REJ10J1025-0200Z

Everywhere you imagine. RENESAS

M3T-MR308/4 V.4.00

User's Manual

Real-time OS for M16C/70,80,M32C/80 Series

User's Manual

Rev.2.00
Nov 1, 2005

Renesas Technology
www.renesas.com

Keep safety first in your circuit designs!

- Renesas Technology Corporation and Renesas Solutions Corporation put the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage. Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of nonflammable material or (iii) prevention against any malfunction or mishap.

Notes regarding these materials

- These materials are intended as a reference to assist our customers in the selection of the Renesas Technology product best suited to the customer's application; they do not convey any license under any intellectual property rights, or any other rights, belonging to Renesas Technology Corporation, Renesas Solutions Corporation or a third party.
- Renesas Technology Corporation and Renesas Solutions Corporation assume no responsibility for any damage, or infringement of any third-party's rights, originating in the use of any product data, diagrams, charts, programs, algorithms, or circuit application examples contained in these materials.
- All information contained in these materials, including product data, diagrams, charts, programs and algorithms represents information on products at the time of publication of these materials, and are subject to change by Renesas Technology Corporation and Renesas Solutions Corporation without notice due to product improvements or other reasons. It is therefore recommended that customers contact Renesas Technology Corporation, Renesas Solutions Corporation or an authorized Renesas Technology product distributor for the latest product information before purchasing a product listed herein. The information described here may contain technical inaccuracies or typographical errors. Renesas Technology Corporation and Renesas Solutions Corporation assume no responsibility for any damage, liability, or other loss rising from these inaccuracies or errors. Please also pay attention to information published by Renesas Technology Corporation and Renesas Solutions Corporation by various means, including the Renesas home page (http://www.renesas.com).
- When using any or all of the information contained in these materials, including product data, diagrams, charts, programs, and algorithms, please be sure to evaluate all information as a total system before making a final decision on the applicability of the information and products. Renesas Technology Corporation and Renesas Solutions Corporation assume no responsibility for any damage, liability or other loss resulting from the information contained herein.
- Renesas Technology semiconductors are not designed or manufactured for use in a device or system that is used under circumstances in which human life is potentially at stake. Please contact Renesas Technology Corporation, Renesas Solutions Corporation or an authorized Renesas Technology product distributor when considering the use of a product contained herein for any specific purposes, such as apparatus or systems for transportation, vehicular, medical, aerospace, nuclear, or undersea repeater use.
- The prior written approval of Renesas Technology Corporation and Renesas Solutions Corporation is necessary to reprint or reproduce in whole or in part these materials.
- If these products or technologies are subject to the Japanese export control restrictions, they must be exported under a license from the Japanese government and cannot be imported into a country other than the approved destination. Any diversion or reexport contrary to the export control laws and regulations of Japan and/or the country of destination is prohibited.
- Please contact Renesas Technology Corporation or Renesas Solutions Corporation for further details on these materials or the products contained therein.

For inquiries about the contents of this document or product, fill in the text file the installer generates in the following directory and email to your local distributor.

\SUPPORT\Product-name\SUPPORT.TXT

Renesas Tools Homepage http://www.renesas.com/en/tools

Preface

The M3T-MR308/4(abbreviated as MR308) is a real-time operating system[1] for the M16C/70,80, M32C/80 series microcomputers. The MR308 conforms to the μITRON Specification.[2]
This manual describes the procedures and precautions to observe when you use the MR308 for programming purposes. For the detailed information on individual service call procedures, refer to the MR308 Reference Manual.

Requirements for MR308 Use

When creating programs based on the MR308, it is necessary to purchase the following product of Renesas.

- C-compiler package M3T-NC308WA(abbreviated as NC308) for M16C/70,80 M32C/80 series microcomputers

Document List

The following sets of documents are supplied with the MR308.

- Release Note
  Presents a software overview and describes the corrections to the Users Manual and Reference Manual.

- Users Manual (PDF file)
  Describes the procedures and precautions to observe when using the MR308 for programming purposes.

- Reference Manual (PDF file)
  Describes the MR308 service call procedures and typical usage examples.

  Please read the release note before reading this manual.

Right of Software Use

The right of software use conforms to the software license agreement. You can use the MR308 for your product development purposes only, and are not allowed to use it for the other purposes. You should also note that this manual does not guarantee or permit the exercise of the right of software use.

[1] Hereinafter abbreviated "real-time OS"
[2] μITRON4.0 Specification is the open real-time kernel specification upon which the TRON association decided
The specification document of μITRON4.0 specification can come to hand from a TRON association homepage (http://www.assoc.tron.org/).

Contents

List of Figures

List of Tables

Chapter 1　User's Manual Organization

The MR308 User's Manual consists of nine chapters and thee appendix.

- Chapter 2 General Information
  Outlines the objective of MR308 development and the function and position of the MR308.

- Chapter 3 Introduction to MR308
  Explains about the ideas involved in MR308 operations and defines some relevant terms.

- Chapter 4 Applications Development Procedure Overview
  Outlines the applications program development procedure for the MR308.

- Chapter 5 Detailed Applications
  Details the applications program development procedure for the MR308.

- Chapter 6 Using Configurator
  Describes the method for writing a configuration file and the method for using the configurator in detail.

- Chapter 7 Application Creation Guide
  Presents useful information and precautions concerning applications program development with MR308.

- Chapter 8 Sample Program Description
  Describes the MR308 sample applications program which is included in the product in the form of a source file.

- Chapter 9 Separate ROMs
  Explains about how to Form Separate ROMs.

Chapter 2 General Information

2.1 Objective of MR308 Development

In line with recent rapid technological advances in microcomputers, the functions of microcomputer-based products have become complicated. In addition, the microcomputer program size has increased. Further, as product development competition has been intensified, manufacturers are compelled to develop their microcomputer-based products within a short period of time.

In other words, engineers engaged in microcomputer software development are now required to develop larger-size programs within a shorter period of time. To meet such stringent requirements, it is necessary to take the following considerations into account.

1. **To enhance software recyclability to decrease the volume of software to be developed.**

   One way to provide for software recyclability is to divide software into a number of functional modules wherever possible. This may be accomplished by accumulating a number of general-purpose subroutines and other program segments and using them for program development. In this method, however, it is difficult to reuse programs that are dependent on time or timing. In reality, the greater part of application programs are dependent on time or timing. Therefore, the above recycling method is applicable to only a limited number of programs.

2. **To promote team programming so that a number of engineers are engaged in the development of one software package**

   There are various problems with team programming. One major problem is that debugging can be initiated only when all the software program segments created individually by team members are ready for debugging. It is essential that communication be properly maintained among the team members.

3. **To enhance software production efficiency so as to increase the volume of possible software development per engineer.**

   One way to achieve this target would be to educate engineers to raise their level of skill. Another way would be to make use of a structured descriptive assembler, C-compiler, or the like with a view toward facilitating programming. It is also possible to enhance debugging efficiency by promoting modular software development.

However, the conventional methods are not adequate for the purpose of solving the problems. Under these circumstances, it is necessary to introduce a new system named real-time OS [3]

To answer the above-mentioned demand, Renesas has developed a real-time operating system, tradenamed MR308, for use with the M16C/70, 80 and M32C/80 series of 16/32-bit microcomputers .

When the MR308 is introduced, the following advantages are offered.

4. **Software recycling is facilitated.**

   When the real-time OS is introduced, timing signals are furnished via the real-time OS so that programs dependent on timing can be reused. Further, as programs are divided into modules called tasks, structured programming will be spontaneously provided.

   That is, recyclable programs are automatically prepared.

5. **Ease of team programming is provided.**

   When the real-time OS is put to use, programs are divided into functional modules called tasks. Therefore, engineers can be allocated to individual tasks so that all steps from development to debugging can be conducted independently for each task.

   Further, the introduction of the real-time OS makes it easy to start debugging some already finished tasks even if the entire program is not completed yet. Since engineers can be allocated to individual tasks, work assignment is easy.

6. **Software independence is enhanced to provide ease of program debugging.**

   As the use of the real-time OS makes it possible to divide programs into small independent modules called tasks, the greater part of program debugging can be initiated simply by observing the small modules.

[3] OS:Operating System

7. Timer control is made easier.

To perform processing at 10 ms intervals, the microcomputer timer function was formerly used to periodically initiate an interrupt. However, as the number of usable microcomputer timers was limited, timer insufficiency was compensated for by, for instance, using one timer for a number of different processing operations.

When the real-time OS is introduced, however, it is possible to create programs for performing processing at fixed time intervals making use of the real-time OS time management function without paying special attention to the microcomputer timer function. At the same time, programming can also be done in such a manner as to let the programmer take that numerous timers are provided for the microcomputer.

8. Software maintainability is enhanced

When the real-time OS is put to use, the developed software consists of small program modules called tasks. Therefore, increased software maintainability is provided because developed software maintenance can be carried out simply by maintaining small tasks.

9. Increased software reliability is assured.

The introduction of the real-time OS makes it possible to carry out program evaluation and testing in the unit of a small module called task. This feature facilitates evaluation and testing and increases software reliability.

10. The microcomputer performance can be optimized to improve the performance of microcomputer-based products.

With the real-time OS, it is possible to decrease the number of unnecessary microcomputer operations such as I/O waiting. It means that the optimum capabilities can be obtained from microcomputers, and this will lead to microcomputer-based product performance improvement.

2.2 Relationship between TRON Specification and MR308

The TRON Specification is an abbreviation for The Real-time Operating system Nucleus specification. It denotes the specifications for the nucleus of a real-time operating system. The TRON Project, which is centered on TRON Specification design, is pushed forward under the leadership of Dr. Ken Sakamura at University of Tokyo.

As one item of this TRON Project, the ITRON Specification is promoted. The ITRON Specification is an abbreviation for the Industrial TRON Specification. It denotes the real-time operating system that is designed with a view toward establishing industrial real-time operating systems.

The ITRON Specification provides a number of functions to properly meet the application requirements. In other words, ITRON systems require relatively large memory capacities and enhanced processing capabilities. The μITRON 2.0 Specification is the arranged version of the ITRON Specification for the higher processing speed, and incorporated only a minimum of functions necessary.

In 1993, μITRON 2.0 Specification and ITRON Specification were unified, which resulted in establishment of μITRON 3.0 Specification, with connecting functions added.

Furthermore, in 1999, μITRON 4.0 Specification[4] with enhanced compatibility was established.

MR308 is the real-time operating system developed for use with the M16C/70, 80 and M32C/80 series of 16/32-bit microcomputers compliant with μITRON 4.0 Specification. μITRON 4.0 Specification stipulates standard profiles as an attempt to ensure software portability. Of these standard profiles, MR308 has implemented in it all service calls except for static APIs and task exception APIs.

[4] μITRON 4.0 Specification is an open, real-time kernel specification set forth by the TRON Association.
The documented specification of μITRON 4.0 Specification can be obtained from the Web site of the TRON Association (http://www.assoc.tron.org/).

2.3 MR308 Features

The MR308 offers the following features.

1. **Real-time operating system conforming to the μITORN Specification.**

   The MR308 is designed in compliance with the μITRON Specification which incorporates a minimum of the ITRON Specification functions so that such functions can be incorporated into a one-chip microcomputer. As the μITRON Specification is a subset of the ITRON Specification, most of the knowledge obtained from published ITRON textbooks and ITRON seminars can be used as is.

   Further, the application programs developed using the real-time operating systems conforming to the ITRON Specification can be transferred to the MR308 with comparative ease.

2. **High-speed processing is achieved.**

   MR308 enables high-speed processing by taking full advantage of the microcomputer architecture.

3. **Only necessary modules are automatically selected to constantly build up a system of the minimum size.**

   MR308 is supplied in the object library format of the M16C/70, 80 and M32C/80 series.

   Therefore, the Linkage Editor LN308 functions are activated so that only necessary modules are automatically selected from numerous MR308 functional modules to generate a system.

   Thanks to this feature, a system of the minimum size is automatically generated at all times.

4. **With the C-compiler NC308WA, it is possible to develop application programs in C language.**

   Application programs of MR308 can be developed in C language by using the C compiler NC308WA. Furthermore, the interface library necessary to call the MR308 functions from C language is included with the software package.

5. **An upstream process tool named "Configurator" is provided to simplify development procedures**

   A configurator is furnished so that various items including a ROM write form file can be created by giving simple definitions.

   Therefore, there is no particular need to care what libraries must be linked.

   In addition, a GUI version of the configurator is available beginning with M3T-MR308 V.4.00. It helps the user to create a configuration file without the need to learn how to write it.

Chapter 3 Introduction to MR308

3.1 Concept of Real-time OS

This section explains the basic concept of real-time OS.

3.1.1 Why Real-time OS is Necessary

In line with the recent advances in semiconductor technologies, the single-chip microcomputer ROM capacity has increased. ROM capacity of 32K bytes.

As such large ROM capacity microcomputers are introduced, their program development is not easily carried out by conventional methods. Fig.3.1 shows the relationship between the program size and required development time (program development difficulty).

This figure is nothing more than a schematic diagram. However, it indicates that the development period increases exponentially with an increase in program size.

For example, the development of four 8K byte programs is easier than the development of one 32K byte program.[5]

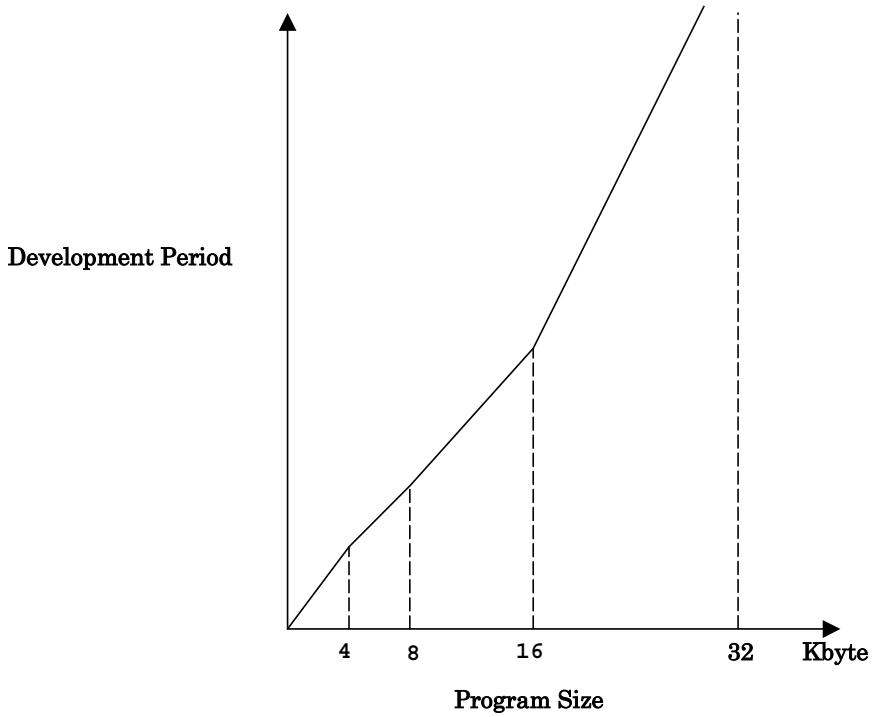


Figure 3.1 Relationship between Program Size and Development Period

Under these circumstances, it is necessary to adopt a method by which large-size programs can be developed within a short period of time. One way to achieve this purpose is to use a large number of microcomputers having a small ROM capacity. Figure 3.2 presents an example in which a number of microcomputers are used to build up an audio equipment system.

[5] On condition that the ROM program burning step need not be performed.

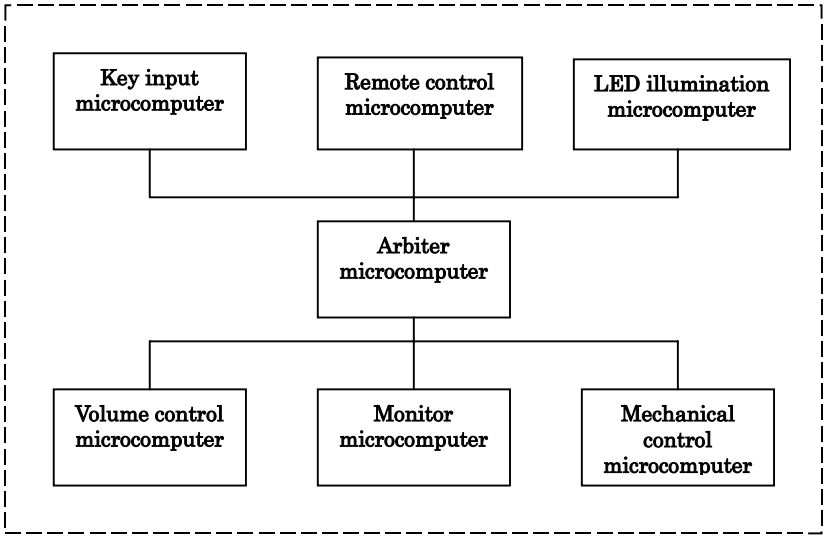


Figure 3.2 Microcomputer-based System Example(Audio Equipment)

Using independent microcomputers for various functions as indicated in the above example offers the following advantages.

1. **Individual programs are small so that program development is easy.**
2. **It is very easy to use previously developed software.**[6]
3. **Completely independent programs are provided for various functions so that program development can easily be conducted by a number of engineers.**

On the other hand, there are the following disadvantages.

1. **The number of parts used increases, thereby raising the product cost.**
2. **Hardware design is complicated.**
3. **Product physical size is enlarged.**

Therefore, if you employ the real-time OS in which a number of programs to be operated by a number of microcomputers are placed under software control of one microcomputer, making it appear that the programs run on separate microcomputers, you can obviate all the above disadvantages while retaining the above-mentioned advantages.

Figure 3.3 shows an example system that will be obtained if the real-time OS is incorporated in the system indicated in Figure 3.2.

[6] In the case presented in エラー! 参照元が見つかりません。 for instance, the remote control microcomputer can be used for other products without being modified.

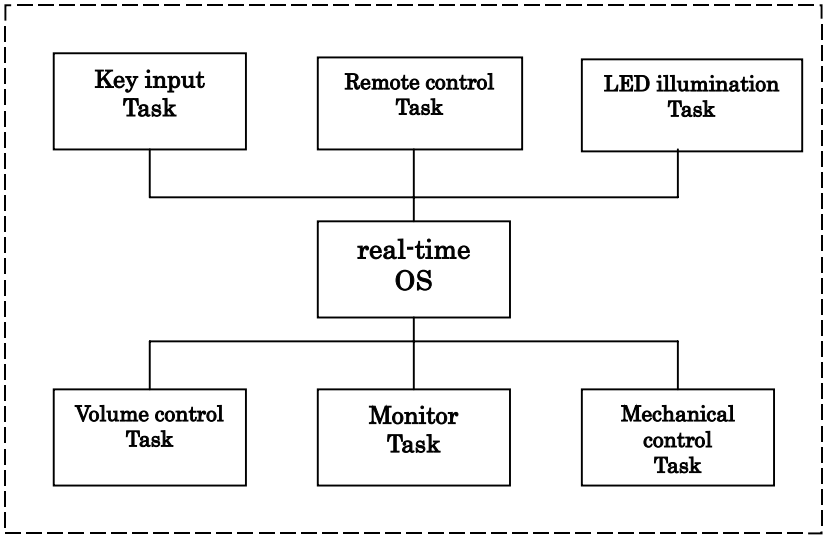


Figure 3.3 Example System Configuration with Real-time OS(Audio Equipment)

In other words, the real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers.

In the real-time OS, the individual programs, which correspond to a number of microcomputers used in a conventional system, are called tasks.

3.1.2 Operating Principles of Real-time OS

The real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers. You should be wondering how the real-time OS makes a one-microcomputer system function like a number of microcomputers.

As shown in Figure 3.4 the real-time OS runs a number of tasks according to the time-division system. That is, it changes the task to execute at fixed time intervals so that a number of tasks appear to be executed simultaneously.

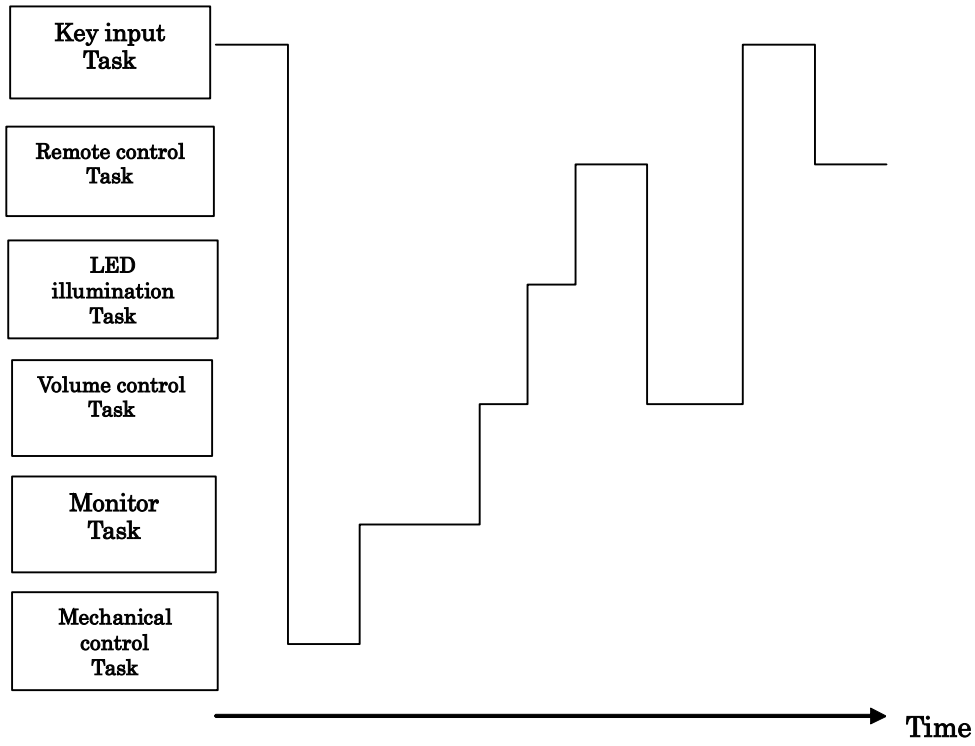


Figure 3.4 Time-division Task Operation

As indicated above, the real-time OS changes the task to execute at fixed time intervals. This task switching may also be referred to as dispatching (technical term specific to real-time operating systems). The factors causing task switching (dispatching) are as follows.

- Task switching occurs upon request from a task.
- Task switching occurs due to an external factor such as interrupt.

When a certain task is to be executed again upon task switching, the system resumes its execution at the point of last interruption (See Figure 3.5).

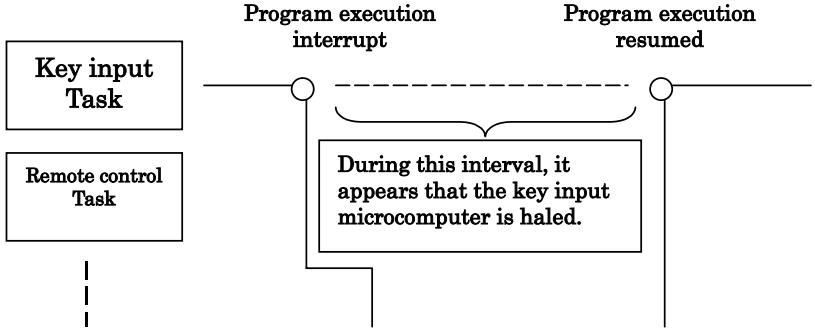


Figure 3.5 Task Execution Interruption and Resumption

In the state shown in Figure 3.5, it appears to the programmer that the key input task or its microcomputer is halted while another task assumes execution control.

Task execution restarts at the point of last interruption as the register contents prevailing at the time of the last interruption are recovered. In other words, task switching refers to the action performed to save the currently executed task register contents into the associated task management memory area and recover the register contents for the task to switch to.

To establish the real-time OS, therefore, it is only necessary to manage the register for each task and change the register contents upon each task switching so that it looks as if a number of microcomputers exist (See Figure 3.6).

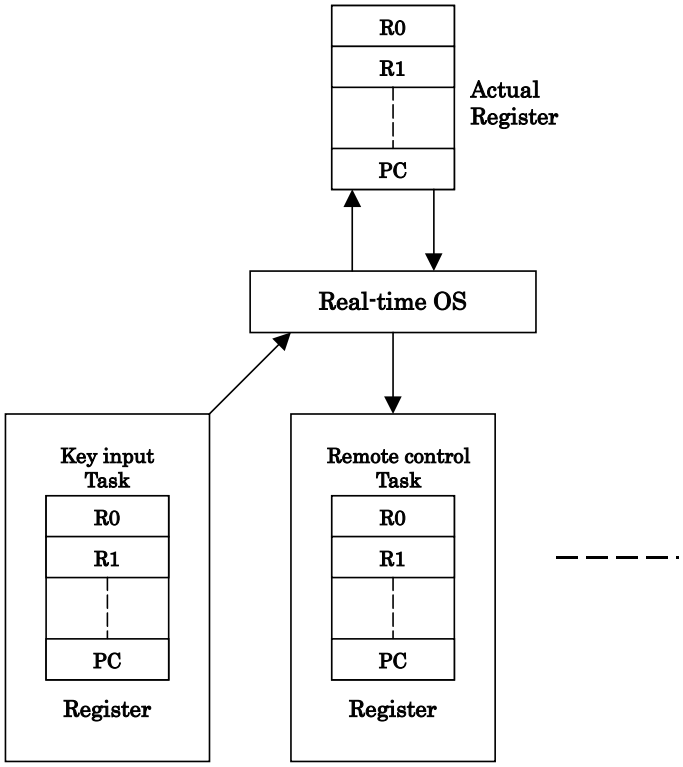


Figure 3.6 Task Switching

The example presented in Figure 3.7 [7] indicates how the individual task registers are managed. In reality, it is necessary to provide not only a register but also a stack area for each task.

[7] It is figure where all the stack areas of the task were arranged in the same section.

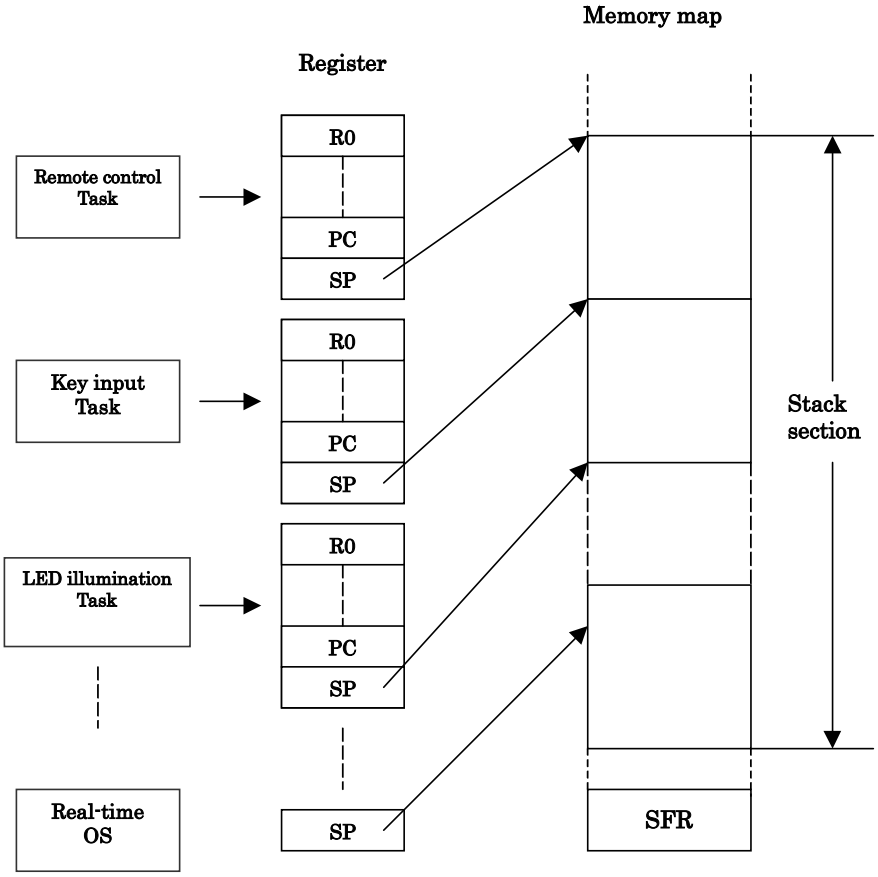


Figure 3.7 Task Register Area

Figure 3.8 shows the register and stack area of one task in detail. In the MR308, the register of each task is stored in a stack area as shown in Figure 3.8. This figure shows the state prevailing after register storage.

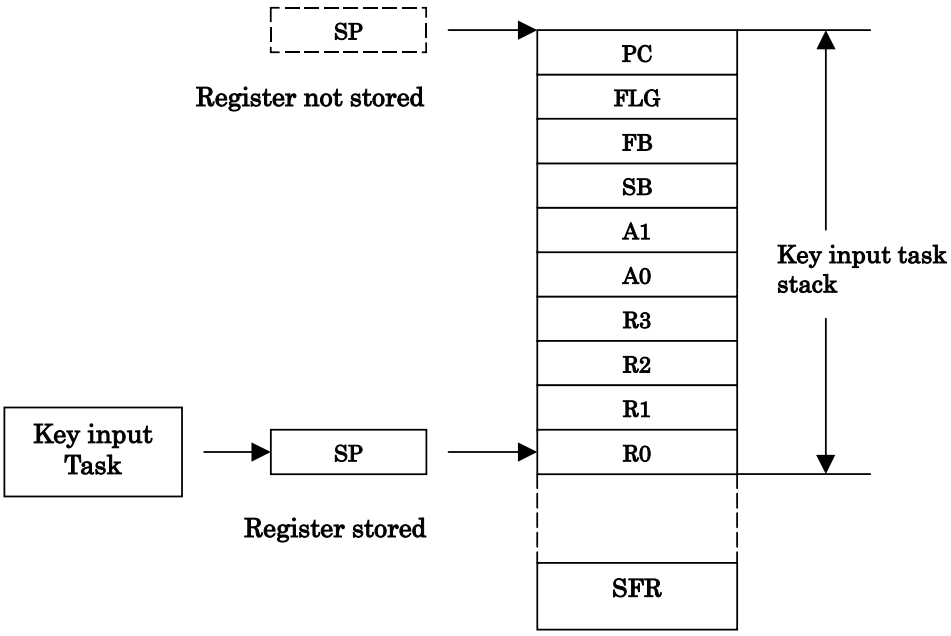


Figure 3.8 Actual Register and Stack Area Management

3.2 Service Call

How does the programmer use the real-time OS in a program?

