

  These waits are not the same as an OS WAIT state. The system state remains as RUN state.

5.6 Power Management Functions

Power management functions are called from T-Kernel/OS. See `tk_set_pow`.
The manner of calling these functions is implementation-dependent. Simple system calls are possible, as is the use of a trap. Use of an extended SVC or other means that makes use of OS functions is not possible, however. Providing these functions in T-Monitor is another option.
The specifications given here for `low_pow` and `off_pow` are reference specifications. Since these functions are used only inside T-Kernel, other specifications may be devised as well. It is even possible to design completely different specifications in order to realize more advanced power-saving features. If the functionality is similar to that specified here, however, it would be best to follow these specifications as closely as practical.

- `void low_pow( void )`

  Switches to low-power mode and waits for an interrupt to be raised. This function is called from the task dispatcher, and performs the following processing.

  (A) Goes to low-power mode.

  (B) Waits for an external interrupt to be raised.

  (C) When an external interrupt is raised, restores normal power mode and returns to its caller.

  This function is called in interrupts disabled state. Interrupts must not be enabled. The speed of response to an interrupt affects processing speed, and should be as fast as possible.

- `void off_pow( void )`

  Suspends the system. When a resume factor occurs, it resumes system operation.

  This function is called from `tk_set_pow`, and performs the following processing.

  (A) Puts the hardware in suspended state.

  (B) Waits for a resume factor to occur.

  (C) When a resume factor occurs, returns from suspended state and returns to its caller.

  This function is called in interrupts disabled state. Interrupts must not be enabled. The device drivers perform the suspending and resuming of peripherals and other devices.

5.7 System Configuration Information Management Functions

System configuration information management functions are provided for storing, managing and making available information about the system configuration (maximum number of tasks, etc.) and any other information. These are not functions for adding or modifying information when the system is running. How the system configuration information is to be stored is not specified here, but it is generally put in memory (ROM/RAM). This functionality is therefore not intended for storing large amounts of information.
Standard definitions are specified for some system configuration information, but additional information may be defined and used for applications, subsystems, or device drivers.
The format of system configuration information consists of a name and defined data as a set.

- **Name**
  The name is a string of up to 16 characters.
  Characters that can be used (UB) are a to z, A to Z, 0 to 9 and _ (underbar).
- **Defined data**
  Data consists of numbers (integers) or character strings.
  Characters that can be used (UB) are any characters other than 0x00 to 0x1F, 0x7F, or 0 xFF (character codes).

Sample:

Name	Defined Data
`SysVer`	1 0
`SysName`	T-Kernel Version 1.00

5.7.1 System Configuration Information Acquisition

System configuration information is acquired by using extended SVC. This function is used inside T-Kernel, and can also be used by applications, subsystems, device drivers and so on. Use inside T-Kernel does not have to go through extended SVC; this choice is implementation-dependent.

- `INT tk_get_cfn( UB *name, INT *val, INT max )`

`name`	Name
`val`	Array storing numeric strings
`max`	Number of elements in val array
return code	Defined numeric information count or error

  Gets numeric string information from system configuration information. This function gets up to `max` items of numerical string information defined by the name designated in the `name` parameter and stores the acquired information in `val`. The number of items of defined numeric string information is passed in the return code. If return code > `max`, this indicates that not all the information could be stored. By designating `max` = 0, the number of numeric strings can be found out without actually storing them in `val`.

  `E_NOEXS` is returned if no information is defined with the name designated in the `name` parameter. The behavior if the information defined as name is a character string is indeterminate.

- `INT tk_get_cfs( UB *name, UB *buf, INT max )`

`name`	Name
`buf`	Array storing character string
`max`	Maximum size of `buf` (in bytes)
return code	Size of defined character string information (in bytes) or error

Gets character string information from system configuration information. This function gets up to `max` characters of character string information defined by the name designated in the `name` parameter and stores the acquired information in `buf`. If the acquired character string is shorter than `max` characters, it is terminated by '`\0`' when stored. The length of the defined character string information (not including '`\0`') is passed in the return code. If return code > `max`, this indicates that not all the information could be stored. By designating `max` = 0, the character string length can be found out without actually storing anything in `buf`.

`E_NOEXS` is returned if no information is defined with the name designated in the `name` parameter. The behavior if the information defined as name is a numeric string is indeterminate.

5.7.2 Standard System Configuration Information

The following information is defined as standard system configuration information. A standard information name is prefixed by T.

N: Numeric string information
S: Character string information

- Product information
  - S: `TSysName` System name (product name)
- Maximum object counts
  - N: `TMaxTskId` Maximum tasks
  - N: `TMaxSemId` Maximum semaphores
  - N: `TMaxFlgId` Maximum event flags
  - N: `TMaxMbxId` Maximum mailboxes
  - N: `TMaxMtxId` Maximum mutexes
  - N: `TMaxMbfId` Maximum message buffers
  - N: `TMaxPorId` Maximum rendezvous ports
  - N: `TMaxMpfId` Maximum fixed-size memory pools
  - N: `TMaxMplId` Maximum variable-size memory pools
  - N: `TMaxCycId` Maximum cyclic handlers
  - N: `TMaxAlmId` Maximum alarm handlers
  - N: `TMaxResId` Maximum resource groups
  - N: `TMaxSsyId` Maximum subsystems
  - N: `TMaxSsyPri` Maximum subsystem priorities
- Other
  - N: `TSysStkSz` Default system stack size (in bytes)
  - N: `TSVCLimit` Lowest protection level for system call invoking
  - N: `TTimPeriod` Timer interrupt interval (ms)
- Device management
  - N: `TMaxRegDev` Maximum device registrations
  - N: `TMaxOpnDev` Maximum device open count
  - N: `TMaxReqDev` Maximum device requests
  - N: `TDEvtMbfSz` Event notification message buffer size (in bytes)
    Maximum event notification message length (in bytes)

If `TDEvtMbfSz` is not defined or if the message buffer size is a negative value, an event notification message buffer is not used.

When multiple values are defined for any of the above numeric strings, they are stored in the same order as in the explanation.

Examples:

```
tk_get_cfn("TDEvtMbfSz", val, 2)
```

`val[0]` = Event notification message buffer size
`val[1]` = Maximum event notification message length

5.8 Subsystem and Device Driver Starting

Entry routines like the following are defined for subsystems and device drivers.

```
ER main( INT ac, UB *av[] )
{
   if ( ac >= 0 ) {
       /* Subsystem/device driver start processing */
   } else {
       /* Subsystem/device driver termination processing */
   }
   return ercd;
}
```

This entry routine simply performs startup processing or termination processing for a subsystem or device driver and does not provide any actual service. It must return to its caller as soon as the startup processing or termination processing is performed. An entry routine must perform its processing as quickly as possible and return to its caller.
An entry routine is called at the time of normal system startup or shutdown and runs in the context of the OS start processing task or termination processing task (protection level 0). In some OS implementations, it may run as a quasi-task portion. In a system that supports dynamic loading of subsystems and device drivers, it may be called at other times besides system startup and shutdown.
When there are multiple subsystems and device drivers, entry routines are called one at a time for each, at system startup and shutdown. In no case are multiple entry routines called by different tasks at the same time. Accordingly, if subsystem or device driver initialization needs to be performed in a certain order, this order can be maintained by completing all necessary processing before returning from an entry routine.
The entry routine function name is normally main, but any other name may be used if, for example, main cannot be used because of linking with the OS.
The methods of registering entry routines with the OS, designating parameters, and designating the order in which entry routines are called are all dependent on the OS implementation.

- Startup processing

`ac`	Number of parameters (≥ 0)
`av`	Parameters (string)
return code	Error

  A value of `ac` ≥ 0 indicates startup processing. After performing the subsystem or device driver initialization, it registers the subsystem or device driver.

  Passing of a negative value (error) as the return code means the startup processing failed. Depending on the OS implementation, the subsystem or device driver may be deleted from memory, so error must not be returned while the subsystem or device driver is in registered state. The registration must first be erased before returning error. Allocated resources must also be released. They are not released automatically.

  The parameters `ac` and `av` are the same as the parameters passed to the standard C language `main()` function, with ac indicating the number of parameters and av indicating a parameter string as an array of `ac` + 1 pointers. The array termination `(av[ac])` is NULL.

  `av[0]` is the name of the subsystem or device driver. Generally this is the file name of the subsystem or device driver, but the kind of name in which it is stored is implementation-dependent. It is also possible to have no name (blank string `""`).

Parameters after `av[1]` are defined separately for each subsystem and device driver.

After exit from the entry routine, the character string space designated by `av` is deleted, so parameters must be saved to a different location as needed.

- Termination processing

`ac`	-1
`av`	NULL
return code	Error

A value of `ac` < 0 indicates termination processing. After deleting the subsystem or device driver registration, the entry routine releases allocated resources. If an error occurs during termination processing, the processing must not be aborted but must be completed to the extent possible. If some of the processing could not be completed normally, error is passed in the return code.

The behavior if termination processing is called while requests to the subsystem or device driver are being processed is dependent on the subsystem or device driver implementation. Generally termination processing is called at system shutdown and requests are not issued during processing. For this reason, ordinarily behavior is not guaranteed in the case of requests issued during termination processing.

Chapter 6

T-Kernel/DS Functions

This chapter gives detailed explanations of the functions provided by T-Kernel Debugger Support (T-Kernel/DS).
T-Kernel/DS provides functions enabling a debugger to reference T-Kernel internal states and run a trace. The functions provided by T-Kernel/DS are only for debugger use and not for use by applications or other programs.

[**General cautions and notes**]

- Except where otherwise noted, T-kernel/DS service calls (`td_`—) can be called from a task-independent portion and while dispatching and interrupts are disabled. There may be some limitations, however, imposed by particular implementations.
- When T-Kernel/DS service calls (`td_`—) are invoked in interrupts disabled state, they are processed without enabling interrupts. Other OS states likewise remain unchanged during this processing. Changes in OS states may occur if a service call is invoked while interrupts or dispatching are enabled, since the OS continues operating.
- T-Kernel/DS service calls (`td_`—) cannot be invoked from a lower protection level than that at which T-Kernel/OS system calls can be invoked (lower than `TSVCLimit`)(`E_CTX`).
- Error codes such as `E_PAR`, `E_MACV`, and `E_CTX` that always have the possibility of occurring are not described here unless there is some special reason for doing so.
- Detection of error codes `E_PAR`, `E_MACV`, and `E_CTX` is implementation-dependent; these may not always be detected as error. For this reason, the service calls must not be invoked in such a way that these errors might occur.

6.1 Kernel Internal State Acquisition Functions

These functions enable a debugger to acquire T-Kernel internal states. They include functions for getting a list of objects, getting task precedence, getting the order in which tasks are queued, getting the status of objects, system, and task registers, and getting time.

td_lst_tsk, td_lst_sem, td_lst_flg, td_lst_mbx td_lst_mtx, td_lst_mbf, td_lst_por, td_lst_mpf td_lst_mpl, td_lst_cyc, td_lst_alm, td_lst_ssy

Reference Object ID List

[**C Language Interface**]

```
INT ct = td_lst_tsk ( ID list[], INT nent ) ;   /* task                      */
INT ct = td_lst_sem ( ID list[], INT nent ) ;   /* semaphore                 */
INT ct = td_lst_flg ( ID list[], INT nent ) ;   /* event flag                */
INT ct = td_lst_mbx ( ID list[], INT nent ) ;   /* mailbox                   */
INT ct = td_lst_mtx ( ID list[], INT nent ) ;   /* mutex                     */
INT ct = td_lst_mbf ( ID list[], INT nent ) ;   /* message buffer            */
INT ct = td_lst_por ( ID list[], INT nent ) ;   /* rendezvous port           */
INT ct = td_lst_mpf ( ID list[], INT nent ) ;   /* fixed-size memory pool    */
INT ct = td_lst_mpl ( ID list[], INT nent ) ;   /* variable-size memory pool */
INT ct = td_lst_cyc ( ID list[], INT nent ) ;   /* cyclic handler            */
INT ct = td_lst_alm ( ID list[], INT nent ) ;   /* alarm handler             */
INT ct = td_lst_ssy ( ID list[], INT nent ) ;   /* subsystem                 */
```

[**Parameters**]

ID	list[]	Location of object ID list
INT	nent	Maximum number of list entries

[**Return Parameters**]

INT	ct	Number of objects used
	or	Error Code

[**Description**]

Gets a list of IDs of objects currently being used, and puts in list up to nent IDs. The number of objects used is passed in the return code. If return code > nent, this means not all IDs could be acquired.

td_rdy_que

Get Task Precedence

[C Language Interface]

```
INT ct = td_rdy_que ( PRI pri, ID list[], INT nent ) ;
```

[Parameters]

PRI	pri	Task priority
ID	list[]	Location of task ID list
INT	nent	Maximum number of list entries

[Return Parameters]

INT	ct	Number of priority pri tasks in a run state
	or	Error Code

[Description]

Gets a list of IDs of the tasks in a run state (READY state or RUN state) whose task priority is `pri`, arranged in order from highest to lowest precedence.
This function stores in the location designated in `list` up to nent task IDs, arranged in order of precedence starting from the highest-precedence task ID at the head of the list.
The number of tasks in a run state with priority `pri` is passed in the return code. If return `code` > `nent`, this means not all task IDs could be stored.

td_sem_que, td_flg_que, td_mbx_que, td_mtx_que td_smbf_que, td_rmbf_que, td_cal_que, td_acp_que td_mpf_que, td_mpl_que

Reference Queue

[**C Language Interface**]

```
INT ct = td_sem_que  ( ID semid, ID list[], INT nent ) ; /* semaphore                */
INT ct = td_flg_que  ( ID flgid, ID list[], INT nent ) ; /* event flag               */
INT ct = td_mbx_que  ( ID mbxid, ID list[], INT nent ) ; /* mailbox                  */
INT ct = td_mtx_que  ( ID mtxid, ID list[], INT nent ) ; /* mutex                    */
INT ct = td_smbf_que ( ID mbfid, ID list[], INT nent ) ; /* message buffer send      */
INT ct = td_rmbf_que ( ID mbfid, ID list[], INT nent ) ; /* message buffer receive   */
INT ct = td_cal_que  ( ID porid, ID list[], INT nent ) ; /* rendezvous call          */
INT ct = td_acp_que  ( ID porid, ID list[], INT nent ) ; /* rendezvous accept        */
INT ct = td_mpf_que  ( ID mpfid, ID list[], INT nent ) ; /* fixed-size memory pool   */
INT ct = td_mpl_que  ( ID mplid, ID list[], INT nent ) ; /* variable-size memory pool */
```