First, it is necessary to call up a real-time OS function from the program in some way or other. Calling a real-time OS function is referred to as a service call. Task activation and other processing operations can be initiated by such a service call (See Figure 3.9).

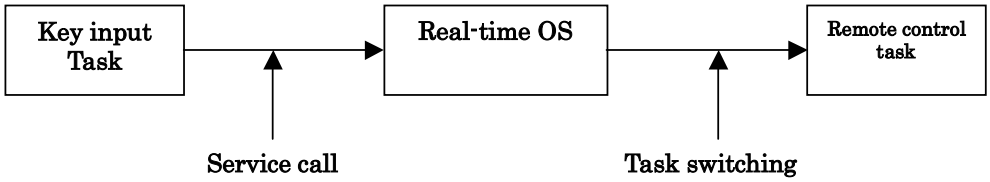


Figure 3.9 Service call

This service call is realized by a function call when the application program is written in C language, as shown below.

```
sta_tsk(ID_main,3);
```

Furthermore, if the application program is written in assembly language, it is realized by an assembler macro call, as shown below.

```
sta_tsk #ID_main,#3
```

3.2.1 Service Call Processing

When a service call is issued, processing takes place in the following sequence.[8]

1. **The current register contents are saved.**
2. **The stack pointer is changed from the task type to the real-time OS (system) type.**
3. **Processing is performed in compliance with the request made by the service call.**
4. **The task to be executed next is selected.**
5. **The stack pointer is changed to the task type.**
6. **The register contents are recovered to resume task execution.**

The flowchart in Figure 3.10 shows the process between service call generation and task switching.

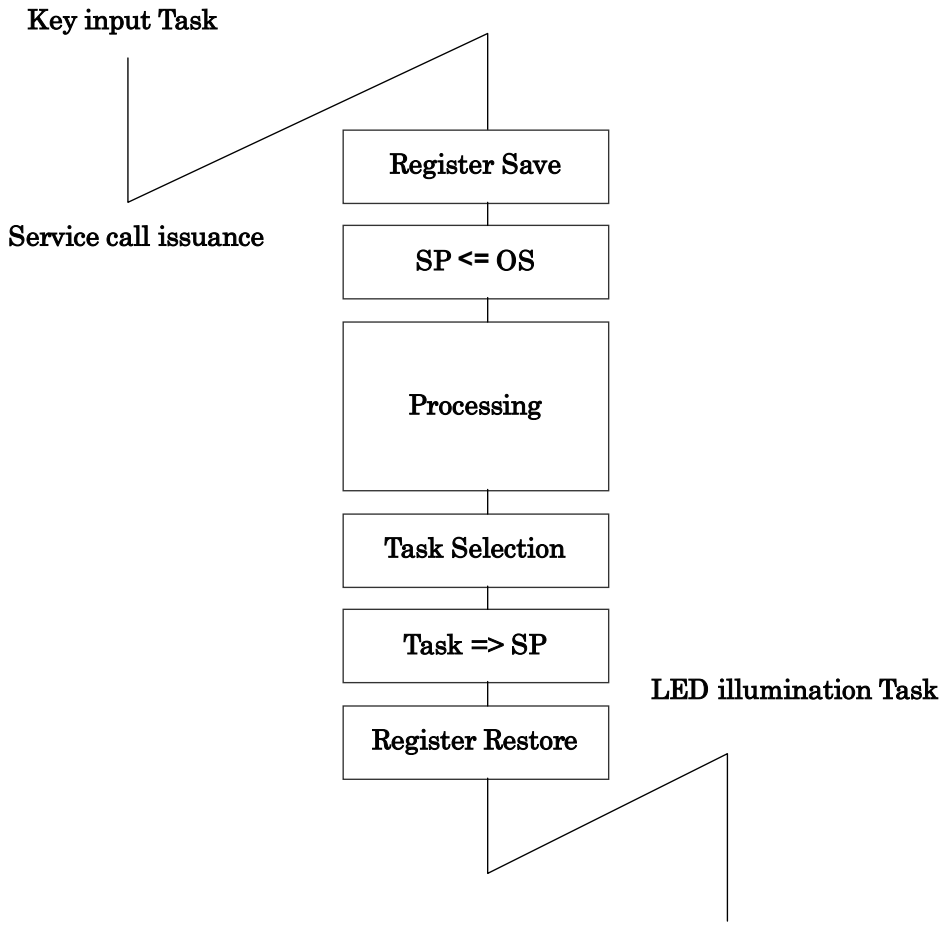


Figure 3.10 Service Call Processing Flowchart

[8] A different sequence is followed if the issued service call does not evoke task switching.

3.2.2 Task Designation in Service call

Each task is identified by the ID number internally in MR308.

For example, the system says, "Start the task having the task ID number 1."

However, if a task number is directly written in a program, the resultant program would be very low in readability. If, for instance, the following is entered in a program, the programmer is constantly required to know what the No. 2 task is.

```
sta_tsk(2,1);
```

Further, if this program is viewed by another person, he/she does not understand at a glance what the No. 2 task is. To avoid such inconvenience, the MR308 provides means of specifying the task by name (function or symbol name).

The program named "configurator cfg308 ,"which is supplied with the MR308, then automatically converts the task name to the task ID number. This task identification system is schematized in Figure 3.11.

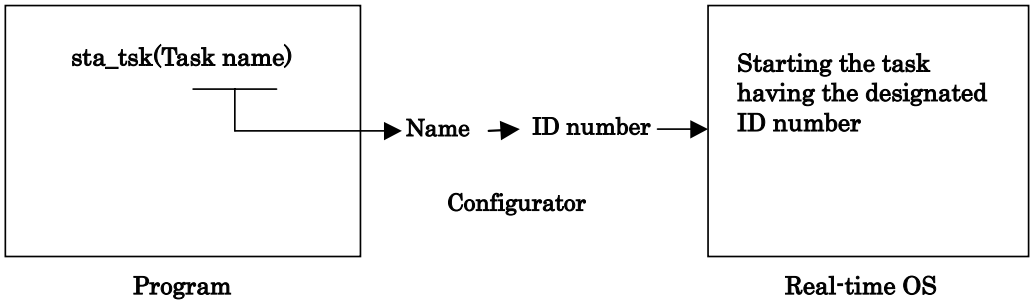


Figure 3.11 Task Identification

```
sta_tsk(ID_task,1);
```

This example specifies that a task corresponding to "ID_task" be invoked.

It should also be noted that task name-to-ID number conversion is effected at the time of program generation. Therefore, the processing speed does not decrease due to this conversion feature.

3.3 Task

This section describes how tasks are managed by MR308.

3.3.1 Task Status

The real-time OS monitors the task status to determine whether or not to execute the tasks.

Figure 3.12 shows the relationship between key input task execution control and task status. When there is a key input, the key input task must be executed. That is, the key input task is placed in the execution (RUNNING) state. While the system waits for key input, task execution is not needed. In that situation, the key input task in the WAITING state.

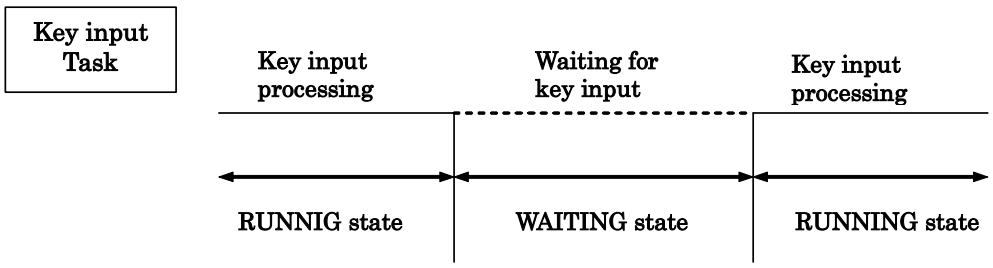


Figure 3.12 Task Status

The MR308 controls the following six different states including the RUNNING and WAITING states.

1. **RUNNING state**
2. **READY state**
3. **WAITING state**
4. **SUSPENDED state**
5. **WAITING-SUSPENDED state**
6. **DORMANT state**

Every task is in one of the above six different states. Figure 3.13 shows task status transition.

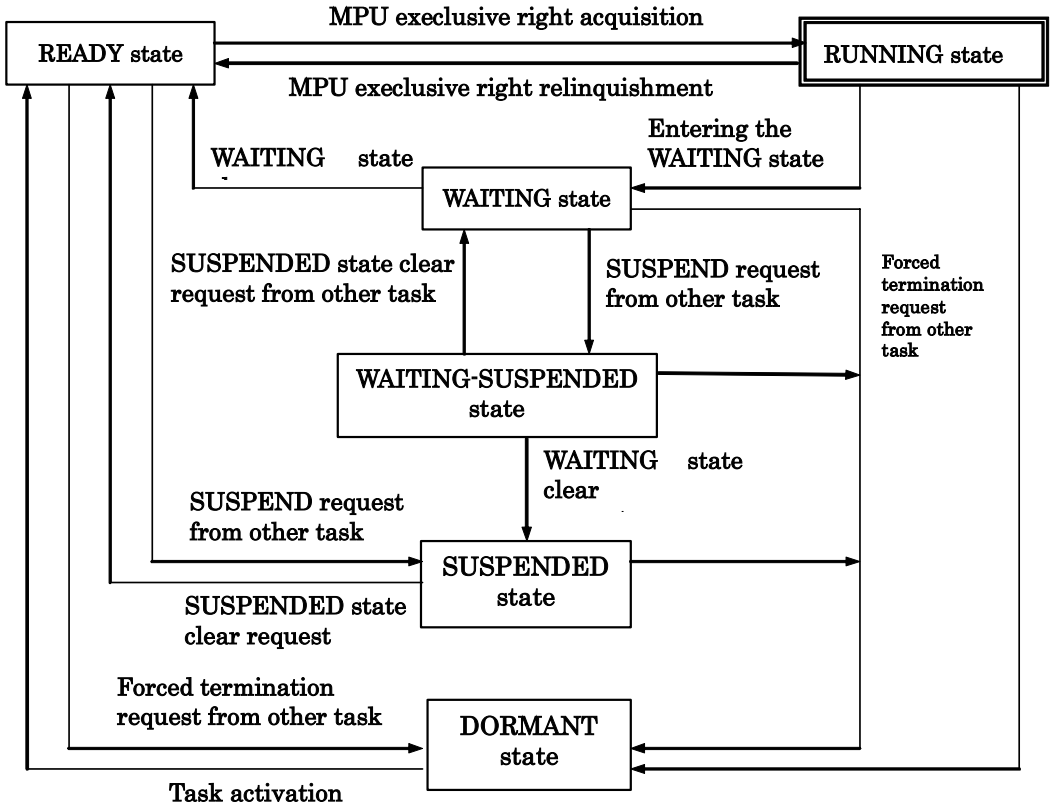


Figure 3.13 MR308 Task Status Transition

1. RUNNING state

In this state, the task is being executed. Since only one microcomputer is used, it is natural that only one task is being executed.

The currently executed task changes into a different state when any of the following conditions occurs.

- The task has normally terminated itself.[9]
- The task has placed itself in the WAITING state.[10]
- Due to interruption or other event occurrence, the interrupt handler has placed a different task having a higher priority in the READY state.
- The priority assigned to the task has been changed so that the priority of another READY task is rendered higher.[11]
- Due to interruption or other event occurrence, the priority of the task or a different READY task has been changed so that the priority of the different task is rendered higher.[12]
- When the ready queue of the issuing task priority is rotated by the rot_rdq or irot_rdq service call and control of execution is thereby abandoned

When any of the above conditions occurs, rescheduling takes place so that the task having the highest priority among those in the RUNNING or READY state is placed in the RUNNING state, and the execution of that task starts.

2. READY state

The READY state refers to the situation in which the task that meets the task execution conditions is still waiting for execution because a different task having a higher priority is currently being executed.

When any of the following conditions occurs, the READY task that can be executed second according

[9] Depends on the ext_tsk service call.
[10] Depends on the dly_tsk, slp_tsk, tslp_tsk, wai_flg, twai_flg, wai_sem, twai_sem, rcv_mbx, trcv_mbx,snd_dtq,tsnd_dtq,rcv_dtq, trcv_dtq, vtsnd_dtq, vsnd_dtq,vtrcv_dtq,tget_mpf, get_mpf or vrcv_dtq service call.
[11] Depends on the chg_pri service call.
[12] Depends on the ichg_pri service call.

to the ready queue [13] is placed in the RUNNING state.

- A currently executed task has normally terminated itself.[14]
- A currently executed task has placed itself in the WAITING state.[15]
- A currently executed task has changed its own priority so that the priority of a different READY task is rendered higher.[16]
- Due to interruption or other event occurrence, the priority of a currently executed task has been changed so that the priority of a different READY task is rendered higher.[17]
- When the ready queue of the issuing task priority is rotated by the rot_rdq or irot_rdq service call and control of execution is thereby abandoned

3. WAITING state

When a task in the RUNNING state requests to be placed in the WAITING state, it exits the RUNNING state and enters the WAITING state. The WAITING state is usually used as the condition in which the completion of I/O device I/O operation or the processing of some other task is awaited.

The task goes into the WAITING state in one of the following ways.

- The task enters the WAITING state simply when the slp_tsk service call is issued. In this case, the task does not go into the READY state until its WAITING state is cleared explicitly by some other task.
- The task enters and remains in the WAITING state for a specified time period when the dly_tsk service call is issued. In this case, the task goes into the READY state when the specified time has elapsed or its WAITING state is cleared explicitly by some other task.
- The task is placed into WAITING state for a wait request by the wai_flg, wai_sem, rcv_mbx, snd_dtq, rcv_dtq, vsnd_dtq, vrcv_dtq, or get_mpf service call. In this case, the task goes from WAITING state to READY state when the request is met or WAITING state is explicitly canceled by another task.
- The tslp_tsk, twai_flg, twai_sem, trcv_mbx, tsnd_dtq, trcv_dtq, vtsnd_dtq, vtrcv_dtq, and tget_mpf service calls are the timeout-specified versions of the slp_tsk, wai_flg, wai_sem, rcv_mbx, snd_dtq, rcv_dtq, vsnd_dtq, vrcv_dtq, and get_mpf service calls. The task is placed into WAITING state for a wait request by one of these service calls. In this case, the task goes from WAITING state to READY state when the request is met or the specified time has elapsed.
- If the task is placed into WAITING state for a wait request by the wai_flg, wai_sem, rcv_mbx, snd_dtq, rcv_dtq, vsnd_dtq, vrcv_dtq, get_mpf, twai_flg, twai_sem, trcv_mbx, tsnd_dtq, trcv_dtq, vtsnd_dtq, vtrcv_dtq, or tget_mpf service call[18], the task is queued to one of the following waiting queues depending on the request.

- **Event flag waiting queue**
- **Semaphore waiting queue**
- **Mailbox message reception waiting queue**
- **Data queue data transmission waiting queue**
- **Data queue data reception waiting queue**
- **Short data queue data transmission waiting queue**
- **Short data queue data reception waiting queue**
- **Fixed-size memory pool acquisition waiting queue**

[13] For the information on the ready queue,see the next chapter.
[14] Depends on the ext_tsk service call.
[15] Depends on the dly_tsk, slp_tsk, tslp_tsk, wai_flg, twai_flg, wai_sem, twai_sem, rcv_mbx, trcv_mbx,snd_dtq,tsnd_dtq,rcv_dtq, trcv_dtq, vtsnd_dtq, vsnd_dtq,vtrcv_dtq,tget_mpf, get_mpf or vrcv_dtq service call.
[16] Depends on the chg_pri service call.
[17] Depends on the ichg_pri service call.
[18] The service call twai_flg, twai_sem, and trcv_msg are included.

4. SUSPENDED state

When the sus_tsk system call is issued from a task in the RUNNING state or the isus_tsk system call is issued from a handler, the READY task designated by the system call or the currently executed task enters the SUSPENDED state. If a task in the WAITING state is placed in this situation, it goes into the WAITING-SUSPENDED state.

The SUSPENDED state is the condition in which a READY task or currently executed task[19] is excluded from scheduling to halt processing due to I/O or other error occurrence. That is, when the suspend request is made to a READY task, that task is excluded from the execution queue.

Note that no queue is formed for the suspend request. Therefore, the suspend request can only be made to the tasks in the RUNNING, READY, or WAITING state.[20] If the suspend request is made to a task in the SUSPENDED state, an error code is returned.

5. WAITING-SUSPENDED

If a forcible wait request is issued to a task currently in a wait state, the task goes to a WAITING-SUSPENDED state. If a forcible wait request is issued to a task that has been placed into a wait state for a wait request by the slp_tsk, wai_flg, wai_sem, rcv_mbx, snd_dtq, rcv_dtq, vsnd_dtq, vrcv_dtq, get_mpf, tslp_tsk, twai_flg, twai_sem, trcv_mbx, tsnd_dtq, trcv_dtq, vtsnd_dtq, vtrcv_dtq, or tget_mpf service call, the task goes to a dual-wait state.

When the wait condition for a task in the WAITING-SUSPENDED state is cleared, that task goes into the SUSPENDED state. It is conceivable that the wait condition may be cleared, when any of the following conditions occurs.

- The task wakes up upon wup_tsk, or iwup_tsk service call issuance.
- The task placed in the WAITING state by the dly_tsk or tslp_tsk service call wakes up after the specified time elapse.
- The request of the task placed in the WAITING state by the wai_flg , wai_sem, rcv_mbx, snd_dtq, rcv_dtq, vsnd_dtq, vrcv_dtq, get_mpf, tslp_tsk, twai_flg, twai_sem, trcv_mbx, tsnd_dtq, trcv_dtq, vtsnd_dtq, vtrcv_dtq, or tget_mpf service call is fulfilled.
- The WAITING state is forcibly cleared by the rel_wai or irel_wai service call

When the SUSPENDED state clear request[21] is made to a task in the WAITING-SUSPENDED state, that task goes into the WAITING state. Since a task in the SUSPENDED state cannot request to be placed in the WAITING state, status change from SUSPENDED to WAITING-SUSPENDED does not possibly occur.

6. DORMANT

This state refers to the condition in which a task is registered in the MR308 system but not activated. This task state prevails when either of the following two conditions occurs.

- The task is waiting to be activated.
- The task is normally terminated[22] or forcibly terminated.[23]

[19] If the task under execution is placed into a forcible wait state by the isus_tsk service call from the handler, the task goes from an executing state directly to a forcible wait state. Please note that in only this case exceptionally, it is possible that a task will go from an executing state directly to a forcible wait state.
[20] If a forcible wait request is issued to a task currently in a wait state, the task goes to a dual-wait state.
[21] rsm_tsk or irsm_tsk service calls
[22] ext_tsk service call
[23] ter_tsk service call

3.3.2 Task Priority and Ready Queue

In the real-time OS, several tasks may simultaneously request to be executed. In such a case, it is necessary to determine which task the system should execute first. To properly handle this kind of situation, the system organizes the tasks into proper execution priority and starts execution with a task having the highest priority. To complete task execution quickly, tasks related to processing operations that need to be performed immediately should be given higher priorities.

The MR308 permits giving the same priority to several tasks. To provide proper control over the READY task execution order, the system generates a task execution queue called "ready queue." The ready queue structure is shown in Figure 3.14[24] The ready queue is provided and controlled for each priority level. The first task in the ready queue having the highest priority is placed in the RUNNING state.[25]

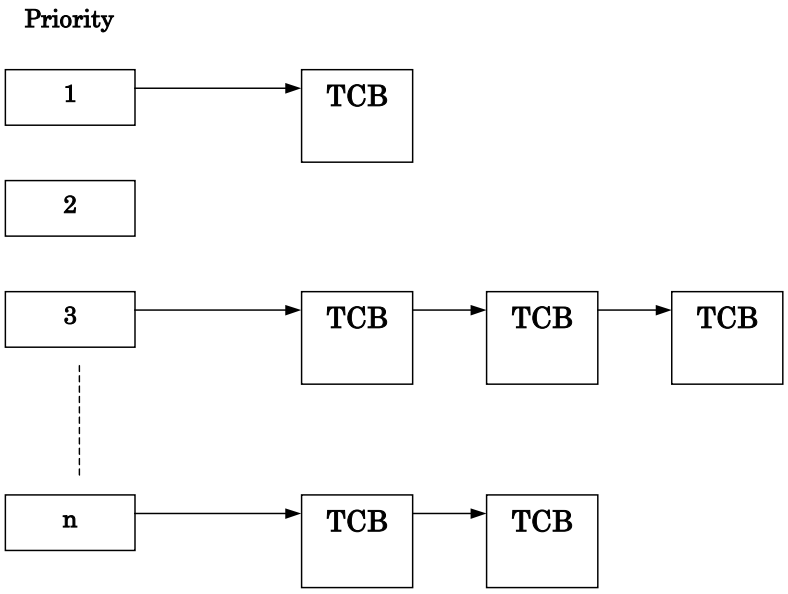


Figure 3.14 Ready Queue (Execution Queue)

[24] The TCB(task control block is described in the next chapter.)
[25] The task in the RUNNING state remains in the ready queue.

3.3.3 Task Priority and Waiting Queue

In The standard profiles in µITRON 4.0 Specification support two waiting methods for each object. In one method, tasks are placed in a waiting queue in order of priority (TA_TPRI attribute); in another, tasks are placed in a waiting queue in order of FIFO (TA_TFIFO).
Figure 3.15 and Figure 3.16 depict the manner in which tasks are placed in a waiting queue in order of "taskD," "taskC," "taskA," and "taskB."

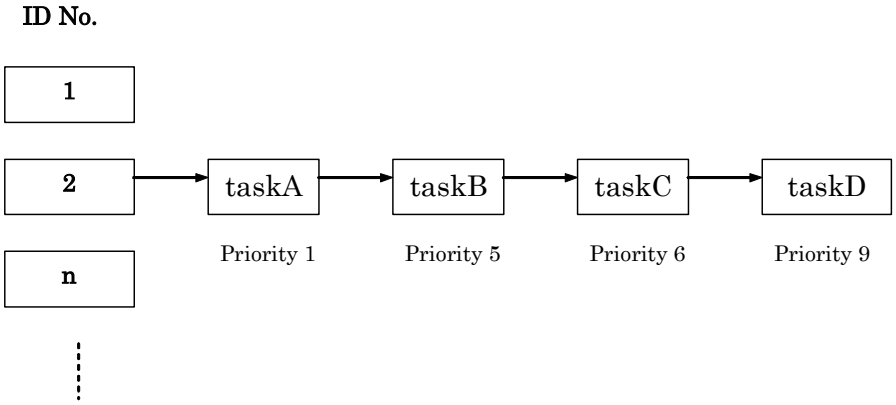


Figure 3.15 Waiting queue of the TA_TPRI attribute

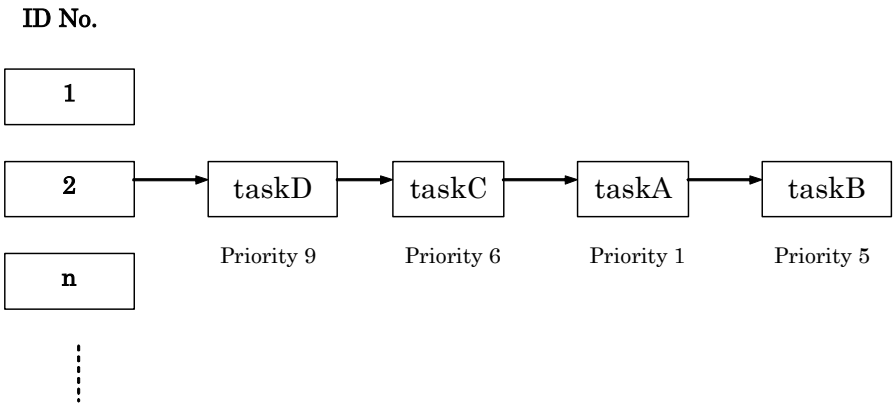


Figure 3.16 Waiting queue of the TA_TFIFO attribute

3.3.4 Task Control Block(TCB)

The task control block (TCB) refers to the data block that the real-time OS uses for individual task status, priority, and other control purposes.

The MR308 manages the following task information as the task control block

- Task connection pointer
  Task connection pointer used for ready queue formation or other purposes.
- Task status
- Task priority
- Task register information and other data[26] storage stack area pointer(current SP register value)
- Wake-up counter
  Task wake-up request storage area.
- Time-out counter or wait flag pattern
  When a task is in a time-out wait state, the remaining wait time is stored; if in a flag wait state, the flag's wait pattern is stored in this area.
- Flag wait mode
  This is a wait mode during eventflag wait.
- Timer queue connection pointer
  This area is used when using the timeout function. This area stores the task connection pointer used when constructing the timer queue.
- Flag wait pattern
  This area is used when using the timeout function.

  This area stores the flag wait pattern when using the eventflag wait service call with the timeout function (twai_flg). No flag wait pattern area is allocated when the eventflag is not used.
- Startup request counter
  This is the area in which task startup requests are accumulated.
- Extended task information
  Extended task information that was set during task generation is stored in this area.

The task control block is schematized in Figure 3.17.

[26] Called the task context

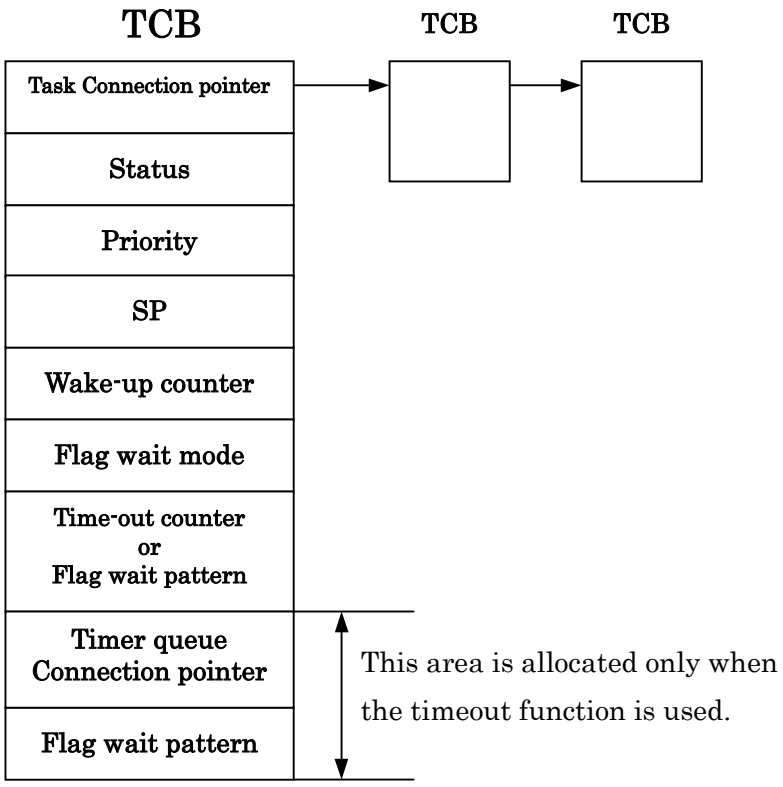


Figure 3.17 Task control block

3.4 System States

3.4.1 Task Context and Non-task Context

The system runs in either context state, "task context" or "non-task context." The differences between the task content and non-task context are shown in Table 3-1. Task Context and Non-task Context.

Table 3-1 Task Context and Non-task Context

	Task context	Non-task context
Invocable service call	Those that can be invoked from task context	Those that can be invoked from non-task context
Task scheduling	Occurs when the queue state has changed to other than dispatch disabled and CPU locked states.	It does not occur.
Stack	User stack	System stack

The processes executed in non-task context include the following.

1. Interrupt Handler

A program that starts upon hardware interruption is called the interrupt handler. The MR308 is not concerned in interrupt handler activation. Therefore, the interrupt handler entry address is to be directly written into the interrupt vector table.

There are two interrupt handlers: Non-kernel interrupts (OS independent interrupts) and kernel interrupts (OS dependent interrupts). For details about each type of interrupt, refer to Section 5.5.

The system clock interrupt handler (isig_tim) is one of these interrupt handlers.

2. Cyclic Handler

The cyclic handler is a program that is started cyclically every preset time. The set cyclic handler may be started or stopped by the sta_cyc(ista_cyc) or stp_cyc(istp_cyc) service call.

The cyclic handler startup time of day is unaffected by a change in the time of day by set_tim(iset_tim).

3. Alarm Handler

The alarm handler is a handler that is started after the lapse of a specified relative time of day. The alarm handler startup time of day is determined by a time of day relative to the time of day set by sta_alm(ista_alm), and is unaffected by a change in the time of day by set_tim(iset_tim).

The cyclic and alarm handlers are invoked by a subroutine call from the system clock interrupt (timer interrupt) handler. Therefore, cyclic and alarm handlers operate as part of the system clock interrupt handler. Note that when the cyclic or alarm handler is invoked, it is executed in the interrupt priority level of the system clock interrupt.

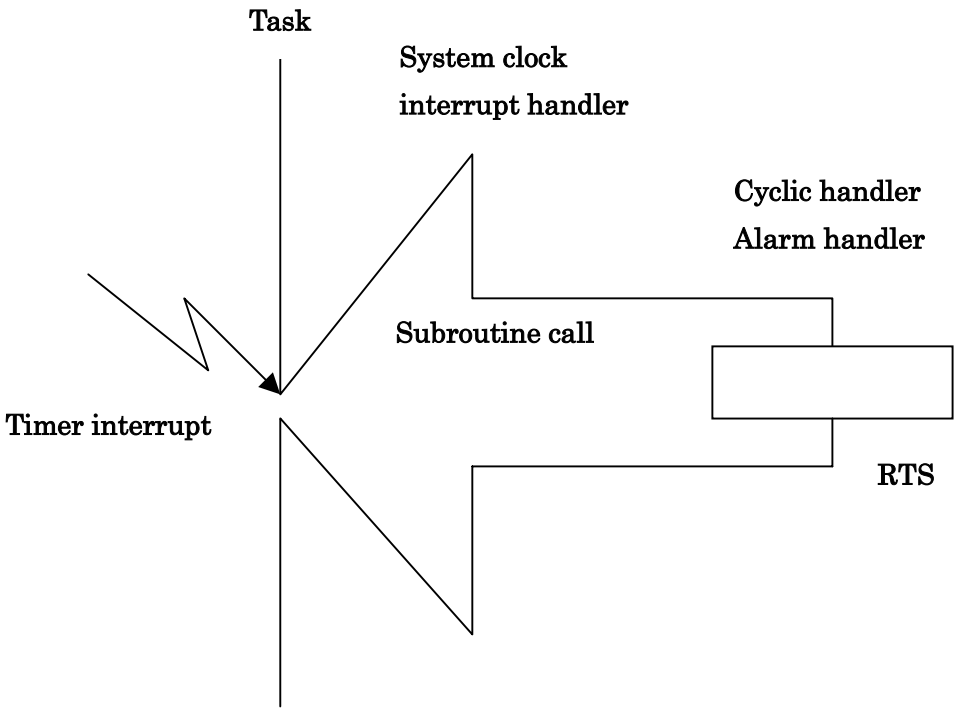


Figure 3.18 Cyclic Handler/Alarm Handler Activation

3.4.2 Dispatch Enabled/Disabled States

The system assumes either a dispatch enabled state or a dispatch disabled state. In a dispatch disabled state, no task scheduling is performed. Nor can service calls be invoked that may cause the service call issuing task to enter a wait state.[27]

The system can be placed into a dispatch disabled state or a dispatch enabled state by the dis_dsp or ena_dsp service call, respectively. Whether the system is in a dispatch disabled state can be known by the sns_dsp service call.