[**Parameters**]

ID	—id	Object ID
ID	list[]	Location of waiting task IDs
INT	nent	Maximum number of list entries

[**Return Parameters**]

INT	ct	Number of waiting tasks
	or	Error Code

[**Error Codes**]

E_ID	Bad identifier
E_NOEXS	Object does not exist

[**Description**]

Gets a list of IDs of tasks waiting for the object designated in —id.
This function stores in the location designated in list up to nent task IDs, arranged in the order in which tasks are queued, starting from the first task in the queue. The number of queued tasks is passed in the return code. If return code > nent, this means not all task IDs could be stored.

td_ref_tsk

Reference Task State

[C Language Interface]

```
ER ercd = td_ref_tsk ( ID tskid, TD_RTSK *rtsk );
```

[Parameters]

ID	tskid	Task ID (TSK_SELF can be designated)
TD_RTSK	rtsk	Packet address for returning the task state

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Bad identifier
E_NOEXS	Object does not exist

[Description]

Gets the state of the task designated in tskid. This function is similar to tk_ref_tsk, with the task start address and stack information added to the state information obtained.

```
typedef struct td_rtsk {
        VP      exinf;      /* extended information              */
        PRI     tskpri;     /* current priority                  */
        PRI     tskbpri;    /* base priority                     */
        UINT    tskstat;    /* task state                        */
        UINT    tskwait;    /* wait factor                       */
        ID      wid;        /* waiting object ID                 */
        INT     wupcnt;     /* queued wakeup request count       */
        INT     suscnt;     /* SUSPEND request nesting count     */
        RELTIM  slicetime;  /* maximum continuous run time (ms)  */
        UINT    waitmask;   /* masked wait factors               */
        UINT    texmask;    /* allowed task exceptions           */
        UINT    tskevent;   /* raised task event                 */
        FP      task;       /* task start address                */
        INT     stksz;      /* user stack size (in bytes)        */
        INT     sstksz;     /* system stack size (in bytes)      */
        VP      istack;     /* user stack pointer initial value  */
        VP      isstack;    /* system stack pointer initial value */
} TD_RTSK;
```


The stack area extends from the stack pointer initial value toward the low addresses for the number of bytes designated as the stack size.

$$\texttt{istack} - \texttt{stksz} \leq \text{user stack area} < \texttt{istack}$$

$$\texttt{isstack} - \texttt{sstksz} \leq \text{system stack area} < \texttt{isstack}$$

Note that the stack pointer initial value (`istack`, `isstack`) is not the same as its current position. The stack area may be used even before a task is started. Calling `td_get_reg` gets the stack pointer current position.

td_ref_sem, td_ref_flg, td_ref_mbx, td_ref_mtx td_ref_mbf, td_ref_por, td_ref_mpf, td_ref_mpl td_ref_cyc, td_ref_alm, td_ref_ssy

Reference Queue

[**C Language Interface**]

```
ER ercd = td_ref_sem ( ID semid, TD_RSEM *rsem );   /* semaphore                */
ER ercd = td_ref_flg ( ID flgid, TD_RFLG *rflg );   /* event flag               */
ER ercd = td_ref_mbx ( ID mbxid, TD_RMBX *rmbx );   /* mailbox                  */
ER ercd = td_ref_mtx ( ID mtxid, TD_RMTX *rmtx );   /* mutex                    */
ER ercd = td_ref_mbf ( ID mbfid, TD_RMBF *rmbf );   /* message buffer           */
ER ercd = td_ref_por ( ID porid, TD_RPOR *rpor );   /* rendezvous port          */
ER ercd = td_ref_mpf ( ID mpfid, TD_RMPF *rmpf );   /* fixed-size memory pool   */
ER ercd = td_ref_mpl ( ID mplid, TD_RMPL *rmpl );   /* variable-size memory pool */
ER ercd = td_ref_cyc ( ID cycid, TD_RCYC *rcyc );   /* cyclic handler           */
ER ercd = td_ref_alm ( ID almid, TD_RALM *ralm );   /* alarm handler            */
ER ercd = td_ref_ssy ( ID  ssid, TD_RSSY *rssy );   /* subsystem                */
```

[**Parameters**]

ID	—id	Object ID
TD_R—	r—	Address of status information packet

[**Return Parameters**]

ER ercd Error code

[**Error Codes**]

E_OK	Normal completion
E_ID	Bad identifier
E_NOEXS	Object does not exist

[**Description**]

Gets the status of an object. This is similar to tk_ref_—. The return packets are defined as follows.

```
/*
*Semaphore status information   td_ref_sem
*/
typedef struct td_rsem {
        VP      exinf;      /* extended information    */
        ID      wtsk;       /* waiting task ID         */
        INT     semcnt;     /* current semaphore count */
} TD_RSEM;
```



```
/*
 *Event flag status information  td_ref_flg
 */
typedef struct td_rflg {
        VP      exinf;      /* extended information       */
        ID      wtsk;       /* waiting task ID            */
        UINT    flgptn;     /* current event flag pattern */
} TD_RFLG;

/*
 *Mailbox status information td_ref_mbx
 */
typedef struct td_rmbx {
VP   exinf; /* extended information */
        ID      wtsk;       /* waiting task ID             */
        T_MSG   *pk_msg;    /* next message to be received */
} TD_RMBX;

/*
 *Mutex status information   td_ref_mtx
 */
typedef struct td_rmtx {
        VP      exinf;      /* extended information        */
        ID      bhtsk;      /* locking task ID             */
        ID      wtsk;       /* ID of task waiting for lock */
} TD_RMTX;

/*
 * Message buffer status information td_ref_mbf
 */
typedef struct td_rmbf {
        VP       exinf;     /* extended information                          */
        ID      wtsk;       /* receive waiting task ID                       */
        ID      stsk;       /* send waiting task ID                          */
        INT     msgsz;      /* size (in bytes) of next message to be received */
        INT     frbufsz;    /* free buffer size (in bytes)                   */
        INT     maxmsz;     /* maximum message length (in bytes)             */
} TD_RMBF;

/*
 *Rendezvous port status information td_ref_por
 */
typedef struct td_rpor {
        VP      exinf;      /* extended information                    */
        ID      wtsk;       /* call waiting task ID                    */
        ID      atsk;       /* acceptance waiting task ID              */
        INT     maxcmsz;    /* call message maximum length (in bytes)  */
        INT     maxrmsz;    /* accept message maximum length (in bytes) */
} TD_RPOR;
```



```
/*
 *Fixed-size memory pool status information  td_ref_mpf
 */
typedef struct td_rmpf {
        VP      exinf;      /* extended information */
        ID      wtsk;       /* waiting task ID      */
        INT     frbcnt;     /* free block count     */
} TD_RMPF;

/*
 *Variable-size memory pool status information    td_ref_mpl
 */
typedef struct td_rmpl {
        VP      exinf;      /* extended information                    */
        ID      wtsk;       /* waiting task ID                         */
        INT     frsz;       /* total free space (in bytes)             */
        INT     maxsz;      /* maximum contiguous free space (in bytes) */
} TD_RMPL;

/*
 *Cyclic handler status information  td_ref_cyc
 */
typedef struct td_rcyc {
        VP      exinf;      /* extended information                   */
        RELTIM  lfttim;     /* time remaining until next handler start */
        UINT    cycstat;    /* cyclic handler status                  */
} TD_RCYC;
]
/*
 *Alarm handler status information   td_ref_alm
 */
typedef struct td_ralm {
        VP      exinf;      /* extended information                   */
        RELTIM  lfttim;     /* time remaining until next handler start */
        UINT    almstat;    /* alarm handler status                   */
} TD_RALM;

/*
 *Subsystem status information   td_ref_ssy
 */
typedef struct td_rssy {
        PRI      ssypri;    /* subsystem priority                    */
        INT      resblksz;  /* resource control block size (in bytes) */
} TD_RSSY;
```


td_ref_tex

Reference Task Exception Status

[C Language Interface]

```
ER ercd = td_ref_tex ( ID tskid, TD_RTEX *pk_rtex );
```

[Parameters]

ID	tskid	Task ID (TSK_SELF can be designated)
TD_RTEX*	pk_rtex	Packet address for returning the task exception status

[Return Parameters]

ER	ercd	Error code

pk_rtex detail:

UINT	pendtex	Raised task exceptions
UINT	texmask	Allowed task exceptions

[Error Codes]

E_OK	Normal completion
E_ID	Bad identifier
E_NOEXS	Object does not exist

[Description]

Gets the task exception status. This is similar to tk_ref_tex.

td_inf_tsk

Reference Task Statistics

[C Language Interface]

```
ER ercd = td_inf_tsk ( ID tskid, TD_ITSK *pk_itsk, BOOL clr );
```

[Parameters]

ID	tskid	Task ID (TSK_SELF can be designated)
TD_ITSK*	pk_itsk	Packet address for returning task statistics
BOOL	clr	Task statistics clear flag

[Return Parameters]

ER	ercd	Error code

pk_itsk detail:

RELTIM	stime	Cumulative system-level run time (ms)
RELTIM	utime	Cumulative user-level run time (ms)

[Error Codes]

E_OK	Normal completion
E_ID	ID number is invalid
E_NOEXS	Object does not exist

[Description]

Gets task statistics. This is similar to tk_inf_tsk. When clr = TRUE ($\neq 0$), accumulated information is reset (cleared to 0) after getting the statistics.

td_get_reg

Get Task Register

[C Language Interface]

```
ER ercd = td_get_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs ) ;
```

[Parameters]

ID	tskid	Task ID (TSK_SELF cannot be designated)

[Return Parameters]

T_REGS	pk_regs	General register
T_EIT	pk_eit	Registers saved when exception is raised
T_CREGS	pk_cregs	Control register
ER	ercd	Error code

The contents of T_REGS, T_EIT, and T_CREGS are defined for each CPU and implementation.

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (issued for current RUN state task)

[Description]

Gets the register values of the task designated in tskid. This is similar to tk_get_reg.
Registers cannot be referenced for the task currently in RUN state. Except when a task-independent portion is executing, the current RUN state task is the invoking task.
When NULL is designated for regs, eit, or cregs, the corresponding register is not referenced.
The contents of T_REGS, T_EIT, and T_CREGS are implementation-dependent.

td_set_reg

Set Task Register

[C Language Interface]

```
ER ercd = td_set_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs ) ;
```

[Parameters]

ID	tskid	Task ID (TSK_SELF cannot be designated)
T_REGS	pk_regs	General registers
T_EIT	pk_eit	Registers saved when exception is raised
T_CREGS	pk_cregs	Control registers

The contents of T_REGS, T_EIT, and T_CREGS are defined for each CPU and implementation.

[Return Parameters]

ER	ercd	Error code

[Error Codes]

E_OK	Normal completion
E_ID	Invalid ID number (tskid is invalid or cannot be used)
E_NOEXS	Object does not exist (the task designated in tskid does not exist)
E_OBJ	Invalid object state (issued for current RUN state task)

[Description]

Sets registers of the task designated in tskid. This is similar to tk_set_reg.
Registers cannot be set for the task currently in RUN state. Except when a task-independent portion is executing, the current RUN state task is the invoking task.
When NULL is designated for regs, eit, or cregs, the corresponding register is not set.
The contents of T_REGS, T_EIT, and T_CREGS are implementation-dependent.

td_ref_sys

Reference System Status

[C Language Interface]

```
ER ercd = td_ref_sys ( TD_RSYS *pk_rsys ) ;
```

[Parameters]

TD_RSYS*	pk_rsys	Packet address for returning status information

[Return Parameters]

ER	ercd	Error code

pk_rsys detail:

INT	sysstat	System status
ID	runtskid	ID of current RUN state task
ID	schedtskid	ID of task scheduled to go to RUN state

[Error Codes]

E_OK	Normal completion

[Description]

Gets the system status. This is similar to tk_ref_sys.

td_get_tim

Get System Time

[C Language Interface]

```
ER ercd = td_get_tim ( SYSTIM *tim, UNIT *ofs ) ;
```

[Parameters]

SYSTIM*	tim	Packet address for returning current time (ms)
UNIT*	ofs	Location for returning elapsed time from tim (nanoseconds)

[Return Parameters]

```
ER & ercd &  Error code
```

tim detail:

Current time (ms)

ofs detail:

Elapsed time from tim (nanoseconds)

[Error Codes]

E_OK	Normal completion

[Description]

Gets the current time as total elapsed milliseconds since 0:00:00 (GMT), January 1, 1985. The value returned in tim is the same as that obtained by tk_get_tim. tim is the resolution of time interrupt intervals (cycles), but even more precise time information is obtained in ofs as the elapsed time from tim in nanoseconds. The resolution of ofs is implementation-dependent, but generally is the timer hardware resolution.
Since tim is time counted based on timer interrupts, in some cases time is not refreshed, when a timer interrupt cycle arrives while interrupts are disabled and the timer interrupt handler is not started (is delayed). In such cases, the time as updated by the previous timer interrupt is returned in tim, and the elapsed time from the previous timer interrupt is returned in ofs. Accordingly, in some cases ofs will be a longer time than the timer interrupt cycle. The length of elapsed time that can be measured by ofs depends on the hardware, but preferably it should be able to measure at least up to twice the timer interrupt cycle ($0 \leq$ ofs $<$ twice the timer interrupt cycle).
Note that the time returned in tim and ofs is the time at some point between the calling of and return from td_get_tim. It is neither the time at which td_get_tim was called nor the time of return from td_get_tim. In order to obtain more accurate information, this function should be called in interrupts disabled state.

td_get_otm

Get System Operating Time

[C Language Interface]

```
ER ercd = td_get_otm ( SYSTIM *tim, UINT *ofs ) ;
```