[27] If a service call not issuable is issued when dispatch disabled, MR308 doesn't return the error and doesn't guarantee the operation.

3.4.3 CPU Locked/Unlocked States

The system assumes either a CPU locked state or a CPU unlocked state. In a CPU locked state, all external interrupts are disabled against acceptance, and task scheduling is not performed either.

The system can be placed into a CPU locked state or a CPU unlocked state by the loc_cpu(iloc_cpu) or unl_cpu(iunl_cpu) service call, respectively. Whether the system is in a CPU locked state can be known by the sns_loc service call.

The service calls that can be issued from a CPU locked state are limited to those that are listed in Table 3-2.[28]

Table 3-2 Invocable Service Calls in a CPU Locked State

loc_cpu	iloc_cpu	unl_cpu	iunl_cpu
ext_tsk	exd_tsk	sns_tex	sns_ctx
sns_loc	sns_dsp	sns_dpn	

3.4.4 Dispatch Disabled and CPU Locked States

In µITRON 4.0 Specification, the dispatch disabled and the CPU locked states are clearly discriminated. Therefore, if the unl_cpu service call is issued in a dispatch disabled state, the dispatch disabled state remains intact and no task scheduling is performed. State transitions are summarized in Table 3-3.

Table 3-3 CPU Locked and Dispatch Disabled State Transitions Relating to dis_dsp and loc_cpu

State number	Content of state		dis_dsp executed	ena_dsp executed	loc_cpu executed	unl_cpu executed
	CPU locked state	Dispatch disabled state				
1	O	X	X	X	=> 1	=> 3
2	O	O	X	X	=> 2	=> 4
3	X	X	=> 4	=> 3	=> 1	=> 3
4	X	O	=> 4	=> 3	=> 2	=> 4

[28] MR308 does not return an error even when an uninvocable service call is issued from a CPU locked state, in which case, however, its operation cannot be guaranteed.

3.5 MR308 Kernel Structure

3.5.1 Module Structure

The MR308 kernel consists of the modules shown in Figure 3.19. Each of these modules is composed of functions that exercise individual module features.

The MR308 kernel is supplied in the form of a library, and only necessary features are linked at the time of system generation. More specifically, only the functions used are chosen from those which comprise these modules and linked by means of the Linkage Editor LN308. However, the scheduler module, part of the task management module, and part of the time management module are linked at all times because they are essential feature functions.

The applications program is a program created by the user. It consists of tasks, interrupt handler, alarm handler, and cyclic handler.[29]

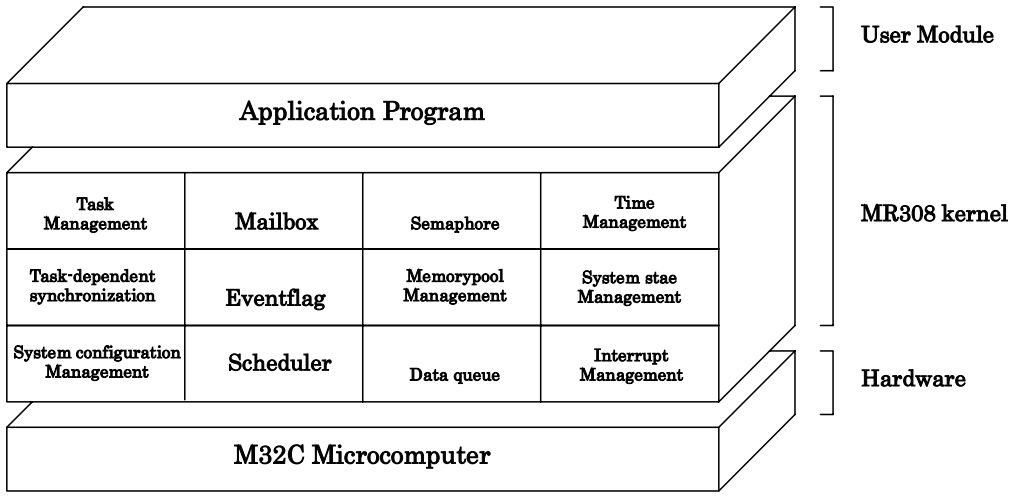


Figure 3.19 MR308 Structure

[29] For details, See 3.5.10.

3.5.2 Module Overview

The MR308 kernel modules are outlined below.

- **Scheduler**
  Forms a task processing queue based on task priority and controls operation so that the high-priority task at the beginning in that queue (task with small priority value) is executed.

- **Task Management Module**
  Exercises the management of various task states such as the RUNNING, READY, WAIT, and SUSPENDED state.

- **Task Synchronization Module**
  Accomplishes inter-task synchronization by changing the task status from a different task.

- **Interrupt Management Module**
  Makes a return from the interrupt handler.

- **Time Management Module**
  Sets up the system timer used by the MR308 kernel and starts the user-created alarm handler[30] and cyclic handler.[31].

- **System Status Management Module**
  Gets the system status of MR308.

- **System Configuration Management Module**
  Reports the MR308 kernel version number or other information.

- **Sync/Communication Module**
  This is the function for synchronization and communication among the tasks. The following three functional modules are offered.

  - Eventflag

    Checks whether the flag controlled within the MR308 is set up and then determines whether or not to initiate task execution. This results in accomplishing synchronization between tasks.

  - Semaphore

    Reads the semaphore counter value controlled within the MR308 and then determines whether or not to initiate task execution. This also results in accomplishing synchronization between tasks.

  - Mailbox

    Provides inter-task data communication by delivering the first data address.

  - Data queue

    Performs 32-bit data communication between tasks.

- **Memory pool Management Module**
  Provides dynamic allocation or release of a memory area used by a task or a handler.

- **Extended Function Module**
  Outside the scope of µITRON 4.0 Specification , this function performs reset processing on short data queues and objects.

[30] This handler actuates once only at preselected times.
[31] This handler periodically actuates.

3.5.3 Task Management Function

The task management function is used to perform task operations such as task start/stop and task priority updating. The MR308 kernel offers the following task management function service calls.

- Activate Task (act_tsk, iact_tsk)
  Activates the task, changing its status from DORMANT to either READY or RUNNING. In this service call, unlike in sta_tsk(ista_tsk), startup requests are accumulated, but startup code cannot be specified.

- Activate Task (sta_tsk, ista_tsk)
  Activates the task, changing its status from DORMANT to either READY or RUNNING. In this service call, unlike in act_tsk(iact_tsk), startup requests are not accumulated, but startup code can be specified.

- Terminate Invoking Task (ext_tsk)
  When the issuing task is terminated, its state changes to DORMANT state. The task is therefore not executed until it is restarted. If startup requests are accumulated, task startup processing is performed again. In that case, the issuing task behaves as if it were reset.

  If written in C language, this service call is automatically invoked at return from the task regardless of whether it is explicitly written when terminated.

- Terminate Task (ter_tsk)
  Other tasks in other than DORMANT state are forcibly terminated and placed into DORMANT state. If startup requests are accumulated, task startup processing is performed again. In that case, the issuing task behaves as if it were reset. (See Figure 3.20).

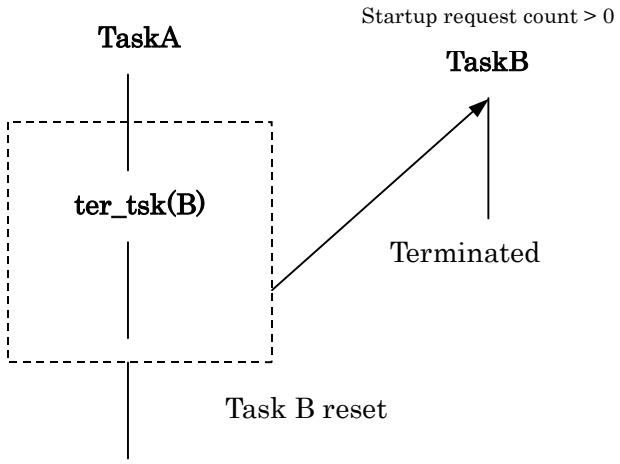
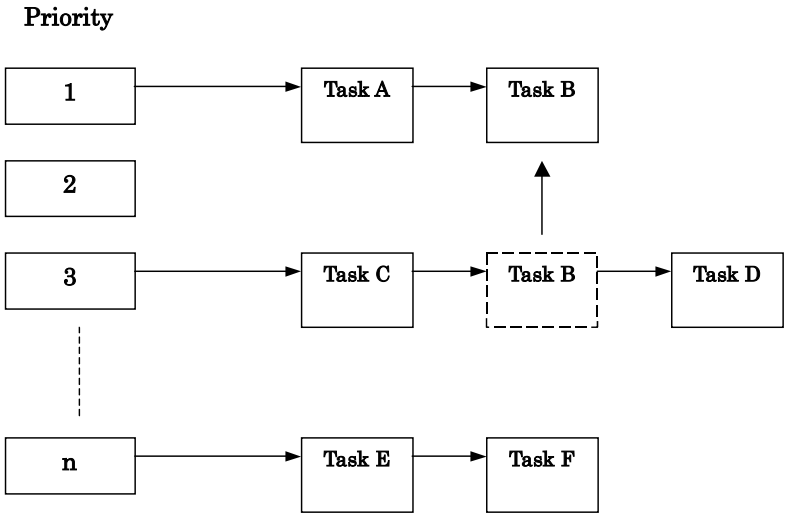


Figure 3.20 Task Resetting

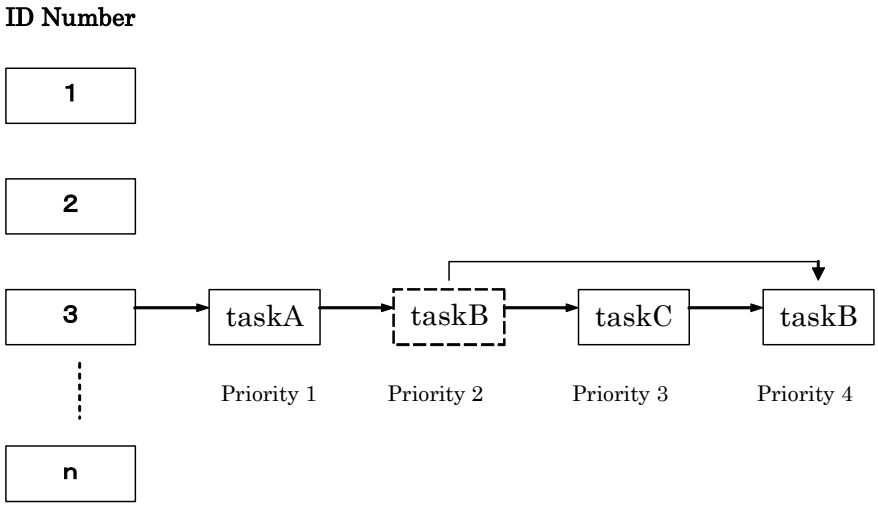
- Change Task Priority (chg_pri, ichg_pri)
  If the priority of a task is changed while the task is in READY or RUNNING state, the ready queue also is updated. (See Figure 3.21).

  Furthermore, if the target task is placed in a waiting queue of objects with TA_TPRI attribute, the waiting queue also is updated. (See Figure 3.22).



When the priority of task B has been changed from 3 to 1

Figure 3.21 Alteration of task priority



When the priority of Task B is changed into 4

Figure 3.22 Task rearrangement in a waiting queue

- Reference task priority (get_pri, iget_pri)
  Gets the priority of a task.

- Reference task status (simple version) (ref_tst, iref_tst)
  Refers to the state of the target task.

- Reference task status (ref_tsk, iref_tsk)
  Refers to the state of the target task and its priority, etc.

3.5.4 Synchronization functions attached to task

The task-dependent synchronization functions attached to task is used to accomplish synchronization between tasks by placing a task in the WAIT, SUSPENDED, or WAIT-SUSPENDED state or waking up a WAIT state task.

The MR308 offers the following task incorporated synchronization service calls.

- Put Task to sleep (slp_tsk,tslp_tsk)
- Wakeup task (wup_tsk, iwup_tsk)
  Wakeups a task that has been placed in a WAIT state by the slp_tsk or tslp_tsk service call.

  No task can be waked up unless they have been placed in a WAIT state by.[32]

  If a wakeup request is issued to a task that has been kept waiting for conditions other than the slp_tsk or tslp_tsk service call or a task in other than DORMANT state by the wup_tsk or iwup_tsk service call, that wakeup request only will be accumulated.

  Therefore, if a wakeup request is issued to a task RUNNING state, for example, this wakeup request is temporarily stored in memory. Then, when the task in RUNNING state is going to be placed into WAIT state by the slp_tsk or tslp_tsk service call, the accumulated wakeup request becomes effective, so that the task continues executing again without going to WAIT state. (See Figure 3.23).

- Cancel Task Wakeup Requests (can_wup)
  Clears the stored wakeup request.(See Figure 3.24).

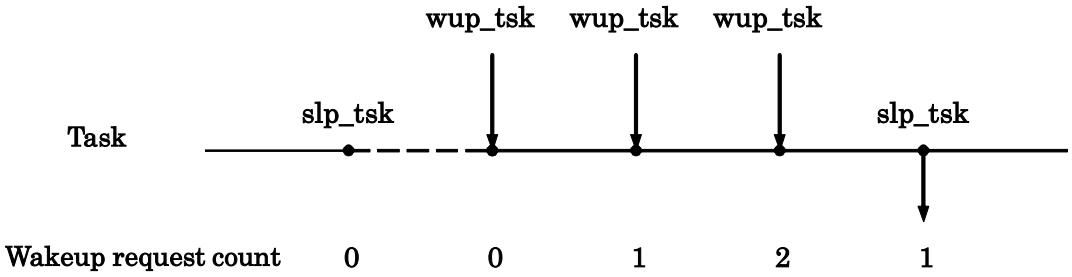


Figure 3.23 Wakeup Request Storage

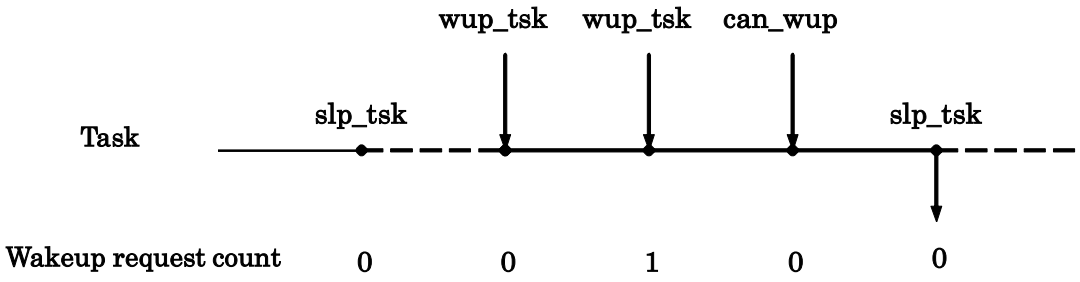


Figure 3.24 Wakeup Request Cancellation

- Suspend task (sus_tsk, isus_tsk)
- Resume suspended task (rsm_tsk, irsm_tsk)
  These service calls forcibly keep a task suspended for execution or resume execution of a task. If a suspend request is issued to a task in READY state, the task is placed into SUSPENDED state; if issued to a task in WAIT state, the task is placed into WAIT-SUSPENDED state. Since MR308 allows

[32] Note that tasks in WAIT state, but kept waiting for the following conditions are not awaken.
Eventflag wait state, semaphore wait state, data transmission wait state, data reception wait state, timeout wait state, fixed length memory pool acquisition wait, short data transmission wait, or short data reception wait

only one forcible wait request to be nested, if sus_tsk is issued to a task in a forcible wait state, the error E_QOVR is returned. (See Figure 3.25).

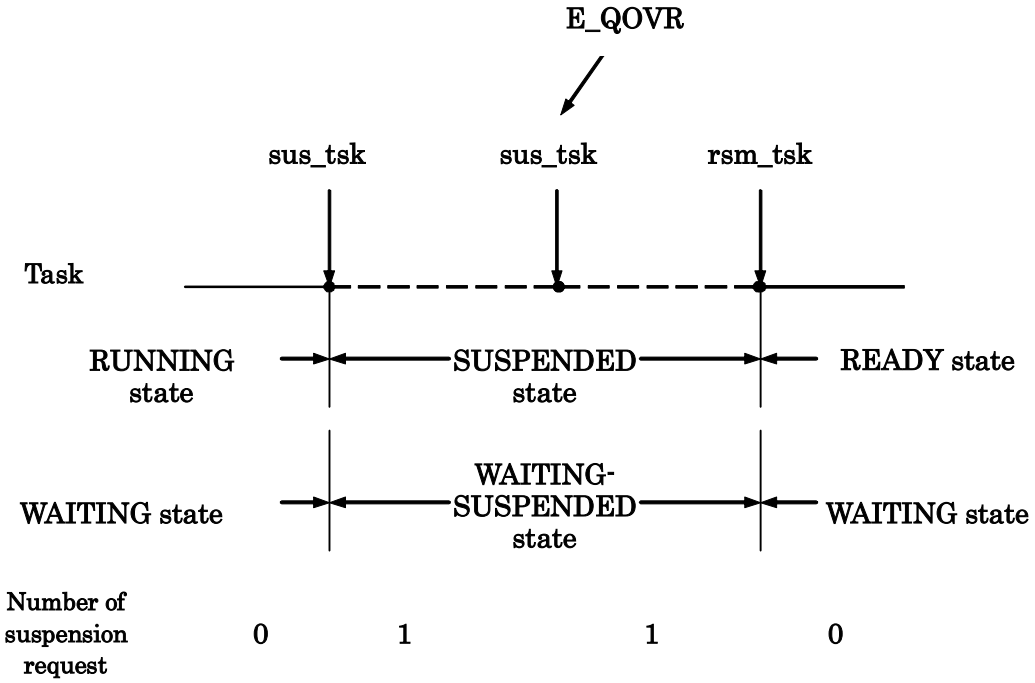


Figure 3.25 Forcible wait of a task and resume

- Forcibly resume suspended task (frsm_tsk, ifrsm_tsk)
  Clears the number of suspension requests nested to 0 and forcibly resumes execution of a task. Since MR308 allows only one suspension request to be nested, this service call behaves the same way as rsm_tsk and irsm_tsk..(See Figure 3.26).

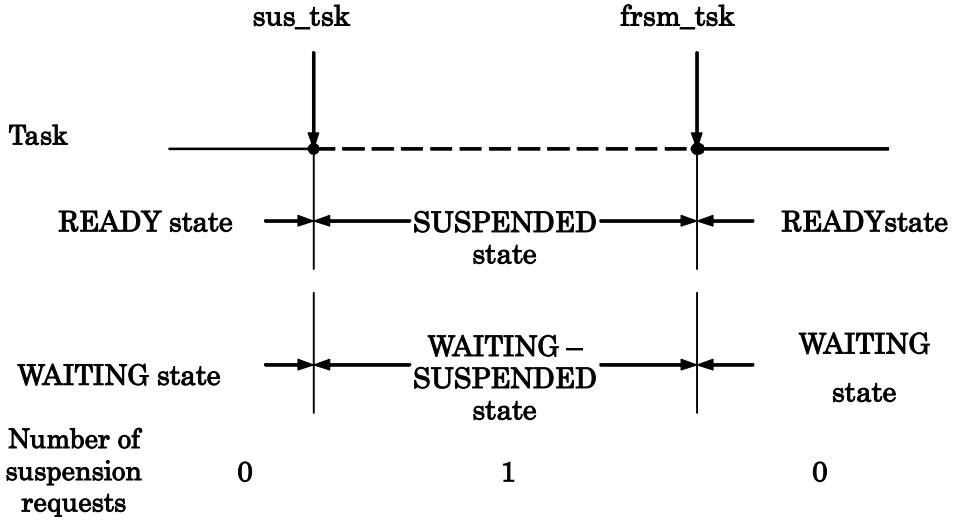


Figure 3.26 Forcible wait of a task and forcible resume

- Release task from waiting (rel_wai, irel_wai)
  Forcibly frees a task from WAITING state. A task is freed from WAITING state by this service call when it is in one of the following wait states.

- Timeout wait state
- Wait state entered by slp_tsk service call (+ timeout included)
- Event flag (+ timeout included) wait state
- Semaphore (+ timeout included) wait state
- Message (+ timeout included) wait state
- Data transmission (+ timeout included) wait state
- Data reception (+ timeout included) wait state
- Fixed–size memory block (+ timeout included) acquisition wait state
- Short data transmission (+ timeout included) wait state
- Short data reception (+ timeout included) wait state

- Delay task (dly_tsk)
  Keeps a task waiting for a finite length of time. Figure 3.27 shows an example in which execution of a task is kept waiting for 10 ms by the dly_tsk service call. The timeout value should be specified in ms units, and not in time tick units.

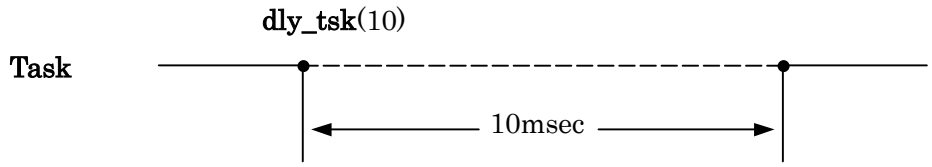


Figure 3.27 dly_tsk service call

3.5.5 Synchronization and Communication Function (Semaphore)

The semaphore is a function executed to coordinate the use of devices and other resources to be shared by several tasks in cases where the tasks simultaneously require the use of them. When, for instance, four tasks simultaneously try to acquire a total of only three communication lines as shown in Figure 3.28, communication line-to-task connections can be made without incurring contention.

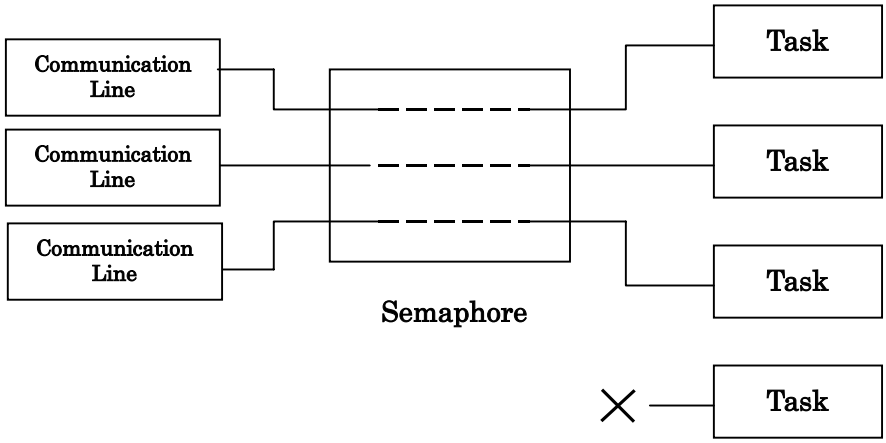


Figure 3.28 Exclusive Control by Semaphore

The semaphore has an internal semaphore counter. In accordance with this counter, the semaphore is acquired or released to prevent competition for use of the same resource.(See Figure 3.29).

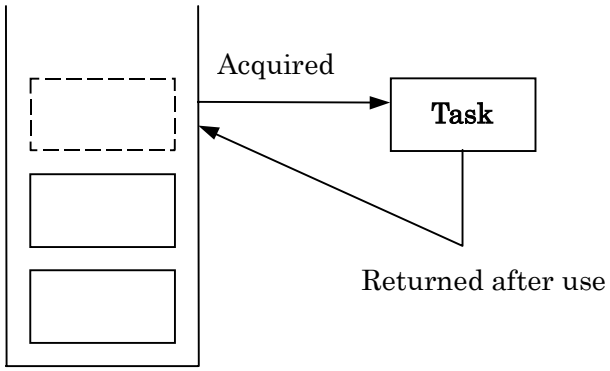


Figure 3.29 Semaphore Counter

The MR308 kernel offers the following semaphore synchronization service calls.

- Release Semaphore Resource(sig_sem, isig_sem)
  Releases one resource to the semaphore. This service call wakes up a task that is waiting for the semaphores service, or increments the semaphore counter by 1 if no task is waiting for the semaphores service.

- Acquire Semaphore Resource(wai_sem, twai_sem)
  Waits for the semaphores service. If the semaphore counter value is 0 (zero), the semaphore cannot be acquired. Therefore, the WAITING state prevails.

- Acquire Semaphore Resource(pol_sem, ipol_sem)
  Acquires the semaphore resource. If there is no semaphore resource to acquire, an error code is returned and the WAITING state does not prevail.

- Reference Semaphore Status (ref_sem, iref_sem)
  Refers the status of the target semaphore. Checks the count value and existence of the wait task for the target semaphore.

  Figure 3.30 shows example task execution control provided by the wai_sem and sig_sem service calls.

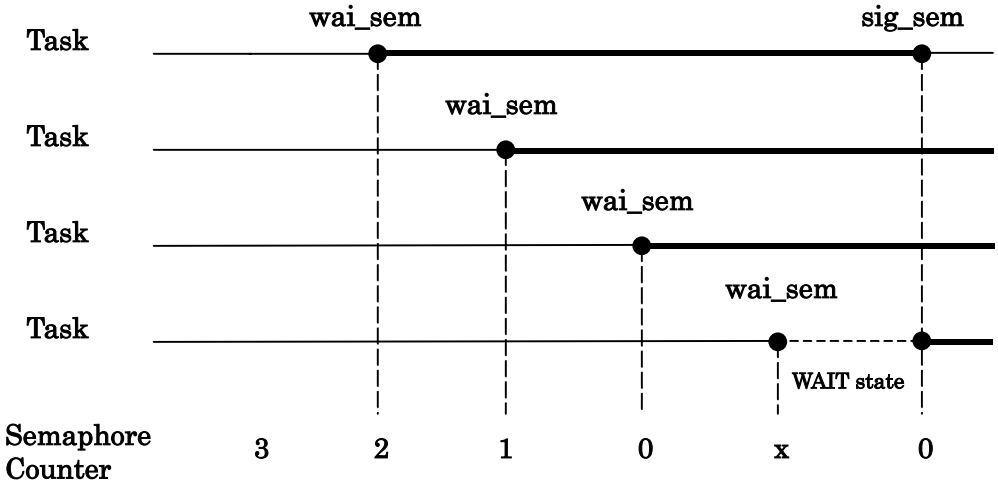


Figure 3.30 Task Execution Control by Semaphore

3.5.6 Synchronization and Communication Function (Eventflag)

The eventflag is an internal facility of MR308 that is used to synchronize the execution of multiple tasks. The eventflag uses a flag wait pattern and a 16-bit pattern to control task execution. A task is kept waiting until the flag wait conditions set are met.

It is possible to determine whether multiple waiting tasks can be enqueued in one eventflag waiting queue by specifying the eventflag attribute TA_WSGL or TA_WMUL.

Furthermore, it is possible to clear the eventflag bit pattern to 0 when the eventflag meets wait conditions by specifying TA_CLR for the eventflag attribute.

There are following eventflag service calls that are provided by the MR308 kernel.

- Set Eventflag (set_flg, iset_flg)
  Sets the eventflag so that a task waiting the eventflag is released from the WAITING state.

- Clear Eventflag (clr_flg, iclr_flg)
  Clears the Eventflag.

- Wait for Eventflag (wai_flg, twai_flg)
  Waits until the eventflag is set to a certain pattern. There are two modes as listed below in which the eventflag is waited for.

  - AND wait
    Waits until all specified bits are set.

  - OR wait
    Waits until any one of the specified bits is set

- Wait for Eventflag (polling)(pol_flg, ipol_flg)
  Examines whether the eventflag is in a certain pattern. In this service call, tasks are not placed in WAITING state.

- Reference Eventflag Status (ref_flg, iref_flg)
  Checks the existence of the bit pattern and wait task for the target eventflag.

Figure 3.31 shows an example of task execution control by the eventflag using the wai_flg and set_flg service calls.

The eventflag has a feature that it can wake up multiple tasks collectively at a time.

In Figure 3.31, there are six tasks linked one to another, task A to task F. When the flag pattern is set to 0xF by the set_flg service call, the tasks that meet the wait conditions are removed sequentially from the top of the queue. In this diagram, the tasks that meet the wait conditions are task A, task C, and task E. Out of these tasks, task A, task C, and task E are removed from the queue.

If this event flag has a TA_CLR attribute, when the waiting of Task A is canceled, the bit pattern of the event flag will be set to 0, and Task C and Task E will not be removed from queue.