[Parameters]

SYSTIM*	tim	Packet address for returning operating time (ms)
UINT*	ofs	Location for returning elapsed time from tim (nanoseconds)

[Return Parameters]

ER	ercd	Error code

tim detail:

Operating time (ms)

ofs detail:

Elapsed time from tim (nanoseconds))

[Error Codes]

E_OK	Normal completion

[Description]

Gets the system operating time (uptime, as elapsed milliseconds since the system was booted). The value returned in tim is the same as that obtained by tk_get_otm. tim is the resolution of time interrupt intervals (cycles), but even more precise time information is obtained in ofs as the elapsed time from tim in nanoseconds. The resolution of ofs is implementation-dependent, but generally is the timer hardware resolution.
Since tim is time counted based on timer interrupts, in some cases time is not refreshed, when a timer interrupt cycle arrives while interrupts are disabled and the timer interrupt handler is not started (is delayed). In such cases, the time as updated by the previous timer interrupt is returned in tim, and the elapsed time from the previous timer interrupt is returned in ofs. Accordingly, in some cases ofs will be a longer time than the timer interrupt cycle. The length of elapsed time that can be measured by ofs depends on the hardware, but preferably it should be able to measure at least up to twice the timer interrupt cycle ($0 \leq$ ofs $<$ twice the timer interrupt cycle).
Note that the time returned in tim and ofs is the time at some point between the calling of and return from td_get_otm. It is neither the time at which td_get_otm was called nor the time of return from td_get_otm. In order to obtain more accurate information, this function should be called in interrupts disabled state.

6.2 Trace Functions

These functions enable a debugger to trace program execution. Execution trace is performed by setting hook routines.

- Return from a hook routine must be made after states have returned to where they were when the hook routine was called. Restoring of registers, however, can be done in accord with the C language function saving rules.
- In a hook routine, limitations on states must not be modified to make them less restrictive than when the routine was called. For example, if the hook routine was called during interrupts disabled state, interrupts must not be enabled.
- A hook routine was called at protection level 0.
- A hook routine inherits the stack at the time of the hook. Too much stack use may therefore cause a stack overflow. The extent to which the stack can be used is not definite, since it differs with the situation at the time of the hook. Switching to a separate stack in the hook routine would be safer.

td_hoc_svc

Define System Call/Extended SVC Hook Routine

[**C Language Interface**]

```
ER ercd = td_hok_svc ( TD_HSVC *hsvc ) ;
```

[**Parameters**]

TD_HSVC	hsvc	Hook routine definition information

hsvc detail:

FP	enter	Hook routine before calling
FP	leave	Hook routine after calling

[**Return Parameters**]

ER	ercd	Error code

[**Description**]

Sets hook routines before and after the issuing of a system call or extended SVC. Setting NULL in hsvc cancels a hook routine.
The objects of a trace are T-Kernel/OS system calls (tk_—) and extended SVC. Depending on the implementation, generally tk_ret_int is not an object of a trace.
T-Kernel/DS service calls (td_—) are not objects of a trace.
A hook routine is called in the context from which the system call or extended SVC was called. For example, the invoking task in a hook routine is the same as the task that invoked the system call or extended SVC.
Since task dispatching and interrupts can occur inside system call processing, enter() and leave() are not necessarily called in succession as a pair in every case. If a system call is one that does not return, leave() will not be called.

```
VP enter( FN fncd, TD_CALINF *calinf, ... )
```

fncd	Function code < 0 System call ≥ 0 Extended SVC
calinf	Caller information
...	Parameters (variable number)
return code	Any value passed to leave()

```
typedef struct td_calinf {
```

As information for determining the address from which a system call or extended SVC was called, it is preferable to include information for performing a stack back-trace. The contents are implementation-dependent, but generally consist of register values such as stack pointer and program counter.


```
} TD_CALINF;
```
This is called right before a system call or extended SVC. The value passed in the return code is passed transparently to the corresponding `leave()`. This makes it possible to confirm the pairing of `enter()` and `leave()` calls or to pass any other information.

```
exinf = enter(fncd, &calinf, ... )
```

`ret =` system call or extended SVC execution

```
leave(fncd , ret, exinf)
```

- System call The parameters are the same as the system call parameters.

  Example:

  For system call `tk_wai_sem( ID semid, INT cnt, TMO tmout )`

  ```
  enter(TFN_WAI_SEM, &calinf, semid, cnt, tmout)
  ```

- Extended SVC The parameters are as in the packet passed to the extended SVC handler. fncd is likewise the same as that passed to the extended SVC handler.

  ```
  enter( FN fncd, TD\_CALINF *calinf, VP pk\_para )
  ```

  ```
  void leave( FN fncd, INT ret, VP exinf )
  ```

`fncd`	Function code
`ret`	Return code of the system call or extended SVC
`exinf`	Any value returned by `enter()`

  This is called right after returning from a system call or extended SVC.

  When a hook routine is set after a system call or extended SVC is called (while the system call or extended SVC is executing), in some cases `leave()` only may be called without calling `enter()`. In such a case NULL is passed in `exinf`. If, on the other hand, a hook routine is canceled after a system call or extended SVC is called, there may be cases when `enter()` is called but not `leave()`.

td_hoc_dsp

Define Task Dispatch Hook Routine

[**C Language Interface**]

```
ER ercd = td_hok_dsp ( TD_HDSP *hdsp ) ;
```

[**Parameters**]

TD_HDSP	hdsp	Hook routine definition information

hdsp detail:

FP	exec	Hook routine when execution starts
FP	stop	Hook routine when execution stops

[**Return Parameters**]

ER	ercd	Error code

[**Description**]

Sets hook routines in the task dispatcher. A hook routine is canceled by setting NULL in hdsp.
The hook routines are called in dispatch disabled state. The hook routines must not invoke T-Kernel/OS system calls (tk_—) or extended SVC. T-Kernel/DS service calls (td_—) may be invoked.

```
void exec( ID tskid, INT lsid )
```

tskid	Task ID of the started or resumed task
lsid	Logical ID of the task designated in tskid

This is called when the designated task starts execution or resumes. At the time exec() is called, the task designated in tskid is already in RUN state and logical space has been switched. However, execution of the tskid task program code occurs after the return from exec().

```
void stop( ID tskid, INT lsid, UINT tskstat )
```

tskid	Task ID of the executed or stopped task
lsid	Logical ID of the task designated in tskid
tskstat	State of the task designated in tskid

This is called when the designated task executes or stops. tskstat indicates the task state after stopping, as one of the following states.

TTS_RDY	READY state
TTS_WAI	WAIT state
TTS_SUS	SUSPEND state
TTS_WAS	WAIT-SUSPEND state
TTS_DM	TDORMANT state
0	NON-EXISTENT state

At the time stop() is called, the task designated in tskid has already entered the state indicated in tskstat. The logical space is indeterminate.

td_hoc_int

Define Interrupt Handler Hook Routine

[C Language Interface]

```
ER ercd = td_hok_int ( TD_HINT *hint ) ;
```

[Parameters]

TD_HINT	hint	Hook routine definition information

hint detail:

FP	enter	Hook routine before calling handler
FP	leave	Hook routine after calling handler

[Return Parameters]

ER	ercd	Error code

[Description]

Sets hook routines before and after an interrupt handler is called. Hook routine setting cannot be done independently for different exception or interrupt factors. One pair of hook routines is set in common for all exception and interrupt factors.
Setting hint to NULL cancels the hook routines.
The hook routines are called as task-independent portion (part of the interrupt handler). Accordingly, the hook routines can call only those system calls that can be invoked from a task-independent portion. Note that hook routines can be set only for interrupt handlers defined by tk_def_int with the TA_HLNG attribute. A TA_ASM attribute interrupt handler cannot be hooked by a hook routine. Hooking of a TA_ASM attribute interrupt handler is possible only by directly manipulating the exception/interrupt vector table. The actual methods are implementation-dependent.

```
void enter( UINT dintno )
void leave( UINT dintno )
```

dintno	Interrupt definition number

The parameters passed to enter() and leave() are the same as those passed to the exception/interrupt handler. Depending on the implementation, information other than dintno may also be passed. A hook routine is called as follows from a high-level language support routine.

```
enter(dintno);
inthdr(dintno); /* exception/interrupt handler */
leave(dintno);
```


`enter()` is called in interrupts disabled state, and interrupts must not be enabled. Since `leave()` assumes the status on return from `inthdr()`, the interrupts disabled or enabled status is indeterminate. `enter()` can obtain only the same information as that obtainable by `inthdr()`. Information that cannot be obtained by `inthdr()` cannot be obtained by `enter()`. The information that can be obtained by `enter()` and `inthdr()` is guaranteed by the specification to include dintno, but other information is implementation-dependent. Note that since interrupts disabled state and other states may change while `leave()` is running, `leave()` does not necessarily obtain the same information as that obtained by `enter()` or `inthdr()`.

Chapter 7

Reference

7.1 List of C Language Interface

7.1.1 T-Kernel/OS

Task Management Functions

```
ID tskid = tk_cre_tsk ( T_CTSK *pk_ctsk );
ER ercd = tk_del_tsk ( ID tskid );
ER ercd = tk_sta_tsk ( ID tskid, INT stacd );
void tk_ext_tsk ( );
void tk_exd_tsk ( );
ER ercd = tk_ter_tsk ( ID tskid );
ER ercd = tk_chg_pri ( ID tskid, PRI tskpri );
ER ercd = tk_chg_slt ( ID tskid, RELTIM slicetime );
ER ercd = tk_get_tsp ( ID tskid, T_TSKSPC *pk_tskspc );
ER ercd = tk_set_tsp ( ID tskid, T_TSKSPC *pk_tskspc );
ID resid = tk_get_rid ( ID tskid );
ID oldid = tk_set_rid ( ID tskid, ID resid );
ER ercd = tk_get_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs );
ER ercd = tk_set_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs );
ER ercd = tk_get_cpr ( ID tskid, INT copno, T_COPREGS *pk_copregs );
ER ercd = tk_set_cpr ( ID tskid, INT copno, T_COPREGS *pk_copregs );
ER ercd = tk_inf_tsk ( ID tskid, T_ITSK *pk_itsk, BOOL clr );
ER ercd = tk_ref_tsk ( ID tskid, T_RTSK *pk_rtsk );
```

Task-Dependent Synchronization Functions

```
ER ercd = tk_slp_tsk ( TMO tmout );
ER ercd = tk_wup_tsk ( ID tskid );
INT wupcnt = tk_can_wup ( ID tskid );
ER ercd = tk_rel_wai ( ID tskid );
ER ercd = tk_sus_tsk ( ID tskid );
ER ercd = tk_rsm_tsk ( ID tskid );
ER ercd =tk_frsm_tsk ( ID tskid );
ER ercd = tk_dly_tsk ( RELTIM dlytim );
ER ercd = tk_sig_tev ( ID tskid, INT tskevt );
```

```
INT tevptn = tk_wai_tev ( INT waiptn, TMO tmout );
INT tskwait = tk_dis_wai ( ID tskid, UINT waitmask );
ER ercd = tk_ena_wai ( ID tskid );
```

Task Exception Handling Functions

```
ER ercd = tk_def_tex ( ID tskid, T_DTEX *pk_dtex );
ER ercd = tk_ena_tex ( ID tskid, UINT texptn );
ER ercd = tk_dis_tex ( ID tskid, UINT texptn );
ER ercd = tk_ras_tex ( ID tskid, INT texcd );
INT texcd = tk_end_tex ( BOOL enatex );
ER ercd = tk_ref_tex ( ID tskid, T_RTEX *pk_rtex );
```

Synchronization and Management Functions

```
ID semid = tk_cre_sem ( T_CSEM *pk_csem );
ER ercd = tk_del_sem ( ID semid );
ER ercd = tk_sig_sem ( ID semid, INT cnt );
ER ercd = tk_wai_sem ( ID semid, INT cnt, TMO tmout );
ER ercd = tk_ref_sem ( ID semid, T_RSEM *pk_rsem );
ID flgid = tk_cre_flg ( T_CFLG *pk_cflg );
ER ercd = tk_del_flg ( ID flgid );
ER ercd = tk_set_flg ( ID flgid, UINT setptn );
ER ercd = tk_clr_flg ( ID flgid, UINT clrptn );
ER ercd = tk_wai_flg ( ID flgid, UINT waiptn, UINT wfmode, UINT *p_flgptn, TMO tmout );
ER ercd = tk_ref_flg ( ID flgid, T_RFLG *pk_rflg );
ID mbxid = tk_cre_mbx ( T_CMBX* pk_cmbx );
ER ercd = tk_del_mbx ( ID mbxid );
ER ercd = tk_snd_mbx ( ID mbxid, T_MSG *pk_msg );
ER ercd = tk_rcv_mbx ( ID mbxid, T_MSG **ppk_msg, TMO tmout );
ER ercd = tk_ref_mbx ( ID mbxid, T_RMBX *pk_rmbx );
```

Extended Synchronization and Communication Functions

```
ID mtxid = tk_cre_mtx ( T_CMTX *pk_cmtx );
ER ercd = tk_del_mtx ( ID mtxid );
ER ercd = tk_loc_mtx ( ID mtxid, TMO tmout );
ER ercd = tk_unl_mtx ( ID mtxid );
ER ercd = tk_ref_mtx ( ID mtxid, T_RMTX *pk_rmtx );
ID mbfid = tk_cre_mbf ( T_CMBF *pk_cmbf );
ER ercd = tk_del_mbf ( ID mbfid );
ER ercd = tk_snd_mbf ( ID mbfid, VP msg, INT msgsz, TMO tmout );
INT msgsz = tk_rcv_mbf ( ID mbfid, VP msg, TMO tmout );
ER ercd = tk_ref_mbf ( ID mbfid, T_RMBF *pk_rmbf );
ID porid = tk_cre_por ( T_CPOR *pk_cpor );
ER ercd = tk_del_por ( ID porid );
INT rmsgsz = tk_cal_por ( ID porid, UINT calptn, VP msg, INT cmsgsz, TMO tmout );
INT cmsgsz = tk_acp_por ( ID porid, UINT acpptn, RNO *p_rdvno, VP msg, TMO tmout );
ER ercd = tk_fwd_por ( ID porid, UINT calptn, RNO rdvno, VP msg, INT cmsgsz );
ER ercd = tk_rpl_rdv ( RNO rdvno, VP msg, INT rmsgsz );
ER ercd = tk_ref_por ( ID porid, T_RPOR *pk_rpor );
```