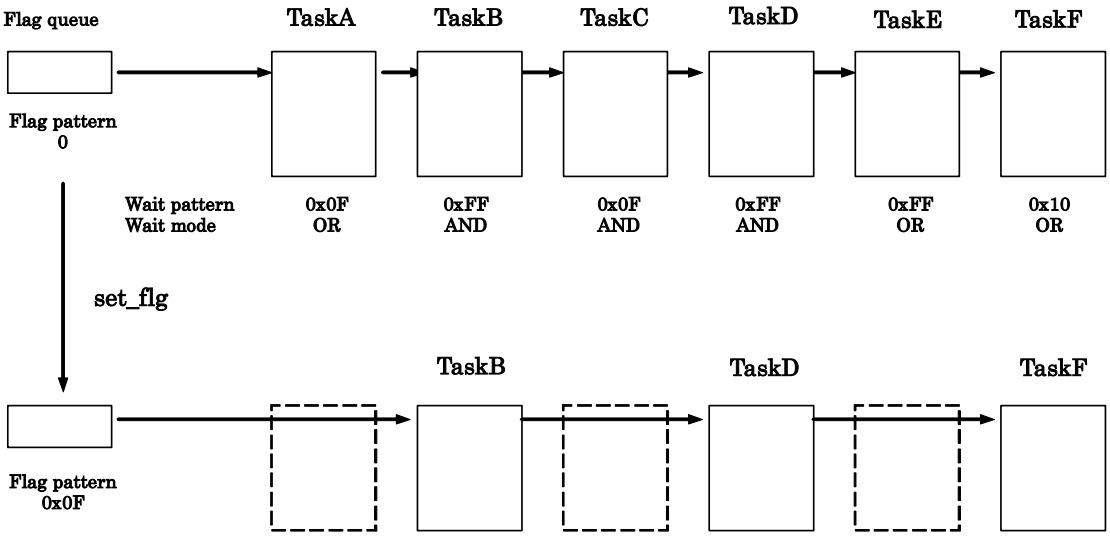


Figure 3.31 Task Execution Control by the Eventflag

3.5.7 Synchronization and Communication Function (Data Queue)

The data queue is a mechanism to perform data communication between tasks. In Figure 3.32, for example, task A can transmit data to the data queue and task B can receive the transmitted data from the data queue.

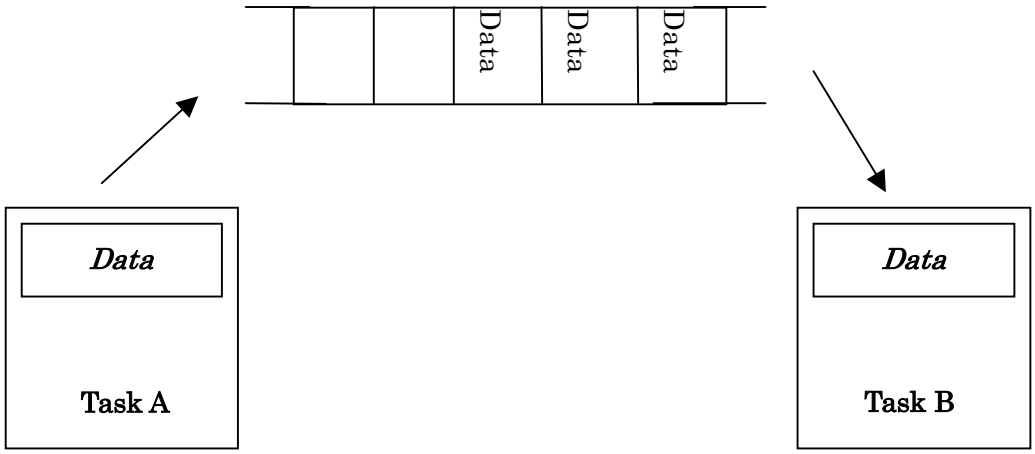


Figure 3.32 Data queue

Data in width of 32 bits can be transmitted to this data queue.

The data queue has the function to accumulate data. The accumulated data is retrieved in order of FIFO[33]. However, the number of data that can be accumulated in the data queue is limited. If data is transmitted to the data queue that is full of data, the service call issuing task goes to a data transmission wait state.

There are following data queue service calls that are provided by the MR308 kernel.

- Send to Data Queue(snd_dtq, tsnd_dtq)
  Transmits data. Namely, data is transmitted to the data queue. If the data queue is full of data, the task goes to a data transmission wait state.

- Send to Data Queue (psnd_dtq, ipsnd_dtq)
  Transmits data. Namely, data is transmitted to the data queue. If the data queue is full of data, the task returns error code without going to a data transmission wait state.

- Forced Send to Data Queue (fsnd_dtq, ifsnd_dtq)
  Transmits data. Namely, data is transmitted to the data queue. If the data queue is full of data, the data at the top of the data queue or the oldest data is removed, and the transmitted data is stored at the tail of the data queue.

- Receive from Data Queue (rcv_dtq, trcv_dtq)
  Receives data. Namely, data is retrieved from the data queue. If the data queue has no data in it, the task is kept waiting until data is transmitted to the data queue.

- Receive from Data Queue (prcv_dtq,iprcv_dtq)
  Receives data. Namely, data is received from the data queue. If the data queue has no data in it, the task returns error code without going to a data reception wait state.

- Reference Data Queue Status (ref_dtq,iref_dtq)
  Checks to see if there are any tasks waiting for data to be entered in the target data queue and refers to the number of the data in the data queue.

[33] First In First Out

3.5.8 Synchronization and Communication Function (Mailbox)

The mailbox is a mechanism to perform data communication between tasks. In Figure 3.33, for example, task A can drop a message into the mailbox and task B can retrieve the message from the mailbox. Since mailbox-based communication is achieved by transferring the beginning address of a message from a task to another, this mode of communication is performed at high speed independently of the message size.

The kernel manages the message queue by means of a link list. The application should prepare a header area that is to be used for a link list. This is called the message header. The message header and the area actually used by the application to store a message are called the message packet. The kernel rewrites the content of the message header as it manages the message queue. The message header cannot be rewritten from the application. The structure of the message queue is shown in Figure 3.34. The message header has its data types defined as shown below.

T_MSG: **Mailbox message header**

T_MSG_PRI: **Mailbox message header with priority included**

Messages in any size can be enqueued in the message queue because the header area is reserved on the application side. In no event will tasks be kept waiting for transmission.

Messages can be assigned priority, so that messages will be received in order of priority beginning with the highest. In this case, TA_MPRI should be added to the mailbox attribute. If messages need to be received in order of FIFO, add TA_MFIFO to the mailbox attribute.[34] Furthermore, if tasks in a message wait state are to receive a message, the tasks can be prioritized in which order they can receive a message, beginning with one that has the highest priority. In this case, add TA_TPRI to the mailbox attribute. If tasks are to receive a message in order of FIFO, add TA_TFIFO to the mailbox attribute.[35]

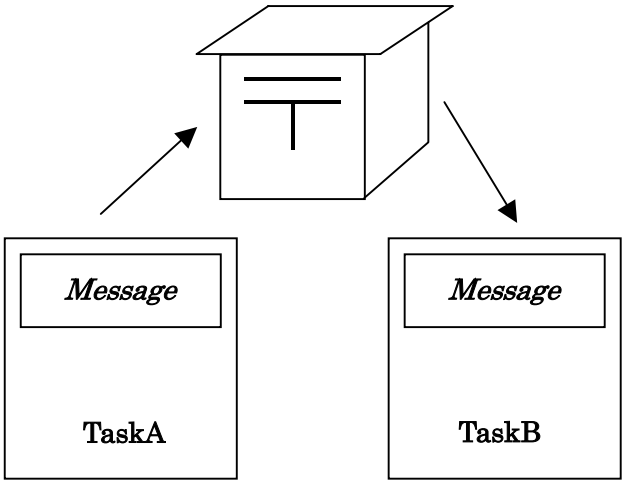


Figure 3.33 Mailbox

[34] It is in the mailbox definition "message_queue" of the configuration file that the TA_MPRI or TA_MFIFO attribute should be added.
[35] It is in the mailbox definition "wait_queue" of the configuration file that the TA_TPRI or TA_TFIFO attribute should be added.

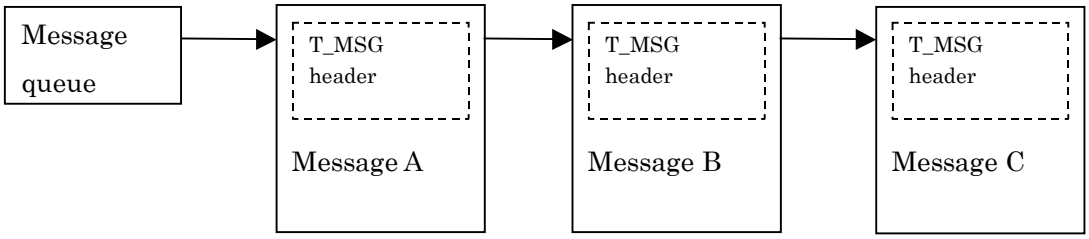


Figure 3.34 Message queue

There are following data queue service calls that are provided by the MR308 kernel.

- Send to Mailbox (snd_mbx, isnd_mbx)
  Transmits a message. Namely, a message is dropped into the mailbox.

- Receive from Mailbox (rcv_mbx, trcv_mbx)
  Receives a message. Namely, a message is retrieved from the mailbox. At this time, if the mailbox has no messages in it, the task is kept waiting until a message is sent to the mailbox.

- Receive from Mailbox (polling) (prcv_mbx, iprcv_mbx)
  Receives a message. The difference from the rcv_mbx service call is that if the mailbox has no messages in it, the task returns error code without going to a wait state.

- Reference Mailbox Status (ref_mbx, iref_mbx)
  Checks to see if there are any tasks waiting for a message to be put into the target mailbox and refers to the message present at the top of the mailbox.

3.5.9 Memory pool Management Function

The memorypool management function provides system memory space (RAM space) dynamic control.
This function is used to manage a specific memory area (memorypool), dynamically obtain memory blocks from the memorypool as needed for tasks or handlers, and release unnecessary memory blocks to the memorypool.
The MR308 supports two types of memorypool management functions, one for fixed-size and the other for variable-size.

Fixed-size Memory pool Management Function
You specify memory block size using configuration file.
The MR308 kernel offers the following Fixed-size memory pool management service calls.

- Acquire Fixed-size Memory Block (get_mpf, tget_mpf)
  Acquires a memory block from the fixed-size memory pool that has the specified ID. If there are no blank memory blocks in the specified fixed-size memory pool, the task that issued this service call goes to WAITING state and is enqueued in a waiting queue.
- Acquire Fixed-size Memory Block (polling) (pget_mpf, ipget_mpf)
  Acquires a memory block from the fixed-size memory pool that has the specified ID. The difference from the get_mpf and tget_mpf service calls is that if there are no blank memory blocks in the memory pool, the task returns error code without going to WAITING state.

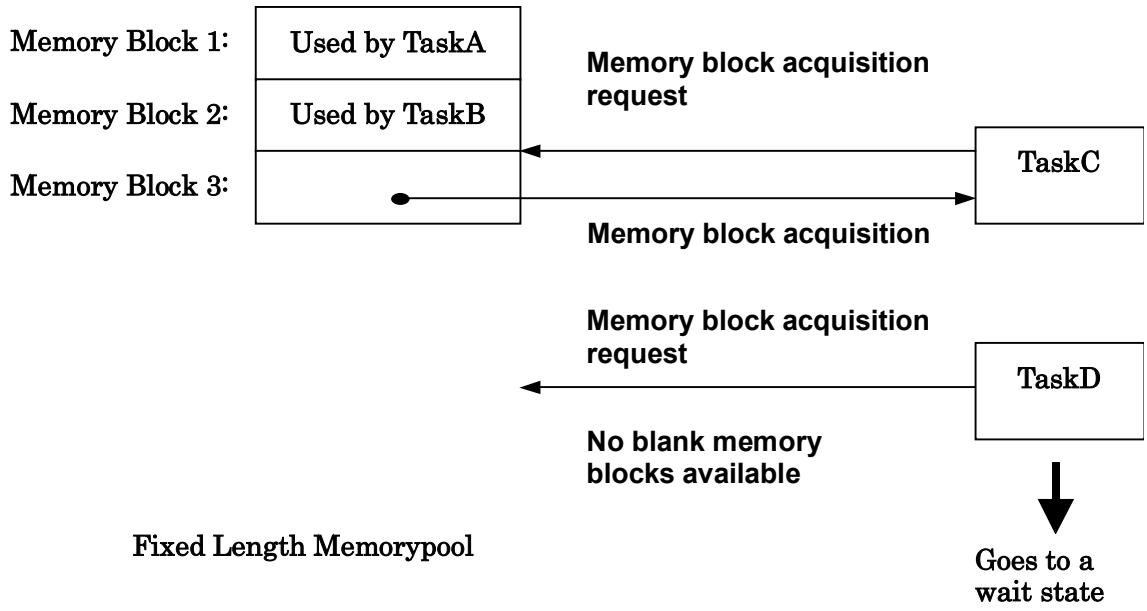


Figure 3.35 Memory Pool Management

- Release Fixed-size Memory Block (rel_mpf, irel_mpf)
  Frees the acquired memory block. If there are any tasks in a wait state for the specified fixed-size memory pool, the task enqueued at the top of the waiting queue is assigned the freed memory block. In this case, the task changes its state from WAITING state to READY state. If there are no tasks in a wait state, the memory block is returned to the memory pool.
- Reference Fixed-size Memory Pool Status (ref_mpf, iref_mpf)
  Checks the number and the size of blank blocks available in the target memory pool.

Variable-size Memory Pool Management Function

The technique that allows you to arbitrary define the size of memory block acquirable from the memory pool is termed Variable-size scheme. The MR308 manages memory in terms of four fixed-size memory block sizes.

The MR308 calculates the size of individual blocks based on the maximum memory block size to be acquired. You specify the maximum memory block size using the configuration file.

```
e.g.
     variable_memorypool[]{
            max_memsize     = 400; <---- Maximum size
            heap_size       = 5000;
     };
```

Defining a variable-size memory pool as shown above causes four fixed-size memory block sizes to become 56 bytes, 112 bytes, 224 bytes, and 448 bytes in compliance with max_memsize.

In the case of user-requested memory, the MR308 performs calculations based on the specified size and selects and allocates the optimum one of four fixed-size memory block sizes. The MR308 cannot allocate a memory block that is not one of the four sizes.

Service calls the MR308 provides include the following.

- Acquire Variable-size Memory Block (pget_mpl)
  Round off a block size you specify to the optimal block size among the four block sizes, and acquires memory having the rounded-off size from the memory pool.

  The following equations define the block sizes:

  $a = (((max\_memsize+(X-1))/ X \times 8)+1) \times 8$
  $b = a \times 2$
  $c = a \times 4$
  $d = a \times 8$

  max_memsize: the value specified in the configuration file
  X: data size for block control (8 byte)

  For example, if you request 200-byte, the MR308 rounds off the size to 244 bytes, and acquires 244-byte memory.

  If memory acquirement goes well, the MR308 returns the first address of the memory acquired along with the error code "E_OK". If memory acquirement fails, the MR308 returns the error code "E_TMOUT".

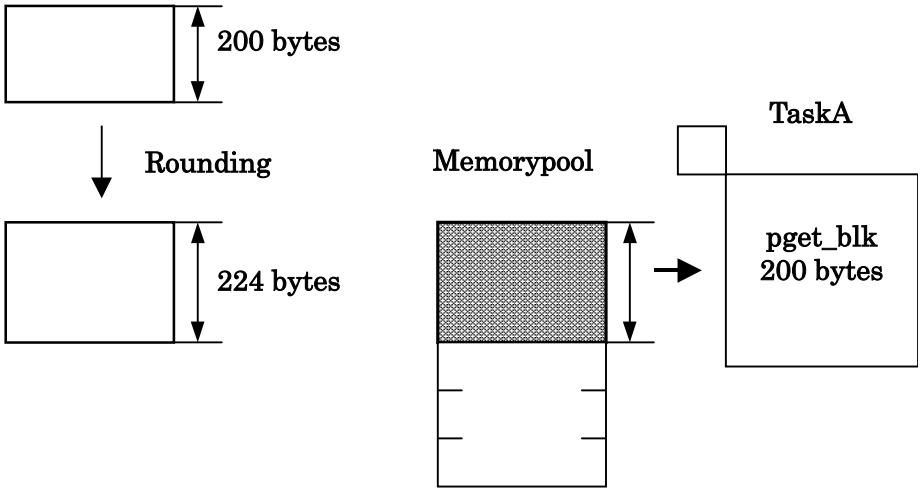


Figure 3.36 pget_mpl processing

- Release Acquire Variable-size Memory Block (rel_mpl)
  Releases a acquired memory block by pget_mpl service call.

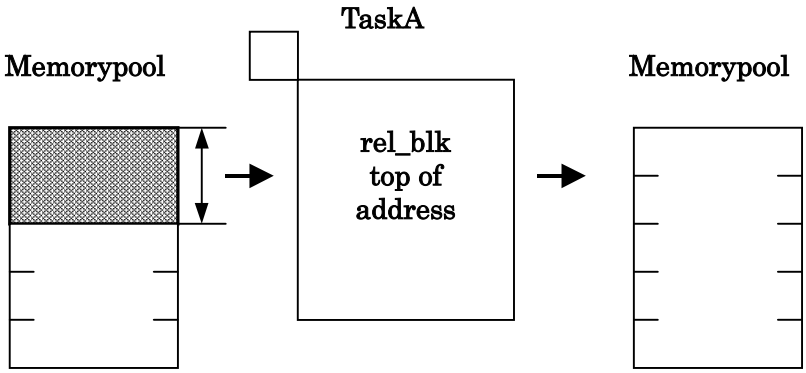


Figure 3.37 rel_mpl processing

- Reference Acquire Variable-size Memory Pool Status (ref_mpl, iref_mpl)
  Checks the total free area of the memory pool, and the size of the maximum free area that can immediately be acquired.

3.5.10 Time Management Function

The time management function provides system time management, time reading[36], time setup[37], and the functions of the alarm handler, which actuates at preselected times, and the cyclic handler, which actuates at preselected time intervals.

The MR308 kernel requires one timer for use as the system clock. There are following time management service calls that are provided by the MR308 kernel. Note, however, that the system clock is not an essential function of MR308. Therefore, if the service calls described below and the time management function of the MR308 are unused, a timer does not need to be occupied for use by MR308.

- Place a task in a finite time wait state by specifying a timeout value
  A timeout can be specified in a service call that places the issuing task into WAITING state.[38] This service call includes tslp_tsk, twai_flg, twai_sem, tsnd_dtq, trcv_dtq, trcv_mbx, tget_mpf, vtsnd_dtq, and vtrcv_dtq. If the wait cancel condition is not met before the specified timeout time elapses, the error code E_TMOUT is returned, and the task is freed from the wait state. If the wait cancel condition is met, the error code E_OK is returned.

  The timeout time should be specified in ms units.

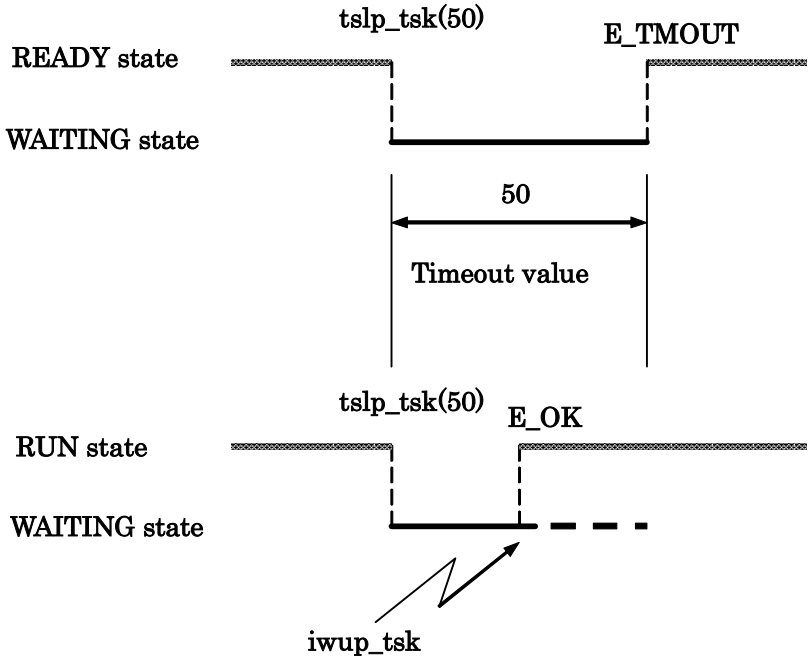


Figure 3.38 Timeout Processing

MR308 guarantees that as stipulated in µITRON specification, timeout processing is not performed until a time equal to or greater than the specified timeout value elapses. More specifically, timeout processing is performed with the following timing.

1. If the timeout value is 0 (for only dly_tsk)
   The task times out at the first time tick after the service call is issued.
2. If the timeout value is a multiple of time tick interval
   The timer times out at the (timeout value / time tick interval) + first time tick. For example, if the time tick interval is 10 ms and the specified timeout value is 40 ms, then the timer times out at the fifth occurrence of the time tick. Similarly, if the time tick interval is 5 ms and the specified timeout value is 15 ms, then the timer times out at the fourth occurrence of the time tick.
3. If the timeout value is not a multiple of time tick interval
   The timer times out at the (timeout value / time tick interval) + second time tick. For example, if the time tick interval is 10 ms and the specified timeout value is 35 ms, then the timer times out

[36] get_tim service call
[37] set_tim service call
[38] SUSPENDED state is not included.

at the fifth occurrence of the time tick.

- Set System Time (set_tim)
- Reference System Time (get_tim)
  The system time indicates an elapsed time from when the system was reset by using 48-bit data. The time is expressed in ms units.

3.5.11 Cyclic Handler Function

The cyclic handler is a time event handler that is started every startup cycle after a specified startup phase has elapsed.

The cyclic handler may be started with or without saving the startup phase. In the former case, the cyclic handler is started relative to the point in time at which it was generated. In the latter case, the cyclic handler is started relative to the point in time at which it started operating. Figure 3.39 and Figure 3.40 show typical operations of the cyclic handler.

If the startup cycle is shorter than the time tick interval, the cyclic handler is started only once every time tick supplied (processing equivalent to isig_tim). For example, if the time tick interval is 10 ms and the startup cycle is 3 ms and the cyclic handler has started operating when a time tick is supplied, then the cyclic handler is started every time tick.

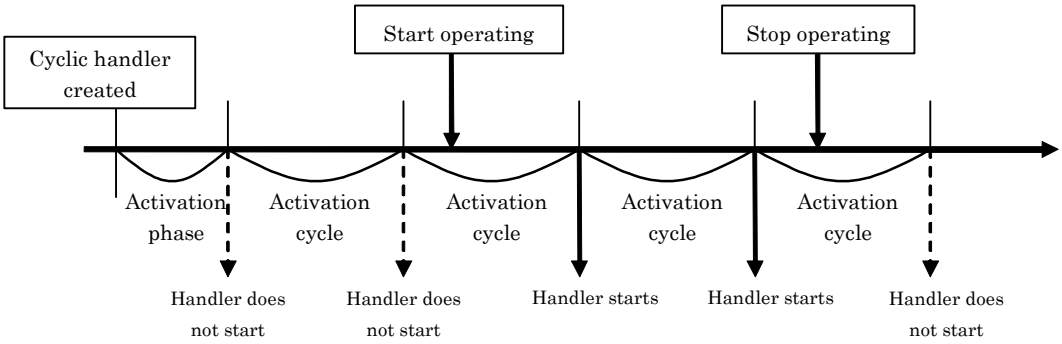


Figure 3.39 Cyclic handler operation in cases where the activation phase is saved

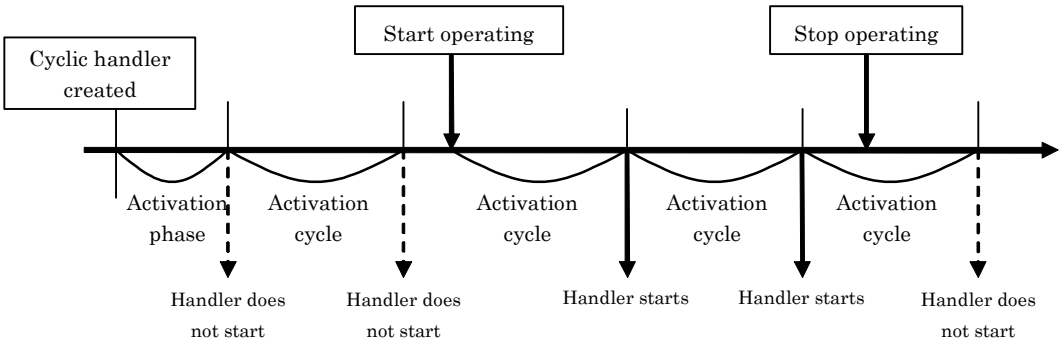


Figure 3.40 Cyclic handler operation in cases where the activation phase is not saved

- Start Cyclic Handler Operation (sta_cyc, ista_cyc)
  Causes the cyclic handler with the specified ID to operational state.

- Stop Cyclic Handler Operation (stp_cyc, istp_cyc)
  Causes the cyclic handler with the specified ID to non-operational state.

- Reference Cyclic Handler Status (ref_cyc, iref_cyc)
  Refers to the status of the cyclic handler. The operating status of the target cyclic handler and the remaining time before it starts next time are inspected.

3.5.12 Alarm Handler Function

The alarm handler is a time event handler that is started only once at a specified time.

Use of the alarm handler makes it possible to perform time-dependent processing. The time of day is specified by a relative time. Figure 3.41 shows a typical operation of the alarm handler.

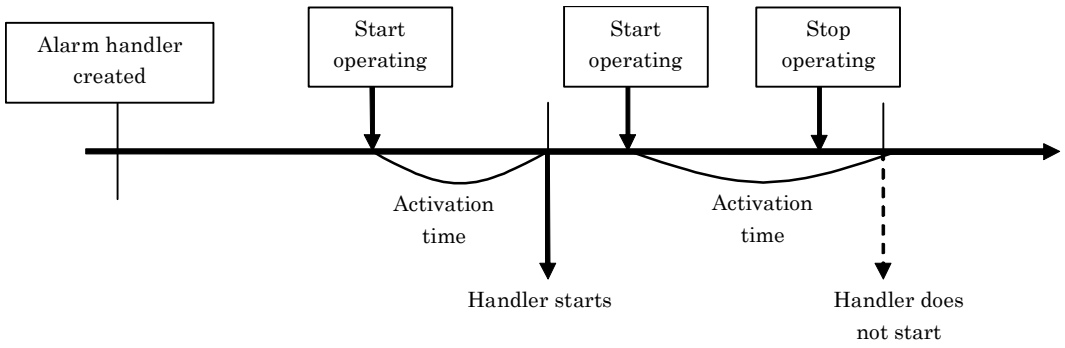


Figure 3.41 Typical operation of the alarm handler

- Start Alarm Handler Operation (sta_alm, ista_alm)
  Causes the alarm handler with the specified ID to operational state.

- Stop alarm Handler Operation (stp_alm, istp_alm)
  Causes the alarm handler with the specified ID to non-operational state.

- Reference Alarm Handler Status (ref_alm, iref_alm)
  Refers to the status of the alarm handler. The operating status of the target alarm handler and the remaining time before it starts are inspected.

3.5.13 System Status Management Function

- Rotate Task Precedence (rot_rdq, irot_rdq)
  This service call establishes the TSS (time-sharing system). That is, if the ready queue is rotated at regular intervals, round robin scheduling required for the TSS is accomplished (See Figure 3.42)

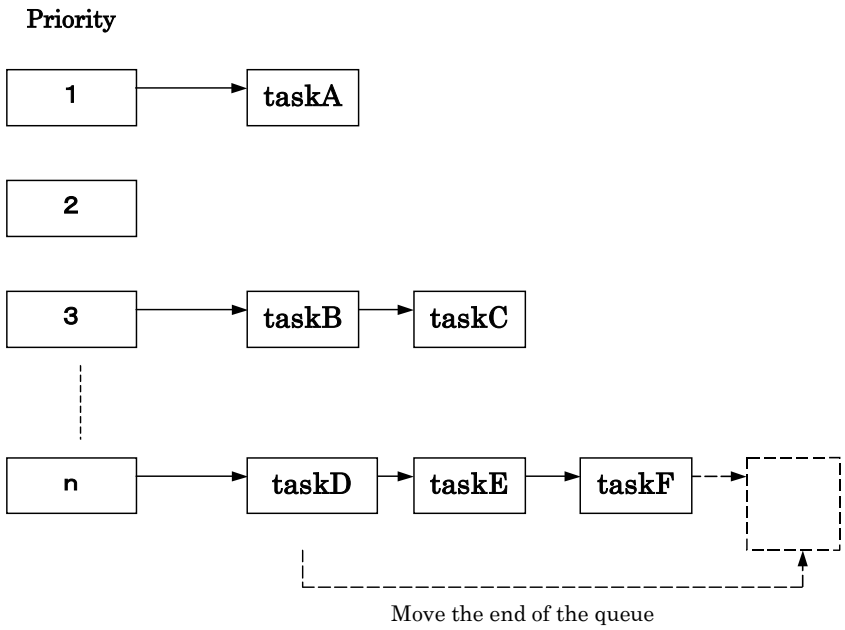


Figure 3.42 Ready Queue Management by rot_rdq System Call

- Reference task ID in the RUNNING state(get_tid, iget_tid)
  References the ID number of the task in the RUNNING state. If issued from the handler, TSK_NONE(=0=) is obtained instead of the ID number.
- Lock the CPU (loc_cpu, iloc_cpu)
  Places the system into a CPU locked state.
- Unlock the CPU (unl_cpu, iunl_cpu)
  Frees the system from a CPU locked state.
- Disable dispatching (dis_dsp)
  Places the system into a dispatching disabled state.
- Enable dispatching (ena_dsp)
  Frees the system from a dispatching disabled state.
- Reference context (sns_ctx)
  Gets the context status of the system.
- Reference CPU state (sns_loc)
  Gets the CPU lock status of the system.
- Reference dispatching state (sns_dsp)
  Gets the dispatching disable status of the system.
- Reference dispatching pending state (sns_dpn)
  Gets the dispatching pending status of the system.

3.5.14 Interrupt Management Function

The interrupt management function provides a function to process requested external interrupts in real time.

The interrupt management service calls provided by the MR308 kernel include the following:

- Returns from interrupt handler (ret_int)
  The ret_int service call activates the scheduler to switch over tasks as necessary when returning from the interrupt handler.
  When using the C language,[39], this function is automatically called at completion of the handler function. In this case, therefore, there is no need to invoke this service call.

Figure 3.43 shows an interrupt processing flow. Processing a series of operations from task selection to register restoration is called a "scheduler.".