Memory Pool Management Functions

```
ID mpfid = tk_cre_mpf ( T_CMPF *pk_cmpf );
ER ercd = tk_del_mpf ( ID mpfid );
ER ercd = tk_get_mpf ( ID mpfid, VP *p_blf, TMO tmout );
ER ercd = tk_rel_mpf ( ID mpfid, VP blf );
ER ercd = tk_ref_mpf ( ID mpfid, T_RMPF *pk_rmpf );
ID mplid = tk_cre_mpl ( T_CMPL *pk_cmpl );
ER ercd = tk_del_mpl ( ID mplid );
ER ercd = tk_get_mpl ( ID mplid, W blksz, VP *p_blk, TMO tmout );
ER ercd = tk_rel_mpl ( ID mplid, VP blk );
ER ercd = tk_ref_mpl ( ID mplid, T_RMPL *pk_rmpl );
```

Time Management Functions

```
ER ercd = tk_set_tim ( SYSTIM *pk_tim );
ER ercd = tk_get_tim ( SYSTIM *pk_tim );
ER ercd = tk_get_otm ( SYSTIM *pk_tim );
ID cycid = tk_cre_cyc ( T_CCYC *pk_ccyc );
ER ercd = tk_del_cyc ( ID cycid );
ER ercd = tk_sta_cyc ( ID cycid );
ER ercd = tk_stp_cyc ( ID cycid );
ER ercd = tk_ref_cyc ( ID cycid, T_RCYC *pk_rcyc );
ID almid = tk_cre_alm ( T_CALM *pk_calm );
ER ercd = tk_del_alm ( ID almid );
ER ercd = tk_sta_alm ( ID almid, RELTIM almtim );
ER ercd = tk_stp_alm ( ID almid );
ER ercd = tk_ref_alm ( ID almid, T_RALM *pk_ralm );
```

Interrupt Management Functions

```
ER ercd = tk_def_int ( UINT dintno, T_DINT *pk_dint );
void tk_ret_int ( );
```

System Management Functions

```
ER ercd = tk_rot_rdq ( PRI tskpri );
ID tskid = tk_get_tid ( );
ER ercd = tk_dis_dsp ( );
ER ercd = tk_ena_dsp ( );
ER ercd = tk_ref_sys ( T_RSYS *pk_rsys );
ER ercd = tk_set_pow ( UINT powmode );
ER ercd = tk_ref_ver ( T_RVER *pk_rver );
```

Subsystem Management Functions

```
ER ercd = tk_def_ssy ( ID ssid, T_DSSY *pk_dssy );
ER ercd = tk_sta_ssy ( ID ssid, ID resid, INT info );
ER ercd = tk_cln_ssy ( ID ssid, ID resid, INT info );
ER ercd = tk_evt_ssy ( ID ssid, INT evttyp, ID resid, INT info );
ER ercd = tk_ref_ssy ( ID ssid, T_RSSY *pk_rssy );
```



```
ID resid = tk_cre_res ( );
ER ercd = tk_del_res ( ID resid );
ER ercd = tk_get_res ( ID resid, ID ssid, VP *p_resblk );
```

7.1.2 T-Kernel/SM

System Memory Management Functions

```
ER tk_get_smb( VP *addr, INT nblk, UINT attr );
ER tk_rel_smb( VP addr );
ER void* Vmalloc( size_t size );
Vcalloc( size_t nmemb, size_t size );
Vrealloc( void *ptr, size_t size );
void Vfree( void *ptr );
ER void* Kmalloc( size_t size );
Kcalloc( size_t nmemb, size_t size );
Krealloc( void *ptr, size_t size );
void Kfree( void *ptr );
```

Address Space Management Functions

```
ER SetTaskSpace( ID tskid );
ER ChkSpaceR( VP addr, INT len );
ER ChkSpaceRW( VP addr, INT len );
ER ChkSpaceRE( VP addr, INT len );
ChkSpaceBstrR( UB *str, INT max );
INT ChkSpaceBstrRW( UB *str, INT max );
INT ChkSpaceTstrR( TC *str, INT max );
INT ChkSpaceTstrRW( TC *str, INT max );
ER LockSpace( VP addr, INT len );
ER UnlockSpace( VP addr, INT len );
INT CnvPhysicalAddr( VP vaddr, INT len, VP *paddr );
```

Device Management Functions

```
ID tk_opn_dev( UB *devnm, UINT omode );
ER tk_cls_dev( ID dd, UINT option );
ID tk_rea_dev( ID dd, INT start, VP buf, INT size, TMO tmout );
ER tk_srea_dev( ID dd, INT start, VP buf, INT size, INT *asize );
ID tk_wri_dev( ID dd, INT start, VP buf, INT size, TMO tmout );
ER tk_swri_dev( ID dd, INT start, VP buf, INT size, INT *asize );
ID tk_wai_dev( ID dd, ID reqid, INT *asize, ER *ioer, TMO tmout );
INT tk_sus_dev( UINT mode );
ID tk_get_dev( ID devid, UB *devnm );
ID tk_ref_dev( UB *devnm, T_RDEV *rdev );
ID tk_oref_dev( ID dd, T_RDEV *rdev );
INT tk_lst_dev( T_LDEV *ldev, INT start, INT ndev );
INT tk_evt_dev( ID devid, INT evttyp, VP evtinf );
ID tk_def_dev( UB *devnm, T_DDEV *ddev, T_IDEV *idev );
ER tk_ref_idv( T_IDEV *idev );
```


Interrupt Management Functions

```
DI( UINT intsts );
EI( UINT intsts );
BOOL isDI( UINT intsts );
UINT DINTNO( INTVEC intvec );
void EnableInt( INTVEC intvec [, INT level] );
void DisableInt( INTVEC intvec );
void ClearInt( INTVEC intvec );
void EndOfInt( INTVEC intvec );
BOOL CheckInt( INTVEC intvec );
```

IO Port Access Support Functions

```
void out_w( INT port, UW data );
void out_h( INT port, UH data );
void out_b( INT port, UB data );
UW in_w( INT port );
UH in_h( INT port );
UB in_b( INT port );
void WaitUsec( UINT usec );
void WaitNsec( UINT nsec );
```

Power Management Functions

```
void low_pow( void );
void off_pow( void );
```

System Configuration Information Management Functions

```
INT tk_get_cfn( UB *name, INT *val, INT max );
INT tk_get_cfs( UB *name, UB *buf, INT max );
```

7.1.3 T-Kernel/DS

Kernel Internal State Acquisition Functions

```
INT ct = td_lst_tsk ( ID list[], INT nent );
INT ct = td_lst_sem ( ID list[], INT nent );
INT ct = td_lst_flg ( ID list[], INT nent );
INT ct = td_lst_mbx ( ID list[], INT nent );
INT ct = td_lst_mtx ( ID list[], INT nent );
INT ct = td_lst_mbf ( ID list[], INT nent );
INT ct = td_lst_por ( ID list[], INT nent );
INT ct = td_lst_mpf ( ID list[], INT nent );
INT ct = td_lst_mpl ( ID list[], INT nent );
INT ct = td_lst_cyc ( ID list[], INT nent );
INT ct = td_lst_alm ( ID list[], INT nent );
INT ct = td_lst_ssy ( ID list[], INT nent );
INT ct = td_rdy_que ( PRI pri, ID list[], INT nent );
INT ct = td_sem_que ( ID semid, ID list[], INT nent );
```



```
INT ct = td_flg_que ( ID flgid, ID list[], INT nent );
INT ct = td_mbx_que ( ID mbxid, ID list[], INT nent );
INT ct = td_mtx_que ( ID mtxid, ID list[], INT nent );
INT ct = td_smbf_que ( ID mbfid, ID list[], INT nent );
INT ct = td_rmbf_que ( ID mbfid, ID list[], INT nent );
INT ct = td_cal_que ( ID porid, ID list[], INT nent );
INT ct = td_acp_que ( ID porid, ID list[], INT nent );
INT ct = td_mpf_que ( ID mpfid, ID list[], INT nent );
INT ct = td_mpl_que ( ID mplid, ID list[], INT nent );
ER ercd = td_ref_tsk ( ID tskid, TD_RTSK *rtsk );
ER ercd = td_ref_sem ( ID semid, TD_RSEM *rsem );
ER ercd = td_ref_flg ( ID flgid, TD_RFLG *rflg );
ER ercd = td_ref_mbx ( ID mbxid, TD_RMBX *rmbx );
ER ercd = td_ref_mtx ( ID mtxid, TD_RMTX *rmtx );
ER ercd = td_ref_mbf ( ID mbfid, TD_RMBF *rmbf );
ER ercd = td_ref_por ( ID porid, TD_RPOR *rpor );
ER ercd = td_ref_mpf ( ID mpfid, TD_RMPF *rmpf );
ER ercd = td_ref_mpl ( ID mplid, TD_RMPL *rmpl );
ER ercd = td_ref_cyc ( ID cycid, TD_RCYC *rcyc );
ER ercd = td_ref_alm ( ID almid, TD_RALM *ralm );
ER ercd = td_ref_ssy ( ID  ssid, TD_RSSY *rssy );
ER ercd = td_ref_tex ( ID tskid, TD_RTEX *pk_rtex );
ER ercd = td_inf_tsk ( ID tskid, TD_ITSK *pk_itsk, BOOL clr );
ER ercd = td_get_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs );
ER ercd = td_set_reg ( ID tskid, T_REGS *pk_regs, T_EIT *pk_eit, T_CREGS *pk_cregs );
ER ercd = td_ref_sys ( TD_RSYS *pk_rsys );
ER ercd = td_get_tim ( SYSTIM *tim, UNIT *ofs );
ER ercd = td_get_otm ( SYSTIM *tim, UINT *ofs );
```

Trace Functions

```
ER ercd = td_hok_svc ( TD_HSVC *hsvc );
ER ercd = td_hok_dsp ( TD_HDSP *hdsp );
ER ercd = td_hok_int ( TD_HINT *hint );
```

7.2 List of Error Codes

Normal Completion Error Class (0)

E_OK	0	Normal completion

Internal Error Class (5 to 8)

E_SYS	ERCD(-5, 0)	System error

An error of unknown cause affecting the system as a whole.

E_NOCOP	ERCD(-6, 0)	The designated coprocessor cannot be used (not installed, or abnormal operation detected)

This error code is returned when the designated coprocessor is not installed in the currently running hardware, or abnormal coprocessor operation was detected.

Unsupported Error Class (9 to 16)

`E_NOSPT` `ERCD(-9, 0)` Unsupported function

When some system call functions are not supported and such a function was designated, error code `E_RSATR` or `E_NOSPTS` is returned. If `E_RSATR` does not apply, error code `E_NOSPT` is returned.

`E_RSFN` `ERCD(-10, 0)` Reserved function code number

This error code is returned when it is attempted to execute a system call designating a reserved function code (undefined function code), and also when it is attempted to execute an undefined extended SVC handler.

`E_RSATR` `ERCD(-11, 0)` Reserved attribute

This error code is returned when an undefined or unsupported object attribute is designated. Checking for this error may be omitted if system-dependent optimization is implemented.

Parameter Error Class (17 to 24)

`E_PAR` `ERCD(-17, 0)` Parameter error

Checking for this error may be omitted if system-dependent optimization is implemented.

`E_ID` `ERCD(-18, 0)` Invalid ID number

`E_ID` is an error that occurs only for objects having an ID number. Error code `E_PAR` is returned when a static error is detected such as designation of an out of range or reserved number for an interrupt definition number.

Call Context Error Class (25 to 32)

`E_CTX` `ERCD(-25, 0)` Context error

This error indicates that the designated system call cannot be issued in the current context (task portion/task-independent portion or handler RUN state).

This error must be issued whenever there is a meaningful context error in issuing a system call, such as calling from a task-independent portion a system call that may put the invoking task in WAIT state. Due to implementation limitations, there may be other system calls that when called from a given context (such as an interrupt handler) will cause this error to be returned.

`E_MACV` `ERCD(-26, 0)` Memory cannot be accessed; memory access privilege error

Error detection is implementation-dependent.

`E_OACV` `ERCD(-27, 0)` Object access privilege error

This error code is returned when a user task tries to manipulate a system object. The definition of system objects and error detection are implementation-dependent.

`E_ILUSE` `ERCD(-28, 0)` System call illegal use

Resource Constraint Error Class (33 to 40)

`E_NOMEM` `ERCD(-33, 0)` Insufficient memory

This error code is returned when there is insufficient memory (no memory) for allocating an object control block space, user stack space, memory pool space, message buffer space or the like.

`E_LIMIT` `ERCD(-34, 0)` System limit exceeded

This error code is returned when it is attempted to create more of an object than the system allows.

Object State Error Class (41 to 48)

`E_OBJ`	`ERCD(-41, 0)`	Invalid object state
`E_NOEXS`	`ERCD(-42, 0)`	Object does not exist
`E_QOVR`	`ERCD(-43, 0)`	Queuing or nesting overflow

Wait Error Class (49 to 56)

`E_RLWAI`	`ERCD(-49, 0)`	WAIT state released
`E_TMOUT`	`ERCD(-50, 0)`	Polling failed or timeout
`E_DLT`	`ERCD(-51, 0)`	The object being waited for was deleted
`E_DISWAI`	`ERCD(-52, 0)`	Wait released by wait disabled state

Device Error Class (57 to 64) (T-Kernel/SM)

`E_IO` `ERCD(-57, 0)` IO error

- Error information specific to individual devices may be defined in `E_IO` subcodes.

`E_NOMDA` `ERCD(-58, 0)` No media

Status Error Class (65 to 72) (T-Kernel/SM)

`E_BUSY`	`ERCD(-65, 0)`	Busy
`E_ABORT`	`ERCD(-66, 0)`	Processing was aborted
`E_RONLY`	`ERCD(-67, 0)`	Write protected