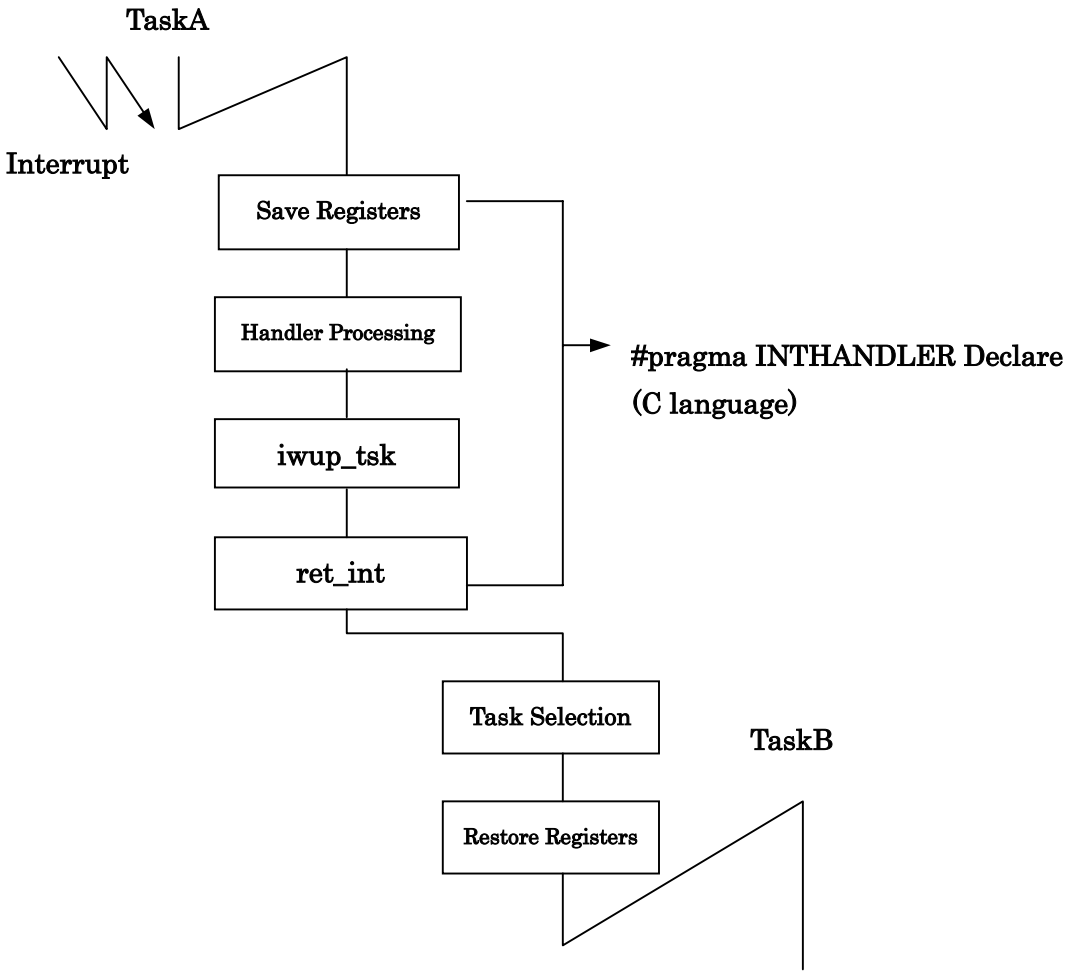


Figure 3.43 Interrupt process flow

[39] In the case that the interruput handler is specified by "#pragma INTHANDLER".

3.5.15 System Configuration Management Function

This function inspects the version information of MR308.

- References Version Information(ref_ver, iref_ver)
  The ref_ver service call permits the user to get the version information of MR308. This version information can be obtained in the standardized format of µITRON specification.

3.5.16 Extended Function (Short Data Queue)

The short data queue is a function outside the scope of µITRON 4.0 Specification. The data queue function handles data as consisting of 32 bits, whereas the short data queue handles data as consisting of 16 bits. Both behave the same way except only that the data sizes they handle are different.

- Send to Short Data Queue (vsnd_dtq, vtsnd_dtq)
  Transmits data. Namely, data is transmitted to the short data queue. If the short data queue is full of data, the task goes to a data transmission wait state.

- Send to Short Data Queue (vpsnd_dtq, vipsnd_dtq)
  Transmits data. Namely, data is transmitted to the short data queue. If the short data queue is full of data, the task returns error code without going to a data transmission wait state.

- Forced Send to Short Data Queue (vfsnd_dtq, vifsnd_dtq)
  Transmits data. Namely, data is transmitted to the data queue. If the data queue is full of data, the data at the top of the data queue or the oldest data is removed, and the transmitted data is stored at the tail of the data queue.

- Receive from Short Data Queue(vrcv_dtq, vtrcv_dtq)
  Receives data. Namely, data is retrieved from the short data queue. If the short data queue has no data in it, the task is kept waiting until data is transmitted to the short data queue.

- Receive from Short Data Queue (vprcv_dtq, viprcv_dtq)
  Receives data. Namely, data is received from the short data queue. If the short data queue has no data in it, the task returns error code without going to a data reception wait state.

- Reference Short Data Queue Status (vref_dtq, viref_dtq)
  Checks to see if there are any tasks waiting for data to be entered in the target short data queue and refers to the number of the data in the data queue.

3.5.17 Extended Function (Reset Function)

The reset function is a function outside the scope of µITRON 4.0 Specification. It initializes the mailbox, data queue, and memory pool, etc.

- Clear Data Queue Area (vrst_dtq)
  Initializes the data queue. If there are any tasks waiting for transmission, they are freed from WAITING state and the error code EV_RST is returned.

- Clear Mailbox Area (vrst_mbx)
  Initializes the mailbox.

- Clear Fixed-size Memory Pool Area (vrst_mpf)
  Initializes the fixed-size memory pool. If there are any tasks in WAITING state, they are freed from the WAITING state and the error code EV_RST is returned.

- Clear Variable-size Memory Pool Area (vrst_mpl)
  Initializes the variable length memory pool.

- Clear Short Data Queue Area (vrst_vdtq)
  Initializes the short data queue. If there are any tasks waiting for transmission, they are freed from WAITING state and the error code EV_RST is returned.

3.5.18 Service calls That Can Be Issued from Task and Handler

Some service calls can be issued from a task, others can be issued from non-task context, and still others can be issued from both. These service calls are listed in Table 3.4.

Table 3.4 List of the service call can be issued from the task and handler

Service Call	Task Context	Non-task Context
act_tsk	o	x
iact_tsk	x	o
can_act	o	x
ican_act	x	o
sta_tsk	o	x
ista_tsk	x	o
ext_tsk	o	x
ter_tsk	o	x
chg_pri	o	x
ichg_pri	x	o
get_pri	o	x
iget_pri	x	o
ref_tsk	o	x
iref_tsk	x	o
ref_tst	o	x
iref_tst	x	o
slp_tsk	o	x
tslp_tsk	o	x
wup_tsk	o	x
iwup_tsk	x	o
can_wup	o	x
ican_wup	x	o
rel_wai	o	x
irel_wai	x	o
sus_tsk	o	x
isus_tsk	x	o
rsm_tsk	o	x
irsm_tsk	x	o
frsm_tsk	o	x
ifrsm_tsk	x	o
dly_tsk	o	x

Service Call	Task Context	Non-task Context
sig_sem	o	x
isig_sem	x	o
wai_sem	o	x
twai_sem	o	x
pol_sem	o	x
ipol_sem	x	o
ref_sem	o	x
iref_sem	x	o
set_flg	o	x
iset_flg	x	o
clr_flg	o	x
iclr_flg	x	o
wai_flg	o	x
twai_flg	o	x
pol_flg	o	x
ipol_flg	x	o
ref_flg	o	x
iref_flg	x	o
snd_dtq	o	x
tsnd_dtq	o	x
psnd_dtq	o	x
ipsnd_dtq	x	o
fsnd_dtq	o	x
ifsnd_dtq	x	o
rcv_dtq	o	x
trcv_dtq	o	x
prcv_dtq	o	x
iprcv_dtq	x	o
ref_dtq	o	x
iref_dtq	x	o
snd_mbx	o	x
isnd_mbx	x	o
rcv_mbx	o	x
trcv_mbx	o	x
prcv_mbx	o	x
iprcv_mbx	x	o
ref_mbx	o	x
iref_mbx	x	o

Service Call	Task Context	Non-task Context
get_mpf	o	x
tget_mpf	o	x
pget_mpf	o	x
rel_mpf	o	x
irel_mpf	x	o
ref_mpf	o	x
iref_mpf	x	o
ipget_mpf	x	o
pget_mpl	o	x
rel_mpl	o	x
ref_mpl	o	x
iref_mpl	x	o
set_tim	o	x
iset_tim	x	o
get_tim	o	x
iget_tim	x	o
sta_cyc	o	x
ista_cyc	x	o
stp_cyc	o	x
istp_cyc	x	o
ref_cyc	o	x
iref_cyc	x	o
sta_alm	o	x
ista_alm	x	o
stp_alm	o	x
istp_alm	x	o
ref_alm	o	x
iref_alm	x	o
rot_rdq	o	x
irot_rdq	x	o
get_tid	o	x
iget_tid	x	o
loc_cpu	o	x
iloc_cpu	x	o
unl_cpu	o	x
iunl_cpu	x	o
dis_dsp	o	x
ena_dsp	o	x
sns_ctx	o	o
sns_loc	o	o
sns_dsp	o	o
sns_dpn	o	o

Service Call	Task Context	Non-task Context
ref_ver	o	x
iref_ver	x	o
vsnd_dtq	o	x
vtsnd_dtq	o	x
vpsnd_dtq	o	x
vipsnd_dtq	x	o
vfsnd_dtq	o	x
vifsnd_dtq	x	o
vrcv_dtq	o	x
vtrcv_dtq	o	x
vprcv_dtq	o	x
viprcv_dtq	x	o
vref_dtq	o	x
viref_dtq	x	o
vrst_mpf	o	x
vrst_mpl	o	x
vrst_mbx	o	x
vrst_dtq	o	x
vrst_vdtq	o	x

Chapter 4 Applications Development Procedure Overview

4.1 Overview

Application programs for MR308 should generally be developed following the procedure described below.

1. Generating a project

When using HEW[40], create a new project using MR308 on HEW.

2. Coding the application program

Write the application program in code form using C or assembly language. If necessary, correct the sample startup program (crt0mr.a30) and section definition file (c_sec.inc or asm_sec.inc).

3. Creating a configuration file

Create a configuration file which has defined in it the task entry address, stack size, etc. by using an editor.

The GUI configurator available for MR308 may be used to create a configuration file.

4. Executing the configurator

From the configuration file, create system data definition files (sys_rom.inc, sys_ram.inc), include files (mr308.inc, kernel_id.h), and a system generation procedure description file (makefile).

5. System generation

Execute the make[41] command or execute build on HEW to generate a system.

6. Writing to ROM

Using the ROM programming format file created, write the finished program file into the ROM. Or load it into the debugger to debug.

Figure 4.1 shows a detailed flow of system generation.

[40] It is abbreviation of High-performance Embedded Workshop.
[41] The make command comes the UNIX standard and UNIX compatible.

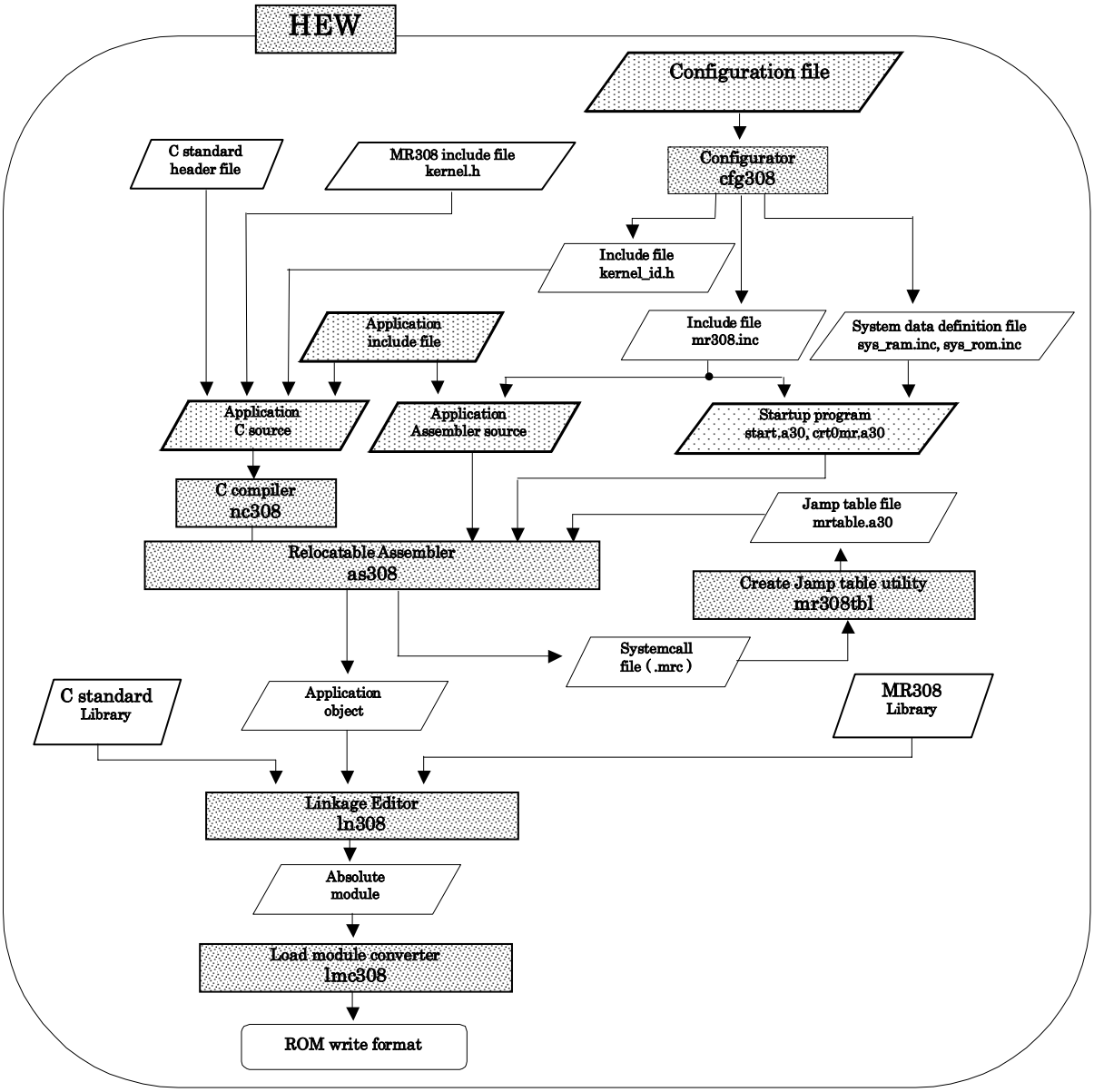


Figure 4.1 MR308 System Generation Detail Flowchart

4.2 Development Procedure Example

This chapter outlines the development procedures on the basis of a typical MR308 application example.

4.2.1 Applications Program Coding

Figure 4.2 shows a program that simulates laser beam printer operations. Let us assume that the file describing the laser beam printer simulation program is named lbp.c. This program consists of the following three tasks and one interrupt handler.

- Main Task
- Image expansion task
- Printer engine task
- Centronics interface interrupt handler

This program uses the following MR308 library functions.

- sta_tsk()
  Starts a task. Give the appropriate ID number as the argument to select the task to be activated. When the kernel_id.h file, which is generated by the configurator, is included, it is possible to specify the task by name (character string).[42]

- wai_flg()
  Waits until the eventflag is set up. In the example, this function is used to wait until one page of data is entered into the buffer via the Centronics interface.

- wup_tsk()
  Wakes up a specified task from the WAITING state. This function is used to start the printer engine task.

- slp_tsk()
  Causes a task in the RUNNING state to enter the WAITING state. In the example, this function is used to make the printer engine task wait for image expansion.

- iset_flg()
  Sets the eventflag. In the example, this function is used to notify the image expansion task of the completion of one-page data input.

[42] The configurator converts the ID number to the associated name(character string) in accordance with the information entered int the configuration file.

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void main() /* main task */
{
    printf("LBP start simulation \n");
    sta_tsk(ID_idle,1);     /* activate idle task */
    sta_tsk(ID_image,1);    /* activate image expansion task */
    sta_tsk(ID_printer,1);  /* activate printer engine task */
}
void image() /* activate image expansion task */
{
    while(1){
            wai_flg(ID_pagein,waiptn,TWF_ANDW, &flgptn);/* wait for 1-page input */

            printf(" bit map expansion processing \n");
            wup_tsk(ID_printer);    /* wake up printer engine task */
    }
}
void printer() /* printer engine task */
{
    while(1){
            slp_tsk();
            printf(" printer engine operation \n");
    }
}
void sent_in() /* Centronics interface handler */
{


    /* Process input from Centronics interface */
    if ( /* 1-page input completed */ )
            iset_flg(ID_pagein,setptn);
}
```

Figure 4.2 Program Example

4.2.2 Configuration File Preparation

Create a configuration file which has defined in it the task entry address, stack size, etc. Use of the GUI configurator available for MR308 helps to create a configuration file easily without having to learn how to write it.

Figure 4.3 Configuration File Example

shows an example configuration file for a laser beam printer simulation program (filename "lbp.cfg").

```
// System Definition
 system{
    stack_size              = 1024;
    priority                = 5;
    system_IPL              = 4;
    tick_nume               = 10;
 };
 //System Clock Definition
 clock{
    mpu_clock               = 20MHz;
    timer                   = A0;
    IPL                     = 4;
};
 //Task Definition
 task[1]{
    name                    = ID_main;
    entry_address           = main();
    stack_size              = 512;
    priority                = 1;
    initial_start           = ON;
 };
 task[2]{
    name                    = ID_image;
    entry_address           = image();
    stack_size              = 512;
    priority                = 2;
 };
 task[3]{
    name                    = ID_printer;
    entry_address           = printer();
    stack_size              = 512;
    priority                = 4;
 };
 task[4]{
    name                    = ID_idle;
    entry_address           = idle();
    stack_size              = 256;
    priority                = 5;
 };
//Eventflag Definition
 flag[1]{
     name                   = pagein;
 };
 //Interrupt Vector Definition
 interrupt_vector[0x23]{
    os_int                  = YES;
    entry_address           = sent_in();
 };
```

Figure 4.3 Configuration File Example

4.2.3 Configurator Execution

When using HEW, select "Build all," which enables the user to execute the procedures described in 4.2.3, "Executing the Configurator," and 4.2.4, "System Generation."

Execute the configurator cfg308 to generate system data definition files (sys_rom.inc, sys_ram.inc), include files (mr308.inc, kernel_id.h), and a system generation procedure description file (makefile) from the configuration file.

```
A> cfg308  -mv  lbp.cfg

MR308 system configurator V.4.00.06
Copyright 2003,2005 RENESAS TECHNOLOGY CORPORATION
AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED.
MR308 version ==> V.4.00 Release 01

A>
```

Figure 4.4 Configurator Execution

4.2.4 System generation

Execute the make command [43] to generate the system.

```
A> make -f  makefile
as308 -F -Dtest=1 crt0mr.a30
nc308 -c task.c
ln308 @ln308.sub

A>
```

Figure 4.5 System Generation

4.2.5 Writing ROM

Using the lmc308 load module converter, convert the absolute module file into a ROM writable format and then write it into ROM. Or read the file into the debugger and debug it.

[43] There are two types of make commands, one of which conforms to the MS-DOS standard, and the other conforms to or is compliant with the UNIX standard. MR308 accepts only the make command that conforms to or is compliant with the UNIX standard. When using MS-DOS, use a UNIX compatible make command (e.g., the make command included with the C compiler from Microsoft Corporation). For details about the usefulness of UNIX compatible make commands, refer to the release notes from Renesas. The description in this chapter is made for the case where a UNIX compatible make command is executed, as an example.

Chapter 5 Detailed Applications

5.1 Program Coding Procedure in C Language

5.1.1 Task Description Procedure

1. Describe the task as a function.

To register the task for the MR308, enter its function name in the configuration file. When, for instance, the function name "task()" is to be registered as the task ID number 3, proceed as follows.

```
task[3]{
        name            = ID_task;

        entry_address   = task();

        stack_size      = 100;

        priority        = 3;

};
```

2. At the beginning of file, be sure to include "itron.h",”kernel.h” which is in system directory as well as "kernel_id.h" which is in the current directory. That is, be sure to enter the following two lines at the beginning of file.

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"
```

3. No return value is provided for the task start function. Therefore, declare the task start function as a void function.

4. A function that is declared to be static cannot be registered as a task.

5. It isn't necessary to describe ext_tsk() at the exit of task start function.[44]If you exit the task from the subroutine in task start function, please describe ext_tsk() in the subroutine.

6. It is also possible to describe the task startup function, using the infinite loop.

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void task(void)
{

        /* process */

}
```

Figure 5.1 Example Infinite Loop Task Described in C Language

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void task(void)
{
        for(;;){
                /* process */

        }
}
```

Figure 5.2 Example Task Terminating with ext_tsk() Described in C Language

[44] The task is ended by ext_tsk() automatically if #pramga TASK is declared in the MR308. Similarly, it is ended by ext_tsk when returned halfway of the function by return sentence.

7. To specify a task, use the string written in the task definition item "name" of the configuration file.[45]

```
wup_tsk(ID_main);
```

8. To specify an event flag, semaphore, or mailbox, use the respective strings defined in the configuration file.

For example, if an event flag is defined in the configuration file as shown below,

```
flag[1]{
        name    = ID_abc;
};
```

To designate this eventflag, proceed as follows.

```
set_flg(ID_abc,&setptn);
```

9. To specify a cyclic or alarm handler, use the string written in the cyclic or alarm handler definition item "name" of the configuration file.

```
sta_cyc(ID_cyc);
```

10. When a task is reactivated by the sta_tsk() service call after it has been terminated by the ter_tsk() service call, the task itself starts from its initial state.[46] However, the external variable and static variable are not automatically initialized when the task is started. The external and static variables are initialized only by the startup program (crt0mr.a30), which actuates before MR308 startup.

11. The task executed when the MR308 system starts up is setup.

12. The variable storage classification is described below.

The MR308 treats the C language variables as indicated in Table 5.1.

Table 5.1 C Language Variable Treatment

Variable storage class	Treatment
Global Variable	Variable shared by all tasks
Non-function static variable	Variable shared by the tasks in the same file
Auto Variable Register Variable Static variable in function	Variable for specific task

[45] The configurator generates the file "kernel_id.h" that is used to convert the ID number of a task into the string to be specified. This means that the #define declaration necessary to convert the string specified in the task definition item "name" into the ID number of the task is made in "kernel_id.h." The same applies to the cyclic and alarm handlers.

[46] The task starts from its start function with the initial priority in a wakeup counter cleared state.

5.1.2 Writing a Kernel (OS Dependent) Interrupt Handler

When describing the kernel (OS-dependent) interrupt handler in C language, observe the following precautions.

1. **Describe the kernel(OS-dependent) interrupt handler as a function [47]**
2. **Be sure to use the void type to declare the interrupt handler start function return value and argument.**
3. **At the beginning of file, be sure to include "itron.h",”kernel.h” which is in the system directory as well as "kernel_id.h" which is in the current directory.**
4. **Do not use the ret_int service call in the interrupt handler.[48]**
5. **The static declared functions can not be registered as an interrupt handler.**

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void inthand(void)

{
        /* process */

        iwup_tsk(ID_main);
}
```

Figure 5.3 Example of Kernel(OS-dependent) Interrupt Handler

[47] A configuration file is used to define the relationship between handlers and functions.
[48] When an kernel(OS-dependent) interrupt handler is declared with #pragma INTHANDLER ,code for the ret_int service call is automatically generated.

5.1.3 Writing Non-kernel (OS-independent) Interrupt Handler

When describing the non-kernel(OS-independent) interrupt handler in C language, observe the following precautions.

1. **Be sure to declare the return value and argument of the interrupt handler start function as a void type.**
2. **No service call can be issued from a non-kernel(an OS-independent) interrupt handler.**
   NOTE: If this restriction is not observed, the software may malfunction.
3. **A function that is declared to be static cannot be registered as an interrupt handler.**
4. **If you want multiple interrupts to be enabled in a non-kernel(an OS-independent) interrupt handler, always make sure that the non-kernel(OS-independent) interrupt handler is assigned a priority level higher than other kernel(OS-dependent) interrupt handlers.[49]**

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void inthand(void)
{
        /* process */
}
```

Figure 5.4 Example of Non-kernel(OS-independent) Interrupt Handler

[49] If you want the non-kernel(OS-independent) interrupt handler to be assigned a priority level lower than kernel(OS-dependent) interrupt handlers, change the description of the non-kernel(OS-independent) interrupt handler to that of the kernel (OS-dependent) interrupt handler.

5.1.4 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in C language, observe the following precautions.

1. **Describe the cyclic or alarm handler as a function.[50]**
2. **Be sure to declare the return value and argument of the interrupt handler start function as a void type.**
3. **At the beginning of file, be sure to include "itron.h",”kernel.h” which is in the system directory as well as "kernel_id.h" which is in the current directory.**
4. **The static declared functions cannot be registered as a cyclic handler or alarm handler.**
5. **The cyclic handler and alarm handler are invoked by a subroutine call from a system clock interrupt handler.**

```
#include <itron.h>
#include <kernel.h>
#include "kernel_id.h"

void cychand(void)
{
        /*process */
}
```

Figure 5.5 Example Cyclic Handler Written in C Language

[50] The handler-to-function name correlation is determined by the configuration file.

5.2 Program Coding Procedure in Assembly Language

This section describes how to write an application using the assembly language.

5.2.1 Writing Task

This section describes how to write an application using the assembly language.

1. **Be sure to include "mr308.inc" at the beginning of file.**
2. **For the symbol indicating the task start address, make the external declaration.[51]**
3. **Be sure that an infinite loop is formed for the task or the task is terminated by the ext_tsk service call.**

```
        .INCLUDE mr308.inc ----- (1)
        .GLB    task    ----- (2)

task:
                ; process
        jmp   task      ----- (3)
```

Figure 5.6 Example Infinite Loop Task Described in Assembly Language

```
        .INCLUDE mr308.inc
        .GLB    task

task:
                ; process
        ext_tsk
```

Figure 5.7 Example Task Terminating with ext_tsk Described in Assembly Language

4. **The initial register values at task startup are indeterminate except the PC, SB, R0 and FLG registers.**
5. **To specify a task, use the string written in the task definition item “name” of the configuration file.**

```
wup_tsk  #ID_task
```

6. **To specify an event flag, semaphore, or mailbox, use the respective strings defined in the configuration file.**

   For example, if a semaphore is defined in the configuration file as shown below,:

```
semaphore[1]{
        name            = abc;
};
```

   To specify this semaphore, write your specification as follows:

```
sig_sem  #ID_abc
```

7. **To specify a cyclic or alarm handler, use the string written in the cyclic or alarm handler definition item “name” of the configuration file**

   For example, if you want to specify a cyclic handler "cyc," write your specification as follows:

```
sta_cyc  #ID_cyc
```

[51] Use the .GLB pseudo-directive

8. Set a task that is activated at MR308 system startup in the configuration file [52]

[52] The relationship between task ID numbers and tasks(program) is defined in the configuration file.

5.2.2 Writing Kernel(OS-dependent) Interrupt Handler

When describing the kernel(OS-dependent) interrupt handler in assembly language, observe the following precautions

1. **At the beginning of file, be sure to include "mr308.inc" which is in the system directory.**
2. **For the symbol indicating the interrupt handler start address, make the external declaration(Global declaration).[53]**
3. **Make sure that the registers used in a handler are saved at the entry and are restored after use.**
4. **Return to the task by ret_int service call.**

```
        .INCLUDE mr308.inc              ------(1)
        .GLB    inth                    ------(2)

inth:
        ;  Registers used are saved to a stack   ------(3)
        iwup_tsk  #ID_task1
                :
                process
                :

        ;  Registers used are restored  ------(3)

        ret_int                         ------(4)
```

Figure 5.8 Example of kernel(OS-depend) interrupt handler

[53] Use the .GLB peudo-directive.

5.2.3 Writing Non-kernel(OS-independent) Interrupt Handler

1. **For the symbol indicating the interrupt handler start address, make the external declaration (public declaration).**
2. **Make sure that the registers used in a handler are saved at the entry and are restored after use.**
3. **Be sure to end the handler by REIT instruction.**
4. **No service calls can be issued from a non-kernel(an OS-independent) interrupt handler.**
   NOTE: If this restriction is not observed, the software may malfunction.

5. **If you want multiple interrupts to be enabled in a non-kernel(an OS-independent) interrupt handler, always make sure that the non-kernel(OS-independent) interrupt handler is assigned a priority level higher than other non-kernel(OS-dependent) interrupt handlers.[54]**

```
        .GLB    inthand                 ----- (1)

inthand:
        ; Registers used are saved to a stack    ----- (2)
        ; interrupt process
        ; Registers used are restored   ----- (2)
        REIT                            ----- (3)
```

Figure 5.9 Example of Non-kernel(OS-independent) Interrupt Handler of Specific Level

[54] If you want the non-kernel(OS-independent) interrupt handler to be assigned a priority level lower than kernel(OS-dependent) interrupt handlers, change the description of the non-kernel(OS-independent) interrupt handler to that of the kernel (OS-dependent) interrupt handler.

5.2.4 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in Assembly Language, observe the following precautions.

1. **At the beginning of file, be sure to include "mr308.inc" which is in the system directory.**
2. **For the symbol indicating the handler start address, make the external declaration.[55]**
3. **Always use the RTS instruction (subroutine return instruction) to return from cyclic handlers and alarm handlers.**

   For examples:

```
.INCLUDE        mr308.inc       ----- (1)
.GLB            cychand         ----- (2)

cychand:
                :
        ; handler process
                :

        rts                     ----- (3)
```

Figure 5.10 Example Handler Written in Assembly Language

[55] Use the .GLB pseudo-directive.

5.3 The Use of INT Instruction

MR308 has INT instruction interrupt numbers reserved for issuing service calls as listed in Table 5.2. For this reason, when using software interrupts in a user application, do not use interrupt numbers 63 through 55 and be sure to use some other numbers.

Table 5.2 Interrupt Number Assignment

Interrupt No.	Service calls Used
63	Service calls that can be issued from only task context
62	Service calls that can be issued from only non-task context. Service calls that can be issued from both task context and non-task context.
61	ret_int service call
60	dis_dsp service call
59	loc_cpu, iloc_cpu service call
58	ext_tsk service call
55	tsnd_dtq, twai_flg, vtsnd_dtq service call

5.4 The Use of registers of bank

The registers of bank is 0, when a task starts on MR308.

MR308 does not change the registers of bank in processing kernel.

You must pay attention to the followings.

- Don’t change the regisers of bank in processing a task.
- If an interrupt handler with regisers of bank 1 have multiple interrupts of an interrupt handler with regisers of bank 1 , the program can not execute normally.

5.5 Regarding Interrupts

5.5.1 Types of Interrupt Handlers

MR308's interrupt handlers consist of kernel(OS-dependent) interrupt handlers and non-kernel (OS-independent) interrupt handlers.

The following shows the definition of each type of interrupt handler.

- Kernel(OS-dependent) interrupt handler
  The kernel(OS-dependent) interrupt handler is defined as one that satisfies one of the following two conditions:

  ♦ Interrupt handlers issuing a service call

  ♦ Interrupt handlers including multiple interrupt handlers issuing a service call

  The kernel(OS-dependent) interrupt handler's IPL value must be below the kernel mask level (OS interrupt disable level = system.IPL). IPL = 0 to system.IPL[56]

- Non-kernel(OS-independent) interrupt handler
  The non-kernel(OS-independent) interrupt handler is defined as one that satisfies both of the following two conditions:

  ♦ Interrupt handlers not issuing a service call

  ♦ Interrupt handlers that do not have multiple interrupts of interrupt handlers issuing a service call (system clock interrupt handler)

  The non-kernel(OS-independent) interrupt handler's IPL value must be between (system.IPL + 1) to 7. Namely, the non-kernel(OS-independent) interrupt handler's IPL value cannot be set below the kernel(OS-independent) interrupt disable level.

Figure 5.11 shows the relationship between the non-kernel(OS-independent) interrupt handlers and kernel(OS-dependent) interrupt handlers where the kernel mask level(OS interrupt disable level) is set to 3.

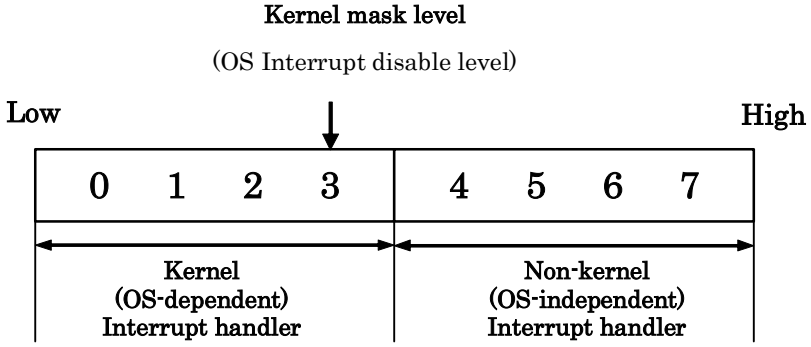


Figure 5.11 Interrupt handler IPLs

5.5.2 The Use of Non-maskable Interrupt

An NMI interrupt and Watchdog Timer interrupt have to use be a non-kernel(OS independent) interrupt handler. If they are a kernel(OS dependent) interrupt handler, the program will not work normally.

[56] system.IPL is set by the configuration file.

5.5.3 Controlling Interrupts

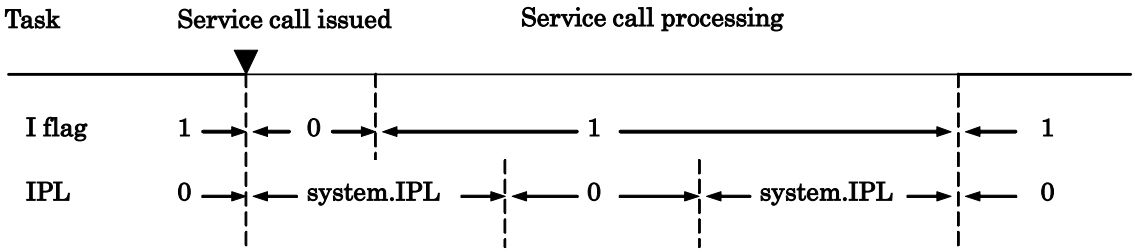
Interrupt enable/disable control in a service call is accomplished by IPL manipulation. The IPL value in a service call is set to the kernel mask level(OS interrupt disable level = system.IPL) in order to disable interrupts for the kernel(OS-dependent) interrupt handler. In sections where all interrupts can be enabled, it is returned to the initial IPL value when the service call was invoked.

Figure 5.12 Interrupt control in a System Call that can be Issued from only a Task

shows the interrupt enable flag and IPL status in a service call.

- For service calls that can be issued from only task context.

When the I flag before issuing a service call is 1.



When the I flag before issuing a service call is 0.

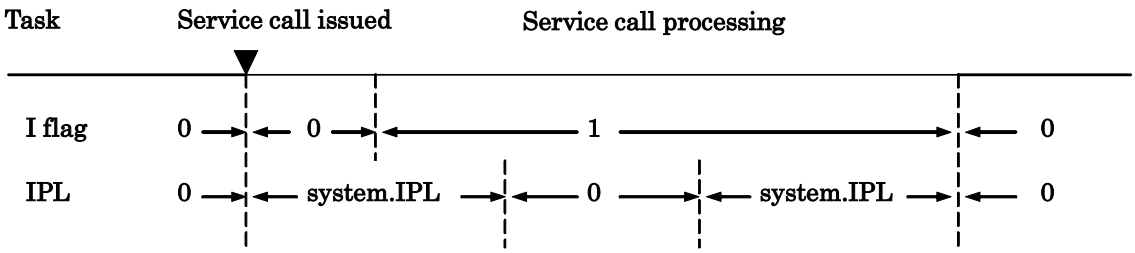
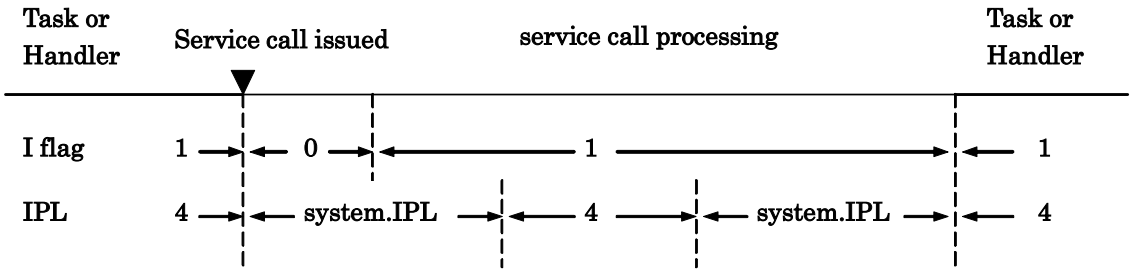


Figure 5.12 Interrupt control in a System Call that can be Issued from only a Task

- For service calls that can be issued from only non-task context or from both task context and non-task context.

When the I flag before issuing a service call is 1



When the I flag before issuing a service call is 0

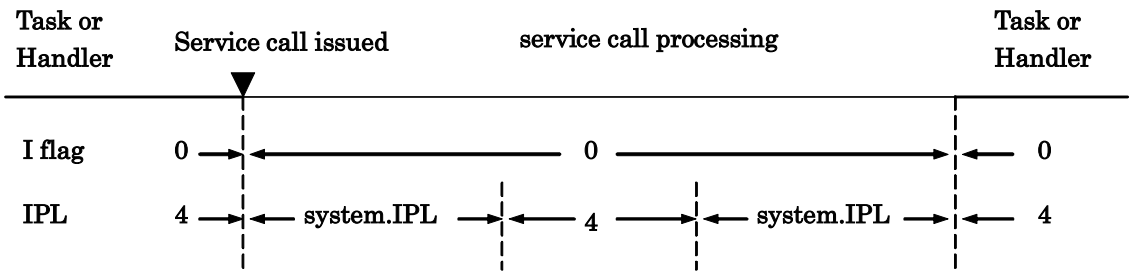


Figure 5.13 Interrupt control in a System Call that can be Issued from a Task-independent

As shown in Figure 5.12 Interrupt control in a System Call that can be Issued from only a Task

and Figure 5.13 Interrupt control in a System Call that can be Issued from a Task-independent

, the interrupt enable flag and IPL change in a service call. For this reason, if you want to disable interrupts in a user application, Renesas does not recommend using the method for manipulating the interrupt disable flag and IPL to disable the interrupts.

The following two methods for interrupt control are recommended:

1. **Modify the interrupt control register (SFR) for the interrupt you want to be disabled.**
2. **Use service calls loc_cpu and unl_cpu.**
   The interrupts that can be controlled by the loc_cpu service call are only the kernel(OS-dependent) interrupt. Use method 1 to control the non-kernel(OS-independent) interrupts.

5.6 Regarding Delay Dispatching

MR308 has four service calls related to delay dispatching.

- dis_dsp
- ena_dsp
- loc_cpu
- unl_cpu

The following describes task handling when dispatch is temporarily delayed by using these service calls.

1. When the execution task in delay dispatching is preempted

While dispatch is disabled, even under conditions where the task under execution should be preempted, no time is dispatched to new tasks that are in an executable state. Dispatching to the tasks to be executed is delayed until the dispatch disabled state is cleared. When dispatch is being delayed.

- Task under execution is in a RUNNING state and is linked to the ready queue
- Task to be executed after the dispatch disabled state is cleared is in a READY state and is linked to the highest priority ready queue (among the queued tasks).

2. isus_tsk,irsm_tsk during dispatch delay

In cases when isus_tsk is issued from an interrupt handler that has been invoked in a dispatch disabled state to the task under execution (a task to which dis_dsp was issued) to place it in a SUSPENDED state. During delay dispatching.

- The task under execution is handled inside the OS as having had its delay dispatching cleared. For this reason, in isus_tsk that has been issued to the task under execution, the task is removed from the ready queue and placed in a SUSPENDED state. Error code E_OK is returned. Then, when irsm_tsk is issued to the task under execution, the task is linked to the ready queue and error code E_OK is returned. However, tasks are not switched over until delay dispatching is cleared.
- The task to be executed after disabled dispatching is re-enabled is linked to the ready queue.

3. rot_rdq, irot_rdq during dispatch delay

When rot_rdq (TPRI_RUN = 0) is issued during dispatch delay, the ready queue of the own task's priority is rotated. Also, when irot_rdq (TPRI_RUN = 0) is issued, the ready queue of the executed task's priority is rotated. In this case, the task under execution may not always be linked to the ready queue. (Such as when isus_tsk is issued to the executed task during dispatch delay.)

4. Precautions

- No service call (e.g., slp_tsk, wai_sem) can be issued that may place the own task in a wait state while in a state where dispatch is disabled by dis_dsp or loc_cpu.
- Note that ena_dsp and dis_dsp cannot be issued while the system is placed in a CPU locked state by loc_cpu.
- Disabled dispatch is re-enabled by issuing ena_dsp once after issuing dis_dsp several times.

5.7 Regarding Initially Activated Task

MR308 permits the user to specify a task that starts from a READY state at system startup time. To do this, add TA_STA as task attribute. This specification should be set in a configuration file.

For details on how to set, refer to page - 105 -.

5.8 Modifying MR308 Startup Program

MR308 comes with two types of startup programs as described below.

- start.a30
  This startup program is used when you created a program using the assembly language.

- crt0mr.a30
  This startup program is used when you created a program using the C language.

  This program is derived from "start.a30" by adding an initialization routine in C language.

The startup programs perform the following:

- Initialize the processor after a reset.
- Initialize C language variables (crt0mr.a30 only).
- Set the system timer.
- Initialize MR308's data area.

Copy these startup programs from the directory indicated by environment variable "LIB308" to the current directory.If necessary, correct or add the sections below:

When using HEW, the user can choose to automatically generate a sample during project generation or use an already created one.

- Setting processor mode register
  Set a processor mode matched to your system to the processor mode register.

- Adding user-required initialization program
  To add an initialization program needed for the user, add it at a place immediately preceding the initialization of standard input/output functions in the C language startup program (crt0mr.a30).

  If the standard input/output functions are unused, make the relevant part a comment.

5.8.1 C Language Startup Program (crt0mr.a30)

Figure 5.14 C Language Startup Program (crt0mr.a30)

shows the C language startup program(crt0mr.a30).

```
 1 ;*****************************************************************
 2 ;
 3 ;      MR308 start up program for C language
 4 ;      COPYRIGHT(C) 2003 RENESAS TECHNOLOGY CORPORATION
 5 ;      AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 6 ;      MR308 V.1.10 Release 1
 7 ;
 8 ; ****************************************************************
 9 ;        "$Id: crt0mr.a30,v 1.1 2005/05/20 06:28:47 inui Exp $"
10 ;*A1* 2005-02-28 for ES
11 ;
12        .LIST   OFF
13        .INCLUDE       c_sec.inc
14        .INCLUDE       mr308.inc
15        .INCLUDE       sys_rom.inc
16        .INCLUDE       sys_ram.inc
17        .LIST   ON
18
19        .GLB    __SYS_INITIAL
20        .GLB    __END_INIT
21        .GLB    __init_sys,__init_tsk
22
23        .IF           M16C70!=0
24 regoffset      .EQU    -0220H
25        .ELSE
26 regoffset      .EQU    0
27        .ENDIF
28
29 ;---------------------------------------------------------------------
30 ; SBDATA area definition
31 ;---------------------------------------------------------------------
32        .GLB    __SB__
33        .SB     __SB__
34
35 ;=====================================================================
36 ; Initialize Macro declaration
37 ;---------------------------------------------------------------------
38 N_BZERO .MACRO  TOP_,SECT_
39        MOV.B   #00H, R0L
40        MOV.L   #TOP_, A1
41        MOV.W   #sizeof SECT_, R3
42        SSTR.B
43        .ENDM
44
45 N_BCOPY .MACRO  FROM_,TO_,SECT_
46        MOV.L   #FROM_,A0
47        MOV.L   #TO_,A1
48        MOV.W   #sizeof SECT_, R3
49        SMOVF.B
50        .ENDM
51
52 BZERO   .MACRO  TOP_,SECT_
53        .local  _end, _loop
54
55        MOV.L   #TOP_, A1
56        MOV.B   #00H, R0L
57        MOV.L   #(sizeof SECT_ & 0FFFFFFH), R3R1
58        XCHG.W  R1,R3
59 _loop:
60        SSTR.B
61        CMP.W   #0,R1
62        JEQ     _end
63        MOV.B   R0L,[A1]
64        ADD.L   #1,A1
65        MOV.W   #0FFFFH,R3
66        SUB.W   #1,R1
67        JMP     _loop
68 _end:
69        .ENDM
70
71 BCOPY   .MACRO  FROM_,TO_,SECT_
72        .local  _end, _loop
```

```
 73
 74        MOV.L   #FROM_,A0
 75        MOV.L   #TO_,A1
 76        MOV.L   #(sizeof SECT_ & 0FFFFFFH), R3R1
 77        XCHG.W  R1,R3
 78 _loop:
 79        SMOVF.B
 80        CMP.W   #0,R1
 81        JEQ     _end
 82        MOV.B   [A0],[A1]
 83        ADD.L   #1,A1
 84        ADD.L   #1,A0
 85        MOV.W   #0FFFFH,R3
 86        SUB.W   #1,R1
 87        JMP     _loop
 88 _end:
 89        .ENDM
 90
 91 ;=====================================================================
 92 ; Interrupt section start
 93 ;---------------------------------------------------------------------
 94        .SECTION       MR_KERNEL,CODE,ALIGN
 95
 96 ;---------------------------------------------------------------------
 97 ; after reset,this program will start
 98 ;---------------------------------------------------------------------
 99 __SYS_INITIAL:
100        LDC     #__Sys_Sp,ISP   ; set initial ISP
101
102        MOV.B   #2,0AH
103        MOV.B   #00,PMOD              ; Set Processor Mode Register
104        MOV.B   #0,0AH
105        LDC     #0010H,FLG
106        LDC     #__SB__,SB
107        LDC     #0000H,FLG
108        LDC     #__Sys_Sp,FB
109        LDC     #__SB__,SB
110
111 ; +-----------------------------------------------------+
112 ; |     ISSUE SYSTEM CALL DATA INITIALIZE               |
113 ; +-----------------------------------------------------+
114        ; For PD308
115        __INIT_ISSUE_SYSCALL
116
117 ;=====================================================================
118 ; MR_RAM zero clear
119 ;---------------------------------------------------------
120        N_BZERO MR_RAM_NE_top,MR_RAM_NE
121        N_BZERO MR_RAM_NO_top,MR_RAM_NO
122        BZERO   MR_RAM_top,MR_RAM
123
124 ;=====================================================================
125 ; NEAR area initialize.
126 ;---------------------------------------------------------
127 ; bss zero clear
128 ;---------------------------------------------------------
129        N_BZERO bss_SE_top,bss_SE
130        N_BZERO bss_SO_top,bss_SO
131
132        N_BZERO bss_NE_top,bss_NE
133        N_BZERO bss_NO_top,bss_NO
134
135 ;---------------------------------------------------------
136 ; initialize data section
137 ;---------------------------------------------------------
138        N_BCOPY data_SEI_top,data_SE_top,data_SE
139        N_BCOPY data_SOI_top,data_SO_top,data_SO
140        N_BCOPY data_NEI_top,data_NE_top,data_NE
141        N_BCOPY data_NOI_top,data_NO_top,data_NO
142
143 ;=====================================================================
144 ; FAR area initialize.
145 ;---------------------------------------------------------
146 ; bss zero clear
147 ;---------------------------------------------------------
148        BZERO   bss_FE_top,bss_FE
149        BZERO   bss_FO_top,bss_FO
150
151 ;---------------------------------------------------------
152 ; Copy edata_E(O) section from edata_EI(OI) section
```

```
153 ;-------------------------------------------------------
154       BCOPY   data_FEI_top,data_FE_top,data_FE
155       BCOPY   data_FOI_top,data_FO_top,data_FO
156
157       LDC     #__Sys_Sp,SP
158       LDC     #__Sys_Sp,FB
159
160
161 ;---------------------------------------------------------------------
162 ; Set System IPL and Set Interrupt Vector
163 ;---------------------------------------------------------------------
164       MOV.B   #0,R0L
165       MOV.B   #__SYS_IPL,R0H
166       LDC     R0,FLG
167       LDC     #__INT_VECTOR,INTB
168
169 ; +-----------------------------------------------------+
170 ; |     System timer interrupt setting                  |
171 ; +-----------------------------------------------------+
172    .IF USE_TIMER
173       MOV.B   #stmr_mod_val,stmr_mod_reg+regoffset    ; set timer mode
174       MOV.W   #stmr_cnt,stmr_ctr_reg+regoffset       ; set interval count
175       MOV.B   #stmr_int_IPL,stmr_int_reg             ; set timer IPL
176       OR.B    #stmr_bit+1,stmr_start+regoffset       ; system timer start
177    .ENDIF
178
179 ; +-----------------------------------------------------+
180 ; |     System timer initialize                         |
181 ; +-----------------------------------------------------+
182    .IF USE_SYSTEM_TIME
183       MOV.W   #__D_Sys_TIME_L,__Sys_time+4
184       MOV.W   #__D_Sys_TIME_M,__Sys_time+2
185       MOV.W   #__D_Sys_TIME_H,__Sys_time
186    .ENDIF
187
188 ; +-----------------------------------------------------+
189 ; |     User Initial Routine ( if there are )           |
190 ; +-----------------------------------------------------+
191 ; Initialize standard I/O
192       .GLB    _init
193       JSR.A   _init
194
195 ; +-----------------------------------------------------+
196 ; |     Initalization of System Data Area               |
197 ; +-----------------------------------------------------+
198       JSR.W   __init_sys
199       JSR.W   __init_tsk
200
201    .IF __MR_TIMEOUT
202       .GLB    __init_tout
203       JSR.W   __init_tout
204    .ENDIF
205
206    .IF __NUM_FLG
207       .GLB    __init_flg
208       JSR.W   __init_flg
209    .ENDIF
210
211    .IF __NUM_SEM
212       .GLB    __init_sem
213       JSR.W   __init_sem
214    .ENDIF
215
216    .IF   __NUM_DTQ
217  .GLB    __init_dtq
218  JSR.W   __init_dtq
219    .ENDIF
220
221    .IF   __NUM_VDTQ                        ;*A1*
222  .GLB    __init_vdtq
223  JSR.W   __init_vdtq
224    .ENDIF
225
226    .IF __NUM_MBX
227       .GLB    __init_mbx
228       JSR.W   __init_mbx
229    .ENDIF
230
231    .IF ALARM_HANDLER
232       .GLB    __init_alh
```

```
233         JSR.W   __init_alh
234     .ENDIF
235
236     .IF CYCLIC_HANDLER
237         .GLB    __init_cyh
238         JSR.W   __init_cyh
239     .ENDIF
240
241     .IF   __NUM_MPF                         ;*A1*
242  ; Fixed Memory Pool
243  .GLB    __init_mpf
244  JSR.W   __init_mpf
245     .ENDIF
246
247     .IF   __NUM_MPL                         ;*A1*
248  ; Variable Memory Pool
249  .GLB    __init_mpl
250  JSR.W   __init_mpl
251     .ENDIF
252
253         ; For PD308
254         __LAST_INITIAL
255
256 __END_INIT:
257
258 ; +-----------------------------------------------------+
259 ; |       Start initial active task                 |
260 ; +-----------------------------------------------------+
261         __START_TASK
262
263         .GLB    __rdyq_search
264         JMP.W   __rdyq_search
265
266 ; +-------------------------------------------+
267 ; |     Define Dummy                          |
268 ; +-------------------------------------------+
269         .GLB    __SYS_DMY_INH
270 __SYS_DMY_INH:
271         REIT
272
273 .IF     CUSTOM_SYS_END
274 ; +-------------------------------------------+
275 ; | Syscall exit rouitne to customize
276 ; +-------------------------------------------+
277         .GLB    __sys_end
278 __sys_end:
279         ; Customize here.
280         REIT
281 .ENDIF
282
283 ; +-------------------------------------------+
284 ; |           exit() function                 |
285 ; +-------------------------------------------+
286         .GLB    _exit,$exit
287 _exit:
288 $exit:
289         JMP     _exit
290
291 .IF USE_TIMER
292 ; +-------------------------------------------+
293 ; |      System clock interrupt handler       |
294 ; +-------------------------------------------+
295         .GLB          __SYS_STMR_INH
296         .ALIGN
297 __SYS_STMR_INH:
298         ; process issue system call
299         ; For PD308
300         __ISSUE_SYSCALL
301
302         ; System timer interrupt handler
303         _STMR_hdr
304
305         ret_int
306 .ENDIF
```

Figure 5.14 C Language Startup Program (crt0mr.a30)

The following explains the content of the C language startup program (crt0mr.a30).

1. **Incorporate a section definition file [13 in Figure 5.14]**
2. **Incorporate an include file for MR308 [14 in Figure 5.14]**
3. **Incorporate a system ROM area definition file [15 in Figure 5.14]**
4. **Incorporate a system RAM area definition file [16 in Figure 5.14]**
5. **This is the initialization program __SYS_INITIAL that is activated immediately after a reset. [99 - 256 in Figure 5.14]**
   - Setting the System Stack pointer [100 in Figure 5.14]
   - Setting the processor mode register [102 - 104 in Figure 5.14]
   - Setting the SB,FB register [105 - 109 in Figure 5.14]
   - Initial set the C language. [129 - 155 in Figure 5.14] When using no standard input/output functions, remove the lines 191 and 192 in Figure 5.14.
   - Setting OS interrupt disable level [164 - 166 in Figure 5.14]
   - Setting the address of interrupt vector table [167 in Figure 5.14]
   - Set MR308's system clock interrupt [172-177 in Figure 5.14]
   - Initial set MR308's system timer [182-186 in Figure 5.14]
6. **Initial set parameters inherent in the application [191 in Figure 5.14]**
7. **Initialize the RAM data used by MR308 [198-251 in Figure 5.14]**
8. **Activate the initial startup task. [254 in Figure 5.14]**
9. **This is a system clock interrupt handler [295-306 in Figure 5.14]**

5.9 Memory Allocation

This section describes how memory is allocated for the application program data.

Use the section file provided by MR308 to set memory allocation.

MR308 comes with the following two types of section files:

- asm_sec.inc
  This file is used when you developed your applications with the assembly language.
  Refer to page - 91 - for details about each section.

- c_sec.inc
  This file is used when you developed your applications with the C language.
  c_sec.inc is derived from "asm_sec.inc" by adding sections generated by C compiler NC308.
  Refer to page - 92 - for details about each section.

Modify the section allocation and start address settings in this file to suit your system.

The following shows how to modify the section file.

e.g.

If you want to change the program section start address from F0000H to F1000H

```
.section        program
.org    0F0000H ; Correct this address to F1000H

        ↓

.section        program

.org    0F1000H ;
```

5.9.1 Section Allocation of start.a30

The section allocation of the sample startup program for the assembly language "start.a30" is defined in "asm_sec.inc".

Edit "asm_sec.inc" if section reallocation is required.

The following explains each section that is defined in the sample section definition file "asm_sec.inc".

- MR_RAM_DBG section
  This section stores the MR308's Debug functions RAM data.
  This section must be mapped the internal area.
- MR_RAM_NE section
- MR_RAM_NO section
  This section is where the RAM data, MR308's system management data, is stored that is referenced in absolute addressing.
  This section must be mapped between 0 and 0FFFFH (near area).
- MR_RAM section
  This section is where the RAM data, MR308's system management data, is stored that is referenced in absolute addressing.
- stack section
  This is the section for the default user stack of each task and for the system stack.
- MR_HEAP section
  This is the section in which the variable-size memory pool, fixed-size memory pool, and data queue area are stored.
- MR_KERNEL section
  This section stores MR308 kernel program..
- MR_CIF section
  This section stores the MR308 C language interface library.
- MR_ROM section
  This section stores data such as task start addresses that area referenced by the MR308 kernel.
- program section
  This section stores user programs.
  This section is not used by the MR308 kernel at all. Therefore, you can use this section as desired.
- program_S section
  This section stores the functions invoked by aspecial page call.
  This section is not used by the MR308 kernel at all.
- fvector section
  This section stores the vector address of special page calls.
  This section is not used by the MR308 kernel at all.
- INTERRUPT_VECTOR section
- FIX_INTERRUPT_VECTOR section
  This section stores interrupt vectors. The start address of this section varies with the type of M16C/80 series microcomputer used. The address in the sample startup program is provided for use by the M16C/80 series micro-computers. This address must be modified if you are using a microcomputer of some other group.

5.9.2 Section Allocation of crt0mr.a30

The section allocation of the sample startup program for the C language "crt0mr.a30" is defined in "c_sec.inc".

Edit "c_sec.inc" if section reallocation is required.

The sections defined in the sample section definition file "c_sec.inc" include the following sections that are defined in the section definition file "asm_sec.inc" of the sample startup program for the assembly language.

- data_SE section
- bss_SE section
- data_SO section
- bss_SO section
- data_NE section
- bss_NE section
- data_NO section
- bss_NO section
- rom_NE section
- rom_NO section
- data_FE section
- bss_FE section
- data_FO section
- bss_FO section
- rom_FE section
- rom_FO section
- data_SEI section
- data_SOI section
- data_NEI section
- data_NOI section
- data_FEI section
- data_FOI section

  These sections are those that are generated by NC308. These sections are not defined in the section file for the assembly language.

  Refer to the NC308 manual for details.

The diagram below shows the section allocation in the sample startup program. (See Figure 5.15 Selection Allocation in C Language Startup Program

)

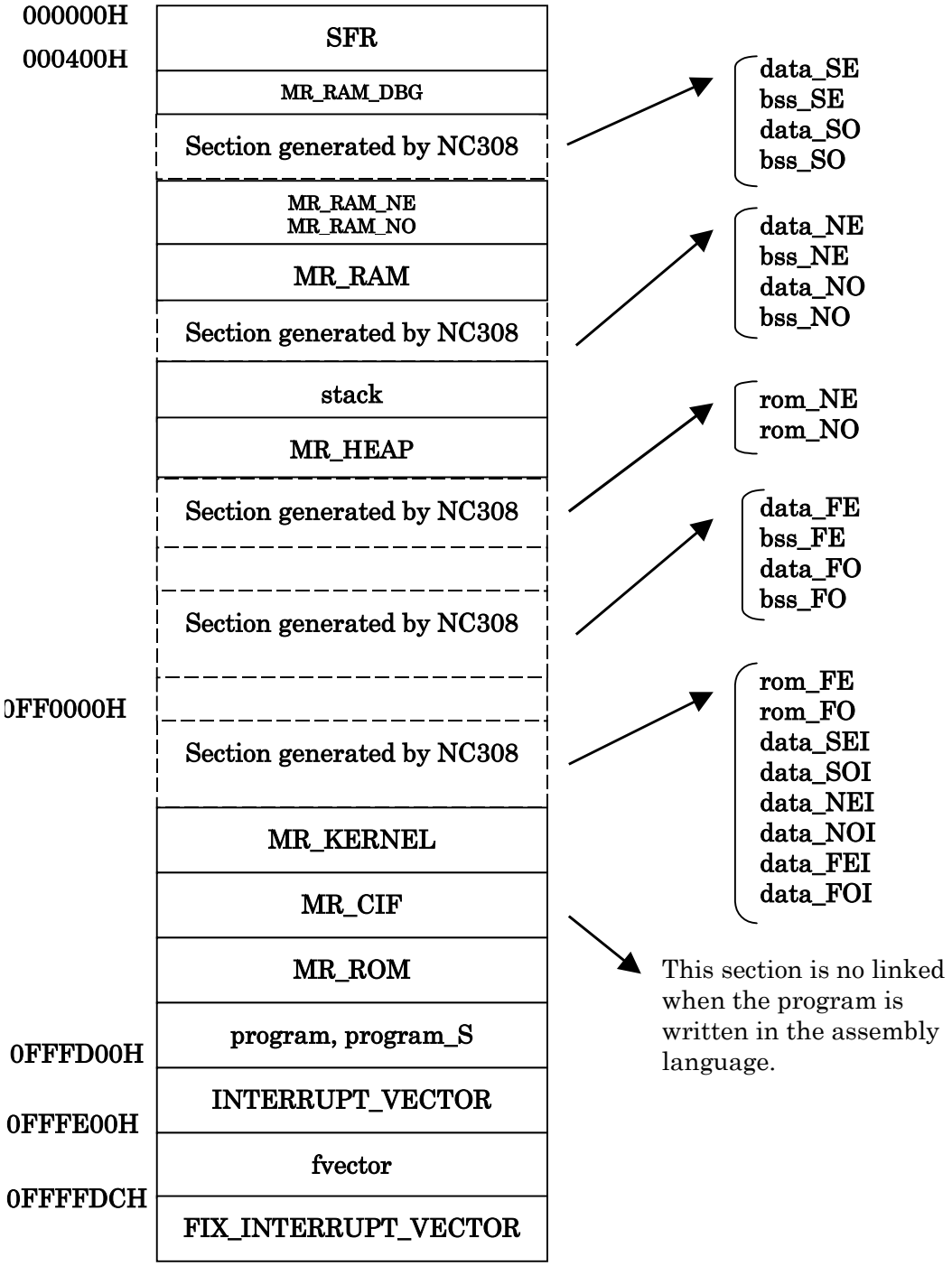


Figure 5.15 Selection Allocation in C Language Startup Program

5.10 Using in M16C/70 Series

When you use M16C/70 series, please be sure to set up the following options.
Refer to the manual of each tool for detailed explanation of these options.

《NC308 Compile option》
-D M16C70=1

《AS308 Assemble option》
-DM16C70=1

Chapter 6 Using Configurator

6.1 Configuration File Creation Procedure

When applications program coding and startup program modification are completed, it is then necessary to register the applications program in the MR308 system.

This registration is accomplished by the configuration file.

6.1.1 Configuration File Data Entry Format

This chapter describes how the definition data are entered in the configuration file.

Comment Statement

A statement from '//' to the end of a line is assumed to be a comment and not operated on.

End of statement

Statements are terminated by ';'.

Numerical Value

Numerical values can be entered in the following format.

1. Hexadecimal Number

Add "0x" or "0X" to the beginning of a numerical value, or "h" or "H" to the end. If the value begins with an alphabetical letter between A and F with "h" or "H" attached to the end, be sure to add "0" to the beginning. Note that the system does not distinguish between the upper- and lower-case alphabetical characters (A-F) used as numerical values.[57]

2. Decimal Number

Use an integer only as in '23'. However, it must not begin with '0'.

3. Octal Numbers

Add '0' to the beginning of a numerical value of 'O' or 'o' to end.

4. Binary Numbers

Add 'B' or 'b' to the end of a numerical value. It must not begin with '0'.

Table 6.1 Numerical Value Entry Examples

Hexadecimal	0xf12 0Xf12 0a12h 0a12H 12h 12H
Decimal	32
Octal	017 17o 17O
Binary	101110b 101010B

It is also possible to enter operators in numerical values. Table 6.2 lists the operators available.

[57] The system distinguishes between the upper- and lower-case letters except for the numbers A-F and a-f.

Table 6.2 Operators

Operator	Priority	Direction of computation
()	High	From left to right
- (Unary_minus)		From right to left
* / %		From left to right
+ - (Binary_minus)	Low	From loft to right

Numerical value examples are presented below.

- 123
- 123 + 0x23
- (23/4 + 3) * 2
- 100B + 0aH

Symbol

The symbols are indicated by a character string that consists of numerals, upper- and lower-case alphabetical letters, _(underscore), and ?, and begins with a non-numeric character.

Example symbols are presented below.

- _TASK1
- IDLE3

Function Name

The function names are indicated by a character string that consists of numerals, upper and lower-case alphabetical letters,'$'(dollar) and '_'(underscore), begins with a non-numeric character, and ends with '()'.

The following shows an example of a function name written in the C language.

- main()
- func()

When written in the assembly language, the start label of a module is assumed to be a function name.

Frequency

The frequency is indicated by a character string that consist of numerals and . (period), and ends with MHz. The numerical values are significant up to six decimal places. Also note that the frequency can be entered using decimal numbers only.

Frequency entry examples are presented below.

- 16MHz
- 8.1234MHz

It is also well to remember that the frequency must not begin with . (period).

Time

The time is indicated by a character string that consists of numerals and . (period), and ends with ms. The time values are effective up to three decimal places when the character string is terminated with ms. Also note that the time can be entered using decimal numbers only.

- 10ms
- 10.5ms

It is also well to remember that the time must not begin with . (period).

6.1.2 Configuration File Definition Items

The following definitions[58] are to be formulated in the configuration file

- System definition
- System clock definition
- Respective maximum number of items
- Task definition
- Eventflag definition
- Semaphore definition
- Mailbox definition
- Data queue definition
- Short data queue definition
- Fixed-size Memory Pool definition
- Variable-size Memory Pool definition
- Cyclic handler definition
- Alarm handler definition
- Interrupt vector definition

[(System Definition Procedure)]

<< Format >>

```
// System Definition
system{
    stack_size      = System stack size ;
    priority        = Maximum value of priority ;
    system_IPL      = Kernel mask level(OS interrupt disable level) ;
    timeout         = Timeout function ;
    task_pause      = Task Pause ;
    tic_deno        = Time tick denominator ;
    tic_nume        = Time tick numerator ;
    message_pri     = Maximum message priority value ;
};
```

<< Content >>

1. **System stack size**

   [(Definition format)] Numeric value

   [(Definition range)] 6 or more

   [(Default value)] 400H

   Define the total stack size used in service call and interrupt processing.

[58] All items except task definition can omitted. If omitted, definitions in the default configuration file are referenced.

2. Maximum value of priority (value of lowest priority)

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] 63

Define the maximum value of priority used in MR308's application programs. This must be the value of the highest priority used.

3. Kernel mask level (OS interrupt disable level)

[(Definition format)] Numeric value

[(Definition range)] 1 to 7

[(Default value)] 7

Set the IPL value in service calls, that is, the OS interrupt disable level.

4. Timeout function

[(Definition format)] Symbol

[(Definition range)] YES or NO

[(Default value)] NO

Specify YES when using or NO when not using tslp_tsk, twai_flg, twai_sem, tsnd_dtq, trcv_dtq, tget_mpf, vtsnd_dtq, vtrcv_dtq and trcv_msg.

5. Task Pause

[(Definition format)] Symbol

[(Definition range)] YES or NO

[(Default value)] NO

Specify YES when using or NO when not using the Task Pause function of OS Debug Function of the debugger.

6. Time tick denominator

[(Definition format)] Numeric value

[(Definition range)] Fixed to 1

[(Default value)] 1

Set the denominator of the time tick.

7. Time tick numerator

[(Definition format)] Numeric value

[(Definition range)] 1 to 65,535

[(Default value)] 1

Set the numerator of the time tick. The system clock interrupt interval is determined by the time tick denominator and numerator that are set here. The interval is the time tick numerator divided by time tick denominator [ms]. That is, the time tick numerator [ms].

The tic_nume value that can be specified for the M32C/82 or 83 operating with 20 MHz is 26 ms because of the microcomputer specification.

8. Maximum message priority value

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

Define the maximum value of message priority.

[(System Clock Definition Procedure)]

<< Format >>

```
// System Clock Definition
clock{
     mpu_clock       = MPU clock ;
     timer           = Timers used for system clock ;
     IPL             = System clock interrupt priority level ;
};
```

<< Content >>

1. MPU clock

[(Definition format)] Frequency(in MHz)

[(Definition range)] None

[(Default value)] 20MHz

Define the MPU operating clock frequency of the microcomputer in MHz units.

For the M16C/70 series, set the same value as the one that is set for the peripheral function operating clock, f1. The M16C/70 series requires that compile options be set. For details, refer to Page - 94 -.

2. Timers used for system clock

[(Definition format)] Symbol

[(Definition range)] A0, A1, A2, A3, A4, B0, B1, B2, B3, B4, B5, OTHER, NOTIMER

[(Default value)] NOTIMER

Define the hardware timers used for the system clock.

If you do not use a system clock, define "NOTIMER."

3. System clock interrupt priority level

[(Definition format)] Numeric value

[(Definition range)] 1 to Kernel mask(OS interrupt disable) level in system definition

[(Default value)] 4

Define the priority level of the system clock timer interrupt. The value set here must be smaller than the kernel mask(OS interrupt disable level.

Interrupts whose priority levels are below the interrupt level defined here are not accepted during system clock interrupt handler processing.

[(Definition respective maximum numbers of items)]
This definition is to be given only in forming the separate ROMs.[59]

Here, define respective maximum numbers of items to be used in two or more applications.

<< Format >>

```
// Max Definition
maxdefine{
   max_task   = the maximum number of tasks defined ;
   max_flag   = the maximum number of eventflags defined ;
   max_dtq    = the maximum number of data queues defined ;
   max_mbx    = the maximum number of mailboxes defined ;
   max_sem    = the maximum number of semaphores defined ;
   max_mpf    = the maximum number of fixed-size
                memory pools defined ;
   max_mpl    = the maximum number of variable-size
                memory pools defined ;
   max_cyh    = the maximum number of cyclic handlers
                defined ;
   max_alh    = the maximum number of alarm handlers
                defined ;
   max_vdtq   = the maximum number of short data queues defined ;
};
```

<< Contents >>

1. **The maximum number of tasks defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 255

   [(Default value)] None

   Define the maximum number of tasks defined.

2. **The maximum number of eventflags defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 255

   [(Default value)] None

3. **The maximum number of data queues defined.**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 255

   [(Default value)] None

   Define the maximum number of data queues defined.

4. **The maximum number of mailboxes defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 255

   [(Default value)] None

   Define the maximum number of mailboxes defined.

[59] For details of forming the into separate ROMs, see page - 145 -.

5. The maximum number of semaphores defined

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

Define the maximum number of semaphores defined.

6. The maximum number of fixed-size memory pools defined

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

7. The maximum number of variable length memory blocks defined.

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

Define the maximum number of variable length memory blocks defined.

8. The maximum number of cyclic activation handlers defined

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

The maximum number of cyclic handler defined

9. The maximum number of alarm handler defined

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

Define the maximum number of alarm handlers defined.

10. The maximum number of short data queues defined.

[(Definition format)] Numeric value

[(Definition range)] 1 to 255

[(Default value)] None

Define the maximum number of short data queues defined.

[(Task definition)]

<< Format >>

```
 // Tasks Definition
task[ ID No. ]{
    name            = ID name ;
    entry_address   = Start task of address ;
    stack_size      = User stack size of task ;
    priority        = Initial priority of task ;
    context         = Registers used ;
    stack_section   = Section name in which the stack is located ;
    initial_start   = TA ACT attribute (initial startup state) ;
    exinf           = Extended information ;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each task ID number.

1. **Task ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the ID name of a task. Note that the function name defined here is output to the kernel_id.h file, as shown below.

   #define Task ID Name task ID

2. **Start address of task**

   [(Definition format)] Symbol or function name

   [(Definition range)] None

   [(Default value)] None

   Define the entry address of a task. When written in the C language, add () at the end or _at the beginning of the function name you have defined.

   The function name defined here causes the following declaration statement to be output in the kernel_id.h file:

```
#pragma TASK Function Name
```

3. User stack size of task

[(Definition format)] Numeric value

[(Definition range)] 12 or more

[(Default value)] 256

Define the user stack size for each task. The user stack means a stack area used by each individual task. MR308 requires that a user stack area be allocated for each task, which amount to at least 12 bytes.

4. Initial priority of task

[(Definition format)] Numeric value

[(Definition range)] 1 to (maximum value of priority in system definition)

[(Default value)] 1

Define the priority of a task at startup time.

As for MR308's priority, the lower the value, the higher the priority.

5. Regisers Used

[(Definition format)] Symbol[,Symbol,....]

[(Definition range)] Selected from R0,R1,R2,R3,A0,A1,SB,FB

[(Default value)] All registers

Define the registers used in a task. MR308 handles the register defined here as a context. Specify the R0 register because task startup code is set in it when the task starts.

However, the registers used can only be selected when the task is written in the assembly language. Select all registers when the task is written in the C language. When selecting a register here, be sure to select all registers that store service call parameters used in each task.

MR308 kernel does not change the registers of bank.

If this definition is omitted, it is assumed that all registers are selected.

6. Section name in which the stack is located

[(Definition format)] Symbol

[(Definition range)] None

[(Default value)] stack

Define the section name in which the stack is located. The section defined here must always have an area allocated for it in the section file (asm_sec.inc or c_sec.inc).

If no section names are defined, the stack is located in the stack section.

7. TA_ACT attribute (initial startup state)

[(Definition format)] Symbol

[(Definition range)] ON or OFF

[(Default value)] OFF

Define the initial startup state of a task.

If this attribute is specified ON, the task goes to a READY state at the initial system startup time.

The task startup code of the initial startup task is 0.

8. Extended information

[(Definition format)] Numeric value

[(Definition range)] 0 to 0xFFFFFFFF

[(Default value)] 0

Define the extended information of a task. This information is passed to the task as argument when it is restarted by a queued startup request, for example.

[(Eventflag definition)]
This definition is necessary to use Eventflag function.

<< Format >>

```
// Eventflag Definition
flag[ ID No. ]{
    name            = Name ;
    wait_queue      = Selecting an event flag waiting queue ;
    initial_pattern = Initial value of the event flag ;
    wait_multi      = Multi-wait attribute ;
    clear_attribute = Clear attribute ;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each eventflag ID number.

1. ID Name

[(Definition format)] Symbol

[(Definition range)] None

[(Default value)] None

Define the name with which an eventflag is specified in a program.

2. Selecting an event flag waiting queue

[(Definition format)] Symbol

[(Definition range)] TA_TFIFO or TA_TPRI

[(Default value)] TA_TFIFO

Select a method in which tasks wait for the event flag. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

3. **Initial value of the event flag**

   [(Definition format)] Numeric value

   [(Definition range)] 0 to 0xFFFF

   [(Default value)] 0

   Specify the initial bit pattern of the event flag.

4. **Multi-wait attribute**

   [(Definition format)] Symbol

   [(Definition range)] TA_WMUL or TA_WSGL

   [(Default value)] TA_WSGL

   Specify whether multiple tasks can be enqueued in the eventflag waiting queue. If TA_WMUL is selected, the TA_WMUL attribute is added, permitting multiple tasks to be enqueued. If TA_WSGL is selected, the TA_WSGL attribute is added, prohibiting multiple tasks from being enqueued.

5. **Clear attribute**

   [(Definition format)] Symbol

   [(Definition range)] YES or NO

   [(Default value)] NO

   Specify whether the TA_CLR attribute should be added as an eventflag attribute. If YES is selected, the TA_CLR attribute is added. If NO is selected, the TA_CLR attribute is not added.

[(Semaphore definition)]

This definition is necessary to use Semaphore function.

<< Format >>

```
// Semaphore Definition
semaphore[ ID No. ]{
    name            = ID name;
    wait_queue      = Selecting a semaphore waiting queue;
    initial_count   = Initial value of semaphore counter;
    max_count       = Maximum value of the semaphore counter;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each semaphore ID number.

1. **ID Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name with which a semaphore is specified in a program.

2. Selecting a semaphore waiting queue

[(Definition format)] Symbol

[(Definition range)] TA_TFIFO or TA_TPRI

[(Default value)] TA_TFIFO

Select a method in which tasks wait for the semaphore. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

3. Initial value of semaphore counter

[(Definition format)] Numeric value

[(Definition range)] 0 to 65535

[(Default value)] 1

Define the initial value of the semaphore counter.

4. Maximum value of the semaphore counter

[(Definition format)] Numeric value

[(Definition range)] 1 to 65535

[(Default value)] 1

Define the maximum value of the semaphore counter.

[(Data queue definition)]
This definition must always be set when the data queue function is to be used.

<< Format >>

```
// Dataqueue Definition
mailbox[ ID No. ]{
    name            = ID name;
    buffer_size     = Number of data queues;
    wait_queue      = Select data queue waiting queue;
};
            :
            :
```

The ID number must be in the range 1 to 255. The ID number can be omitted. If omitted, ID numbers are automatically assigned in order of numbers beginning with the smallest.

<< Content >>

For each data queue ID number, define the items described below.

1. ID name

[(Definition format)] Symbol

[(Definition range)] None

[(Default value)] None

Define the name by which the data queue is specified in a program.

2. Number of data

[(Definition format)] Numeric Value

[(Definition range)] 0 to 0x1FFF

[(Default value)] 0

Specify the number of data that can be transmitted. What should be specified here is the number of data, and not a data size.

3. Selecting a data queue waiting queue

[(Definition format)] Symbol

[(Definition range)] TA_TFIFO or TA_TRPI

[(Default value)] TA_TFIFO

Select a method in which tasks wait for data queue transmission. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

[(Short data queue definition)]
This definition must always be set when the short data queue function is to be used.

<< Format >>

```
// Vdataqueue Definition
mailbox[ ID No. ]{
    name            = ID name;
    buffer_size     = Number of data queues;
    wait_queue      = Select data queue waiting queue;
};
            :
            :
```

The ID number must be in the range 1 to 255. The ID number can be omitted. If omitted, ID numbers are automatically assigned in order of numbers beginning with the smallest.

<< Content >>

For each short data queue ID number, define the items described below.

1. ID name

[(Definition format)] Symbol

[(Definition range)] None

[(Default value)] None

Define the name by which the short data queue is specified in a program.

2. Number of data

[(Definition format)] Numeric Value

[(Definition range)] 0 to 0x3FFF

[(Default value)] 0

Specify the number of data that can be transmitted. What should be specified here is the number of data, and not a data size.

3. **Selecting a data queue waiting queue**

   [(Definition format)] Symbol

   [(Definition range)] TA_TFIFO or TA_TRPI

   [(Default value)] TA_TFIFO

   Select a method in which tasks wait for short data queue transmission. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

[(Mailbox definition)]
This definition must always be set when the mailbox function is to be used.

<< Format >>

```
// Mailbox Definition
mailbox[ ID No. ]{
    name            = ID name;
    wait_queue      = Select mailbox waiting queue;
    message_queue   = Select message queue;
    max_pri         = Maximum message priority;
};
            :
            :
```

The ID number must be in the range 1 to 255. The ID number can be omitted. If omitted, ID numbers are automatically assigned in order of numbers beginning with the smallest.

<< Content >>

For each mailbox ID number, define the items described below.

1. **ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name by which the mailbox is specified in a program.

2. **Select mailbox waiting queue**

   [(Definition format)] Symbol

   [(Definition range)] TA_TFIFO or TA_TPRI

   [(Default value)] TA_TFIFO

   Select a method in which tasks wait for the mailbox. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

3. **Select message queue**

   [(Definition format)] Symbol

   [(Definition range)] TA_MFIFO or TA_MRPI

   [(Default value)] TA_MFIFO

   Select a method by which a message queue of the mailbox is selected. If TA_MFIFO is selected, messages are enqueued in order of FIFO. If TA_MPRI is selected, messages are enqueued in order of priority beginning with the one that has the highest priority.

4. **Maximum message priority**

   [(Definition format)] Numeric Value

   [(Definition range)] 1 to "maximum value of message priority" that was specified in "definition of maximum number of items"

   [(Default value)] 1

   Specify the maximum priority of message in the mailbox.

[(Fixed-size memory pool definition)]
This definition must always be set when the fixed-size memory pool function is to be used.

<< Format >>

```
// Fixed Memory pool Definition
memorypool[ ID No. ]{
    name            = ID name ;
    section         = Section Name ;
    num_block       = Number of blocks in memory pool ;
    siz_block       = Block size of Memory pool ;
    siz_block       = Select memory pool waiting queue ;
};
```

The ID number must be in the range 1 to 255. The ID number can be omitted. If omitted, ID numbers are automatically assigned in order of numbers beginning with the smallest.

<< Content >>

For each memory pool ID number, define the items described below.

1. **ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name by which the memory pool is specified in a program.

2. **Section name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] MR_HEAP

   Define the name of the section in which the memory pool is located. The section defined here must always have an area allocated for it in the section file (asm_sec.inc or c_sec.inc).

   If no section names are defined, the memory pool is located in the MR_HEAP section.

3. **Number of block**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 65,535

   [(Default value)] 1

   Define the total number of blocks that comprise the memory pool.

4. **Size (in bytes)**

   [(Definition format)] Numeric value

   [(Definition range)] 4 to 65,535

   [(Default value)] 256

   Define the size of the memory pool per block. The RAM size to be used as a memory pool is determined by this definition: (number of blocks) x (size) in bytes.

5. **Selecting a memory pool waiting queue**

   [(Definition format)] Symbol

   [(Definition range)] TA_TFIFO or TA_TPRI

   [(Default value)] TA_TFIFO

   Select a method in which tasks wait for acquisition of the fixed-size memory pool. If TA_TFIFO is selected, tasks are enqueued in order of FIFO. If TA_TPRI is selected, tasks are enqueued in order of priority beginning with the one that has the highest priority.

[(Variable-size memory pool definition)]
This definition is necessary to use Variable-size memory pool function.

<< Format >>

```
// Variable-Size Memory pool Definition
variable_memorypool[ ID No. ]{
    name            = ID Name;
    max_memsize     = The maximum memory block size to be allocated;
    mpl_section     = Section name;
    heap_size       = Memory pool size ;
};
```

The ID number must be in the range 1 to 255. The ID number can be omitted. If omitted, ID numbers are automatically assigned in order of numbers beginning with the smallest.

<< Content >>

1. **ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name by which the memory pool is specified in a program.

2. **The maximum memory block size to be allocated**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 65520

   [(Default value)] None

   Specify, within an application program, the maximum memory block size to be allocated.

3. Section name

[(Definition format)] Symbol

[(Definition range)] None

[(Default value)] MR_HEAP

Define the name of the section in which the memory pool is located. The section defined here must always have an area allocated for it in the section file (asm_sec.inc or c_sec.inc).

If no section names are defined, the memory pool is located in the MR_HEAP section.

4. Memory pool size

[(Definition format)] Numeric value

[(Definition range)] 16 to 0xFFFFFFFF

[(Default value)] None

Specify a memory pool size.

Round off a block size you specify to the optimal block size among the four block sizes, and acquires memory having the rounded-off size from the memory pool.

The following equations define the block sizes:

a = (((max_memsize+(X-1))/ (X × 8))+1) × 8
b = a × 2
c = a × 4
d = a × 8

max_memsize: the value specified in the configuration file
X: data size for block control (8 byte per a block control)

Variable-size memory pool function needs 8 byte RAM area per a block control. Memory pool size needs a size more than a, b, c or d that can be stored max_memsize + 8.

[(Cyclic handler definition)]
This definition is necessary to use Cyclic handler function.

<< Format >>

```
// Cyclic Handlar Definition
 cyclic_hand[ ID No. ]{
    name                    = ID name ;
    interval_counter        = Activation cycle ;
    start                   = TA STA attribute ;
    phsatr                  = TA PHS attribute ;
    phs_counter             = Activation phase ;
    entry_address           = Start address;
    exitf                   = Extended information;
 };
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each cyclic handler ID number.

1. **ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name by which the memory pool is specified in a program.

2. **Activation cycle**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 32767

   [(Default value)] None

   Define the activation cycle at which time the cyclic handler is activated periodically. The activation cycle here must be defined in the same unit of time as the system clock's unit time that is defined in system clock definition item. If you want the cyclic handler to be activated at 1-second intervals, for example, the activation cycle here must be set to 1000.

3. **TA_STA attribute**

   [(Definition format)] Symbol

   [(Definition range)] ON or OFF

   [(Default value)] OFF

   Specify the TA_STA attribute of the cyclic handler. If ON is selected, the TA_STA attribute is added; if OFF is selected, the TA_STA attribute is not added.

4. **TA_PHS attribute**

   [(Definition format)] Symbol

   [(Definition range)] ON or OFF

   [(Default value)] OFF

   Specify the TA_PHS attribute of the cyclic handler. If ON is selected, the TA_PHS attribute is added; if OFF is selected, the TA_PHS attribute is not added.

5. **Activation phase**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 0xFFFFFFFF

   [(Default value)] None

   Define the activation phase of the cyclic handler. The time representing this startup phase must be defined in ms units.

6. **Start Address**

   [(Definition format)] Symbol or Function Name

   [(Definition range)] None

   [(Default value)] None

   Define the start address of the cyclic handler.

   Note that the function name defined here will have the declaration statement shown below output to the kernel_id.h file.

   ```
   #pragma CYCHANDLER function name
   ```

7. **Extended information**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 0xFFFFFFFF

   [(Default value)] 0

   Define the extended information of the cyclic handler. This information is passed as argument to the cyclic handler when it starts.

[(Alarm handler definition)]
This definition is necessary to use Alarm handler function.

<< Format >>

```
// Alarm Handlar Definition
alarm_hand[ ID No. ]{
    name            = ID name;
    entry_address   = Start address;
    exitf           = Extended information ;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each alarm handler ID number.

1. **ID name**

   [(Definition format)] Symbol

   [(Definition range)] None

   [(Default value)] None

   Define the name by which the alarm handler is specified in a program.

2. **Start address**

   [(Definition format)] Symbol or Function Name

   [(Definition range)] None

   Define the start address of the alarm handler. The function name defined here causes the following declaration statement to be output in the kernel_id.h file.

3. **Extended information**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to 0xFFFFFFFF

   [(Default value)] 0

   Define the extended information of the alarm handler. This information is passed as argument to the alarm handler when it starts.

[(Interrupt vector definition)]
This definition is necessary to use Interrupt function.

<< Format >>

```
// Interrupt Vector Definition
interrupt_vector[ Vector No. ]{
    os_int          = Kernel-managed (OS dependent) interrupt handler;
    entry_address   = Start address;
    pragma_switch   = Switch passed to PRAGMA extended function;
};
            :
            :
```

The vector number can be written in the range of 0 to 63 and 247 to 255. However, whether or not the defined vector number is valid depends on the microcomputer used

The relationship between interrupt causes and interrupt vector numbers for the M16C/80 series is shown in Table 6.3.

Configurator can't create an Initialize routine (interrupt control register, interrupt causes etc.) for this defined interrupt. You need to create that.

<< Content >>

1. **Kernel (OS dependent) interrupt handler**

   [(Definition format)] Symbol

   [(Definition range)] YES or NO

   Define whether the handler is a kernel(OS dependent) interrupt handler. If it is a kernel(OS dependent) interrupt handler, specify YES; if it is a non-kernel(OS independent) interrupt handler, specify No.

   If this item is defined as YES, the declaration statement shown below is output to the kernel_id.h file.

   ```
   #pragma INTHANDLER /V4 function name
   ```

   If this item is defined as NO, the declaration statement shown below is output to the kernel_id.h file.

   ```
   #pragma INTERRUPT /V4 function name
   ```

2. **Start address**

   [(Definition format)] Symbol or function name

   [(Definition range)] None

   [(Default value)] __SYS_DMY_INH

   Define the entry address of the interrupt handler. When written in the C language, add () at the end or at the beginning of the function name you have defined.

3. **Switch passed to PRAGMA extended function**

   [(Definition format)] Symbol

   [(Definition range)] E, F, or B

   [(Default value)] None

   Specify the switch to be passed to #pragma INTHANDLER or #pragma INTERRUPT. If "E" is specified, the "/E" switch is assumed, in which case multiple interrupts (another interrupt within an interrupt) are enabled. If "F" is specified, the "/F" switch is assumed, in which case the FREIT instruction is output at return from the interrupt handler. If "B" is specified, the "/B" switch is assumed, in which case register bank 1 is specified.

   Two or more switches can be specified at the same time. For kernel (OS dependent) interrupt handlers, however, only the "E" switch can be specified. For non-kernel (OS independent) interrupt handlers, the "E," "F," and "B" switches can be specified, subject to a limitation that "E" and "B" cannot be

specified at the same time.

[Precautions]

1. Regarding the method for specifying a register bank

A kernel (OS dependent) interrupt handler that uses register bank 1 cannot be written in C language. Such an interrupt handler can only be written in assembly language. When writing in assembly language, make sure the statements at the entry and exit of the interrupt handler are written as shown below.

(Always be sure to clear the B flag before issuing the ret_int service call.)

Example: interrupt;

```
fset    B
fclr    B
ret_int
```

Internally in the MR308 kernel, register banks are not switched over.

2. Regarding the method for specifying a high-speed interrupt

To ensure an effective use of high-speed interrupts, make sure the registers of register bank 1 are used in the high-speed interrupt. Note also that high-speed interrupts cannot be used for the kernel (OS dependent) interrupt handler.

3. Do not use NMI and watchdog timer interrupts in the kernel (OS dependent) interrupt.

Table 6.3Interrupt Causes and Vector Numbers

Interrupt cause	Interrupt vector number	Section Name
DMA0	8	INTERRUPT_VECTOR
DMA1	9	INTERRUPT_VECTOR
DMA2	10	INTERRUPT_VECTOR
DMA3	11	INTERRUPT_VECTOR
Timer A0	12	INTERRUPT_VECTOR
Timer A1	13	INTERRUPT_VECTOR
Timer A2	14	INTERRUPT_VECTOR
Timer A3	15	INTERRUPT_VECTOR
Timer A4	16	INTERRUPT_VECTOR
UART0 transmit	17	INTERRUPT_VECTOR
UART0 receive	18	INTERRUPT_VECTOR
UART1 transmit	19	INTERRUPT_VECTOR
UART1 receive	20	INTERRUPT_VECTOR
Timer B0	21	INTERRUPT_VECTOR
Timer B1	22	INTERRUPT_VECTOR
Timer B2	23	INTERRUPT_VECTOR
Timer B3	24	INTERRUPT_VECTOR
Timer B4	25	INTERRUPT_VECTOR
INT5 external interrupt	26	INTERRUPT_VECTOR
INT4 external interrupt	27	INTERRUPT_VECTOR
INT3 external interrupt	28	INTERRUPT_VECTOR
INT2 external interrupt	29	INTERRUPT_VECTOR
INT1 external interrupt	30	INTERRUPT_VECTOR
INT0 external interrupt	31	INTERRUPT_VECTOR
Timer B5	32	INTERRUPT_VECTOR
UART2 transmit /NACK	33	INTERRUPT_VECTOR
UART2 receive /ACK	34	INTERRUPT_VECTOR
UART3 transmit /NACK	35	INTERRUPT_VECTOR
UART3 receive /ACK	36	INTERRUPT_VECTOR
UART4 transmit /NACK	37	INTERRUPT_VECTOR
UART4 receive /ACK	38	INTERRUPT_VECTOR
BUS conflict (UART2)	39	INTERRUPT_VECTOR
BUS conflict (UART3)	40	INTERRUPT_VECTOR
BUS conflict (UART4)	41	INTERRUPT_VECTOR
A/D	42	INTERRUPT_VECTOR
Key input interrupt	43	INTERRUPT_VECTOR
User Software interrupt	44	INTERRUPT_VECTOR
:		INTERRUPT_VECTOR
:		INTERRUPT_VECTOR
User Software interrupt	54	INTERRUPT_VECTOR
Software interrupt for MR308	55	INTERRUPT_VECTOR
User Software interrupt	56	INTERRUPT_VECTOR
User Software interrupt	57	INTERRUPT_VECTOR
Software interrupt for MR308	58	INTERRUPT_VECTOR
:		INTERRUPT_VECTOR
Software interrupt for MR308	62	INTERRUPT_VECTOR
Software interrupt for MR308	63	INTERRUPT_VECTOR
Undefined instruction	247	FIX_INTERRUPT_VECTOR
Over flow	248	FIX_INTERRUPT_VECTOR
BRK instruction	249	FIX_INTERRUPT_VECTOR
Address match	250	FIX_INTERRUPT_VECTOR
		FIX_INTERRUPT_VECTOR
Watch dog timer	252	FIX_INTERRUPT_VECTOR
		FIX_INTERRUPT_VECTOR
NMI	254	FIX_INTERRUPT_VECTOR
Reset	255	FIX_INTERRUPT_VECTOR

6.1.3 Configuration File Example

The following is the configuration file example.

```
 1 ////////////////////////////////////////////////////////////////////////////
 2 //
 3 //    kernel.cfg : building file for MR308 Ver.4.00
 4 //
 5 //    Generated by M3T-MR308 GUI Configurator at 2005/02/28 19:01:20
 6 //
 7 ////////////////////////////////////////////////////////////////////////////
 8
 9 // system definition
10 system{
11    stack_size       = 256;
12    system_IPL = 4;
13    message_pri       = 64;
14    timeout   = NO;
15    task_pause        = NO;
16    tick_nume = 10;
17    tick_deno = 1;
18 };
19
20 // max definition
21 maxdefine{
22    max_task = 3;
23    max_flag = 4;
24    max_sem  = 3;
25    max_dtq  = 3;
26    max_mbx  = 4;
27    max_mpf  = 3;
28    max_mpl  = 3;
29    max_cyh  = 4;
30    max_alh  = 2;
31 };
32
33 // system clock definition
34 clock{
35    timer_clock      = 20.000000MHz;
36    timer     = A0;
37    IPL       = 3;
38 };
39
40 task[]{
41    entry_address     = task1();
42    name      = ID_task1;
43    stack_size       = 256;
44    priority = 1;
45    initial_start     = OFF;
46    exinf     = 0x0;
47 };
48 task[]{
49    entry_address     = task2();
50    name      = ID_task2;
51    stack_size       = 256;
52    priority = 5;
53    initial_start     = ON;
54    exinf     = 0xFFFF;
55 };
56 task[3]{
57    entry_address     = task3();
58    name      = ID_task3;
59    stack_size       = 256;
60    priority = 7;
61    initial_start     = OFF;
62    exinf     = 0x0;
63 };
64
65 flag[]{
66    name      = ID_flg1;
67    initial_pattern  = 0x00000000;
68    wait_queue       = TA_TFIFO;
69    clear_attribute  = NO;
70    wait_multi       = TA_WSGL;
71 };
72 flag[1]{
73    name      = ID_flg2;
74    initial_pattern  = 0x00000001;
```

```
 75    wait_queue       = TA_TFIFO;
 76    clear_attribute  = NO;
 77    wait_multi       = TA_WMUL;
 78 };
 79 flag[2]{
 80    name     = ID_flg3;
 81    initial_pattern  = 0x0000ffff;
 82    wait_queue       = TA_TPRI;
 83    clear_attribute  = YES;
 84    wait_multi       = TA_WMUL;
 85 };
 86 flag[]{
 87    name     = ID_flg4;
 88    initial_pattern  = 0x00000008;
 89    wait_queue       = TA_TPRI;
 90    clear_attribute  = YES;
 91    wait_multi       = TA_WSGL;
 92 };
 93
 94 semaphore[]{
 95    name     = ID_sem1;
 96    wait_queue       = TA_TFIFO;
 97    initial_count    = 0;
 98    max_count= 10;
 99 };
100 semaphore[2]{
101    name     = ID_sem2;
102    wait_queue       = TA_TFIFO;
103    initial_count    = 5;
104    max_count= 10;
105 };
106 semaphore[]{
107    name     = ID_sem3;
108    wait_queue       = TA_TPRI;
109    initial_count    = 255;
110    max_count= 255;
111 };
112
113 dataqueue[]{
114    name     = ID_dtq1;
115    wait_queue       = TA_TFIFO;
116    buffer_size      = 10;
117 };
118 dataqueue[2]{
119    name     = ID_dtq2;
120    wait_queue       = TA_TPRI;
121    buffer_size      = 5;
122 };
123 dataqueue[3]{
124    name     = ID_dtq3;
125    wait_queue       = TA_TFIFO;
126    buffer_size      = 256;
127 };
128
129 mailbox[]{
130    name     = ID_mbx1;
131    wait_queue       = TA_TFIFO;
132    message_queue    = TA_MFIFO;
133    max_pri  = 4;
134 };
135 mailbox[]{
136    name     = ID_mbx2;
137    wait_queue       = TA_TPRI;
138    message_queue    = TA_MPRI;
139    max_pri  = 64;
140 };
141 mailbox[]{
142    name     = ID_mbx3;
143    wait_queue       = TA_TFIFO;
144    message_queue    = TA_MPRI;
145    max_pri  = 5;
146 };
147 mailbox[4]{
148    name     = ID_mbx4;
149    wait_queue       = TA_TPRI;
150    message_queue    = TA_MFIFO;
151    max_pri  = 6;
152 };
153
154 memorypool[]{
```

```
155     name      = ID_mpf1;
156     wait_queue        = TA_TFIFO;
157     section   = MR_RAM;
158     siz_block= 16;
159     num_block= 5;
160 };
161 memorypool[2]{
162     name      = ID_mpf2;
163     wait_queue        = TA_TPRI;
164     section   = MR_RAM;
165     siz_block= 32;
166     num_block= 4;
167 };
168 memorypool[3]{
169     name      = ID_mpf3;
170     wait_queue        = TA_TFIFO;
171     section   = MPF3;
172     siz_block= 64;
173     num_block= 256;
174 };
175
176 variable_memorypool[]{
177     name      = ID_mpl1;
178     max_memsize       = 8;
179     heap_size= 16;
180 };
181 variable_memorypool[]{
182     name      = ID_mpl2;
183     max_memsize       = 64;
184     heap_size= 256;
185 };
186 variable_memorypool[3]{
187     name      = ID_mpl3;
188     max_memsize       = 256;
189     heap_size= 1024;
190 };
191
192 cyclic_hand[]{
193     entry_address     = cyh1();
194     name      = ID_cyh1;
195     exinf     = 0x0;
196     start     = ON;
197     phsatr    = OFF;
198     interval_counter = 0x1;
199     phs_counter       = 0x0;
200 };
201 cyclic_hand[]{
202     entry_address     = cyh2();
203     name      = ID_cyh2;
204     exinf     = 0x1234;
205     start     = OFF;
206     phsatr    = ON;
207     interval_counter = 0x20;
208     phs_counter       = 0x10;
209 };
210 cyclic_hand[]{
211     entry_address     = cyh3;
212     name      = ID_cyh3;
213     exinf     = 0xFFFF;
214     start     = ON;
215     phsatr    = OFF;
216     interval_counter = 0x20;
217     phs_counter       = 0x0;
218 };
219 cyclic_hand[4]{
220     entry_address     = cyh4();
221     name      = ID_cyh4;
222     exinf     = 0x0;
223     start     = ON;
224     phsatr    = ON;
225     interval_counter = 0x100;
226     phs_counter       = 0x80;
227 };
228
229 alarm_hand[]{
230     entry_address     = alm1();
231     name      = ID_alm1;
232     exinf     = 0xFFFF;
233 };
234 alarm_hand[2]{
```

```
235     entry_address     = alm2;
236     name      = ID_alm2;
237     exinf     = 0x12345678;
238 };
239
240
241 //
242 // End of Configuration
243 //
```

6.2 Configurator Execution Procedures

6.2.1 Configurator Overview

The configurator is a tool that converts the contents defined in the configuration file into the assembly language include file, etc.Figure 6.1 outlines the operation of the configurator.

When used on HEW, the configurator is automatically started, and an application program is built.

1. Executing the configurator requires the following input files:

- Configuration file (XXXX.cfg)
  This file contains description of the system's initial setup items. It is created in the current directory.

- Default configuration file (default.cfg)
  This file contains default values that are referenced when settings in the configuration file are omitted. This file is placed in the directory indicated by environment variable "LIB308" or the current directory. If this file exists in both directories, the file in the current directory is prioritized over the other.

- makefile template files (makefile.dos, makefile, Makefile)
  This file is used as a template file when generating makefile.[60] (Refer to Section 6.2.4)

- include template file(mr308.inc, sys_ram.inc)
  This file serves as the template file of include file "mr308.inc" and “sys_ram.inc”. It resides in the directory indicated by environment variable "LIB308."

- MR308 version file (version)
  This file contains description of MR308's version. It resides in the directory indicated by environment variable "LIB308." The configurator reads in this file and outputs MR308's version information to the startup message.

2. When the configurator is executed, the files listed below are output.

Do not define user data in the files output by the configurator. Starting up the configurator after entering data definitions may result in the user defined data being lost.

- System data definition file (sys_rom.inc, sys_ram.inc)
  This file contains definition of system settings.

- Include file (mr308.inc)
  This is an include file for the assembly language.

- System generation procedure description file(makefile)
  This file is used to generate the system automatically.

[60] This makefile is a system generation procedure description file that can be processed by UNIX standard make commands or those conforming to UNIX standards.

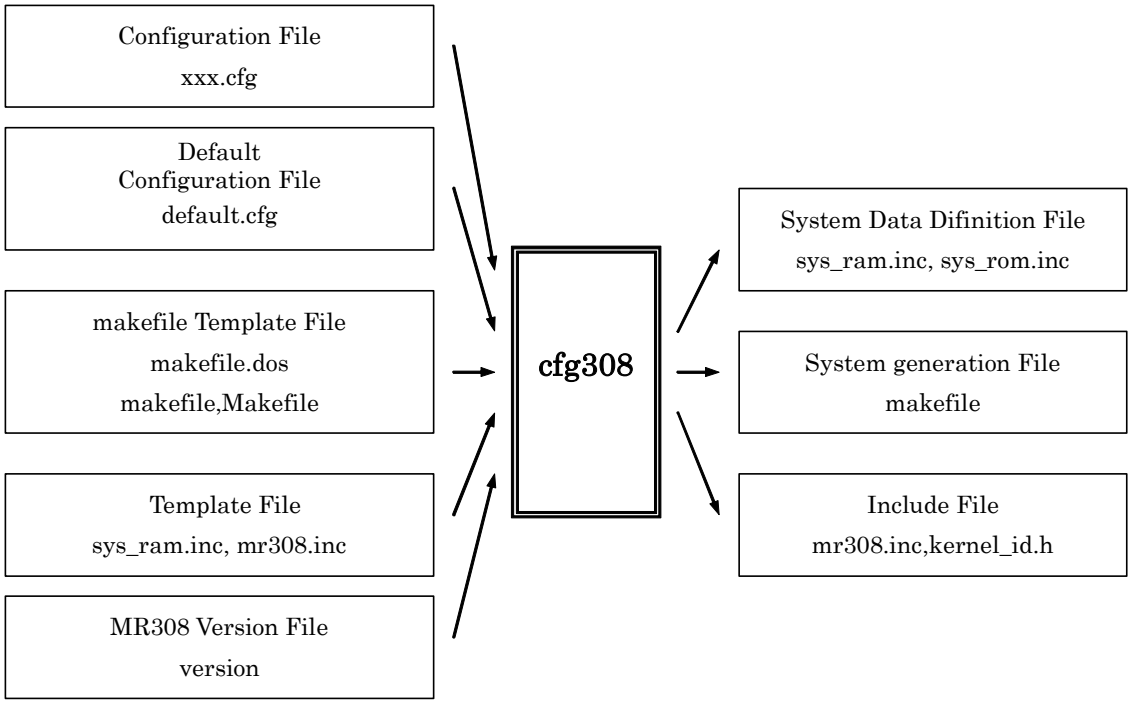


Figure 6.1 The operation of the Configurator

6.2.2 Setting Configurator Environment

Before executing the configurator, check to see if the environment variable "LIB308" is set correctly.

The configurator cannot be executed normally unless the following files are present in the directory indicated by the environment variable "LIB308":

- Default configuration file (default.cfg)
  This file can be copied to the current directory for use. In this case, the file in the current directory is given priority.

- System RAM area definition database file (sys_ram.inc)
- mr308.inc template file (mr308.inc)
- Section definition file(c_sec.inc or asm_sec.inc)
- Startup file(crt0mr.a30 or start.a30)
- makefile template file(makefile.dos)
- MR308 version file(version)

6.2.3 Configurator Start Procedure

Start the configurator as indicated below.

```
A> cfg308  [-vmV]  Configuration file name
```

Normally, use the extension .cfg for the configuration file name.

Command Options

-v Option

Displays the command option descriptions and detailed information on the version.

-V Option

Displays the information on the files generated by the command.

-m Option

Creates the UNIX standard or UNIX-compatible system generation procedure description file (make-file). If this option is not selected, makefile creation does not occur.[61]

If the startup file (crt0mr.a30 or start.a30) and the section definition file are not in the current directory, the configurator copies them to the current directory form the directory indicated by the environment variable “LIB308”.

[61] UNIX standard "makefile" and one conforming to UNIX standards have a function to delete the work file by a "clean" target. Namely,if you want to delete the object file generated by the make command,for example,enter the following:
> make clean

6.2.4 makefile generate Function

The configurator follows the procedure below to generate makefile.

1. Examine the source file's dependency relationship.

Assuming that the files bearing extensions .c and .a30 in the current directory respectively to be the C language and the assembly language files, the configurator examines the dependency relationship of the files to be included by those.

Consequently, observe the following precautions when creating a source file:

- The source file must be placed in the current directory.
- Use the extension '.c' for the C language source file and '.a30' for the assembly language source file.

2. Write the file dependency relationship to makefile

Using "makefile" or "Makefile" in the current directory or "makefile.dos" in the directory indicated by the environment variable "LIB308" as a template file, the configurator creates "makefile" in the current directory.

6.2.5 Precautions on Executing Configurator

The following lists the precautions to be observed when executing the configurator:

- If you have re-run the configurator, always be sure to execute make clean or delete all object files (extension .r30) and execute the make command. In this case, an error may occur during linking.
- Do not modify the startup program name and the section definition file name. Otherwise, an error may be encountered when executing the configurator.
- The configurator cfg308 can only generate UNIX standard makefile or one conforming to UNIX standards. Namely, it does not generate MS-DOS standard makefile.

6.2.6 Configurator Error Indications and Remedies

If any of the following messages is displayed, the configurator is not normally functioning. Therefore, correct the configuration file as appropriate and the execute the configurator again.

Error messages

cfg308 Error : syntax error near line xxx (xxxx.cfg)
There is an syntax error in the configuration file.

cfg308 Error : not enough memory
Memory is insufficient.

cfg308 Error : illegal option --> <x>
The configurator's command option is erroneous.

cfg308 Error : illegal argument --> <xx>
The configurator's startup format is erroneous.

cfg308 Error : can't write open <XXXX>
The XXXX file cannot be created. Check the directory attribute and the remaining disk capacity available.

cfg308 Error : can't open <XXXX>
The XXXX file cannot be accessed. Check the attributes of the XXXX file and whether it actually exists.

cfg308 Error : can't open version file
The MR308 version file "version" cannot be found in the directory indicated by the environment variable "LIB308".

cfg308 Error : can't open default configuration file
The default configuration file cannot be accessed. "default.cfg" is needed in the current directory or directory "LIB308" specifying.

cfg308 Error : can't open configuration file <xxxx.cfg>
The configuration file cannot be accessed. Check that the file name has been properly designated.

cfg308 Error : illegal XXXX --> <xx> near line xxx (xxxx.cfg)
The value or ID number in definition item XXXX is incorrect. Check the valid range of definition.

cfg308 Error : Unknown XXXX --> <xx> near line xx (xxxx.cfg)
The symbol definition in definition item XXXX is incorrect. Check the valid range of definition.

cfg308 Error : too big XXXX's ID number --> <xx> (xxxx.cfg)
A value is set to the ID number in XXXX definition that exceeds the total number of objects defined.The ID number must be smaller than the total number of objects.

cfg308 Error : too big task[x]'s priority --> <xx> near line xxx (xxxx.cfg)
The initial priority in task definition of ID number x exceeds the priority in system definition.

cfg308 Error : too big IPL --> <xx> near line xxx (xxxx.cfg)
The system clock interrupt priority level for system clock definition item exceeds the value of IPL within

service call of system definition item.

cfg308 Error : system timer's vector <x>conflict near line xxx
A different vector is defined for the system clock timer interrupt vector. Confirm the vector No.x for interrupt vector definition.

cfg308 Error : XXXX is not defined (xxxx.cfg)
"XXXX" item must be set in your configuration file.

cfg308 Error : system's default is not defined
These items must be set int the default configuration file.

cfg308 Error : double definition <XXXX> near line xxx (xxx.cfg)
XXXX is already defined. Check and delete the extra definition.

cfg308 Error : double definition XXXX[x] near line xxx (default.cfg)
cfg308 Error : double definition XXXX[x] near line xxx (xxxx.cfg)
The ID number in item XXXX is already registered. Modify the ID number or delete the extra definition.

cfg308 Error : you must define XXXX near line xxx (xxxx.cfg)
XXXX cannot be omitted.

cfg308 Error : you must define SYMBOL near line xxx (xxxx.cfg)
This symbol cannot be omitted.

cfg308 Error : start-up-file (XXXX) not found
The start-up-file XXXX cannot be found in the current directory. The startup file "start.a30" or "crt0mr.a30" is required in the current directory.

cfg308 Error : bad start-up-file(XXXX)
There is unnecessary start-up-file in the current directory.

cfg308 Error : no source file
No source file is found in the current directory.

cfg308 Error : zero divide error near line xxx (xxxx.cfg)
A zero divide operation occurred in some arithmetic expression.

cfg308 Error : task[X].stack_size must set XX or more near line xxx (xxxx.cfg)
You must set more than XX bytes.in task[x].stack_size.

cfg308 Error : “R0” must exist in task[x].context near line xxx (xxxx.cfg)
You must select R0 register in task[x].context.

cfg308 Error : can’t define address match interrupt definition for Task Pause Function near line xxx (xxxx.cfg)
Another interrupt is defined in interrupt vector definition needed by Task Pause Function.

cfg308 Error : Set system timer [system.timeout = YES] near line xxx (xxxx.cfg)
Set clock.timer symbol except “NOTIMER”.

Warning messages

The following message are a warning. A warning can be ignored providing that its content is understood.

cfg308 Warning : system is not defined (xxxx.cfg)

cfg308 Warning : system.XXXX is not defined (xxxx.cfg)
System definition or system definition item XXXX is omitted in the configuration file.

cfg308 Warning : system.message_size is not defined (xxxx.cfg)
The message size definition is omitted in the system definition. Please specify message size (16 or 32) of the Mailbox function.

cfg308 Warning : task[x].XXXX is not defined near line xxx (xxxx.cfg)
The task definition item XXXX in ID number is omitted.

cfg308 Warning : Already definition XXXX near line xxx (xxxx.cfg)
XXXX has already been defined.The defined content is ignored, check to delete the extra definition.

cfg308 Warning : interrupt_vector[x]'s default is not defined (default.cfg)
The interrupt vector definition of vector number x in the default configuration file is missing.

cfg308 Warning : interrupt_vector[x]'s default is not defined near line xxx (xxxx.cfg)
The interrupt vector of vector number x in the configuration file is not defined in the default configuration file.

cfg308 Warning : Initial Start Task not defined
The task of task ID number 1 was defined as the initial startup task because no initial startup task is defined in the configuration file.

cfg308 Warning : system.stack_size is an uneven number near line xxx
cfg308 Warning : task[x].stack_size is an uneven number near line xxx
Please set even size in system.stack_size or task[x].stack_size.

Other messages

The following message are a warning message that is output only when generating makefile.The configurator skips the sections that have caused such a warning as it generates makefile.

cfg308 Error : xxxx (line xxx): include format error.
The file read format is incorrect. Rewrite it to the correct format.

cfg308 Warning : xxxx (line xxx): can't find <XXXX>

cfg308 Warning : xxxx (line xxx): can't find "XXXX"
The include file XXXX cannot be found. Check the file name and whether the file actually exists.

cfg308 Warning : over character number of including path-name
The path-name of include file is longer than 255 characters.

6.3 Editing makefile

Here you edit makefile the configurator generated, and set compilation options, libraries, and so on. The procedure for setting them is given below.

1. **NC308WA command options**

   You define command options of the C compiler in "CFLAGS". Be sure to define the "-c" option.

2. **AS308 command options**

   You define command options of the assembler in "ASFLAGS".

3. **LN308 command options**

   You define command options of the linker in "LDFLAGS". There are no particular options you need to specify.

4. **Specifying libraries**

   You define libraries in "LIBS".

   The configurator picks up necessary libraries from the configuration file and from the current directory, and defines them in 'LIBS". Either add or delete libraries when necessary.

If you create the own makefile for MR308 system, be sure to describe the following 4 items in the makefile.

1. **MR308 Library Specifications**

   you must specify libraries mr308.lib and c308mr.lib.

2. **Assemble Option Specifications**

   Make sure to specify assemble option "-F" when assembling the source file, described in the assemble language, which issues the service call.

3. **Process Before Linking**

   Before executing a link, make sure to execute the following two processes, in the order as are listed.

   1. mr308tbl

   2. as308 mrtable.a30

   MR308 comes equipped with the mr308tbl utility. Execute it in the directory where Configurator (cfg308) executes. If that is not the same directory where the service call file (XXX.mrc) and the r30 file are output by C Compiler or Assembler, you need to specify the directory at parameters of mr308tbl as following. .

   Ex) mr308tbl outputdir

   If you use Service call Issue Function on PD308, you need to add $(LIB308) at parameter of mr308tbl.

   Once mr308tbl is executed, the mrtable.a30 file will be created. After these two processes are completed, execute the link including the mrtable.r30 file.

6.4 About an error when you execute make

The following warning message of mr308tbl is displayed when you execute make.

mr308tbl Warning : You need not specify systime.timeout YES in configuration file

Unless the following service calls are used, there is no need to set "Timeout=YES" in the system definition of a configuration file.

tslp_tsk, twai_flg, trcv_mbx, twai_sem, tsnd_dtq, trcv_dtq, vtsnd_dtq, vtrcv_dtq

This waning will disappear when you define “TIMEOUT = NO;” of the system definition in your configuration file.
If you don’t use the following service call, you had better to define “TIMEOUT = NO;” in the configuration file

Chapter 7 Application Creation Guide

7.1 Processing Procedures for System Calls from Handlers

When a service call is issued from a handler, task switching does not occur unlike in the case of a service call from a task. However, task switching occurs when a return from a handler [62] is made.

The processing procedures for service calls from handlers are roughly classified into the following three types.

1. **A service call from a handler that caused an interrupt during task execution**
2. **A service call from a handler that caused an interrupt during service call processing**
3. **A service call from a handler that caused an interrupt (multiplex interrupt) during handler execution**

[62] The service call can't be issued from OS-independent handler. Therefore, The handler described here does not include the OS-independent handler.

7.1.1 System Calls from a Handler That Caused an Interrupt during Task Execution

Scheduling (task switching) is initiated by the ret_int service call [63](See Figure 7.1).

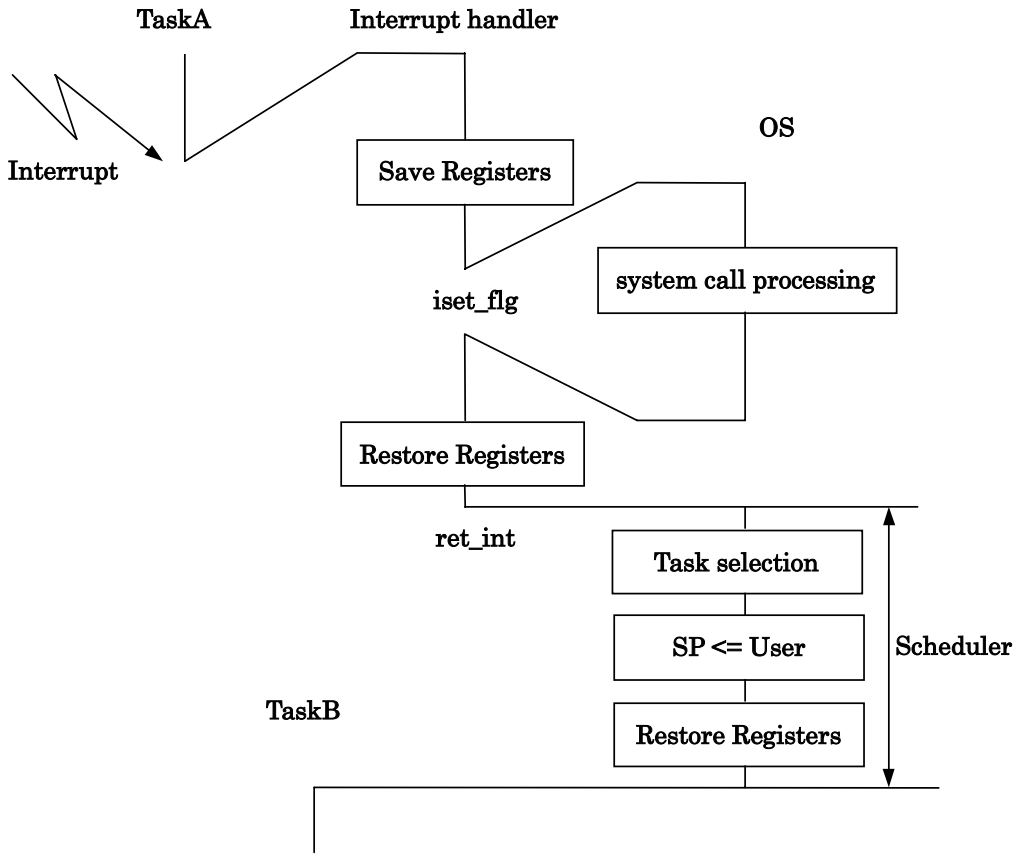


Figure 7.1 Processing Procedure for a System Call a Handler that caused an interrupt during Task Execution

[63] The ret_int service call is issued automatically when OS-dependent handler is written in C language (when #pragma INTHANDLER specified)

7.1.2 System Calls from a Handler That Caused an Interrupt during System Call Processing

Scheduling (task switching) is initiated after the system returns to the interrupted service call processing (See Figure 7.2).

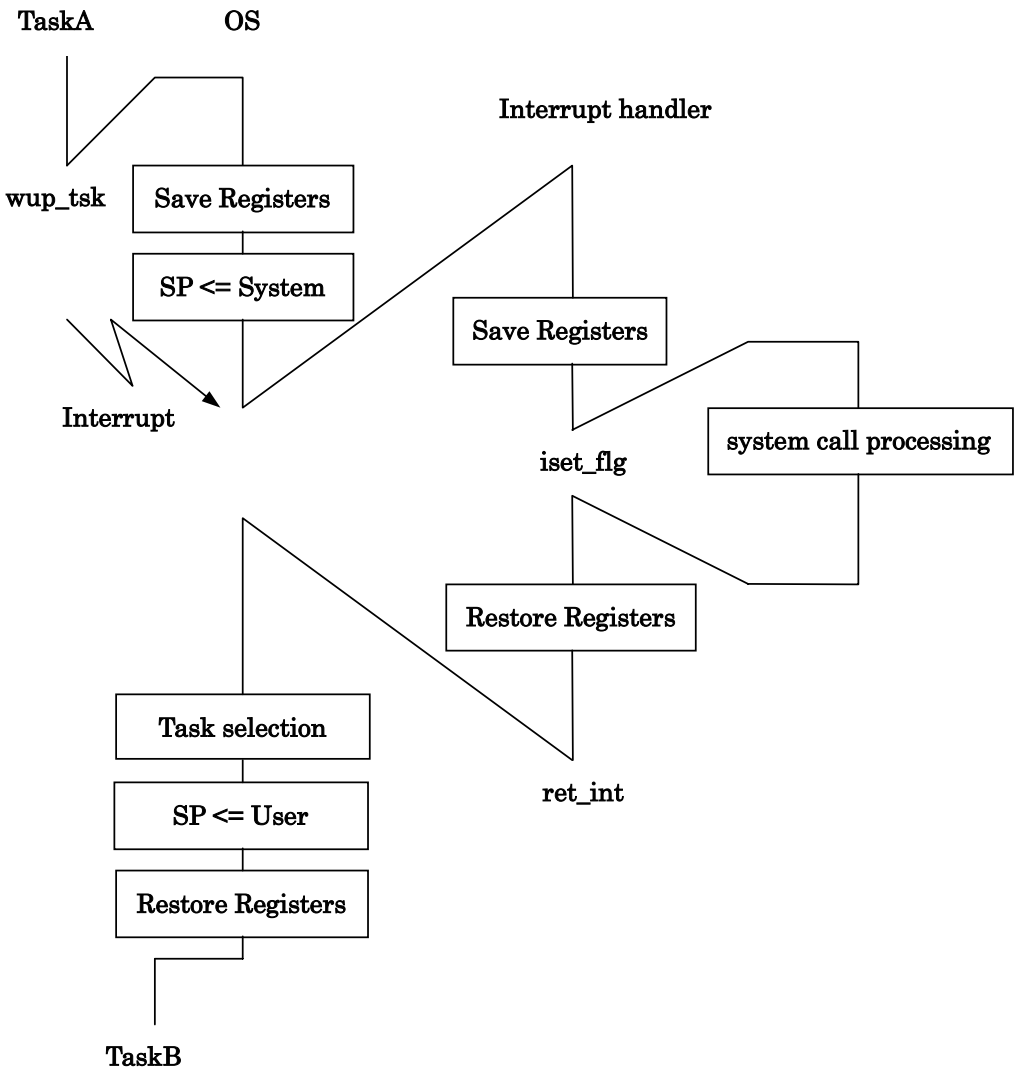


Figure 7.2 Processing Procedure for a System Call from a Handler that caused an interrupt during System Call Processing

7.1.3 System Calls from a Handler That Caused an Interrupt during Handler Execution

Let us think of a situation in which an interrupt occurs during handler execution (this handler is hereinafter referred to as handler A for explanation purposes). When task switching is called for as a handler (hereinafter referred to as handler B) that caused an interrupt during handler A execution issued a service call, task switching does not take place during the execution of the service call (ret_int service call) returned from handler B, but is effected by the ret_int service call from handler A (See Figure 7.3).

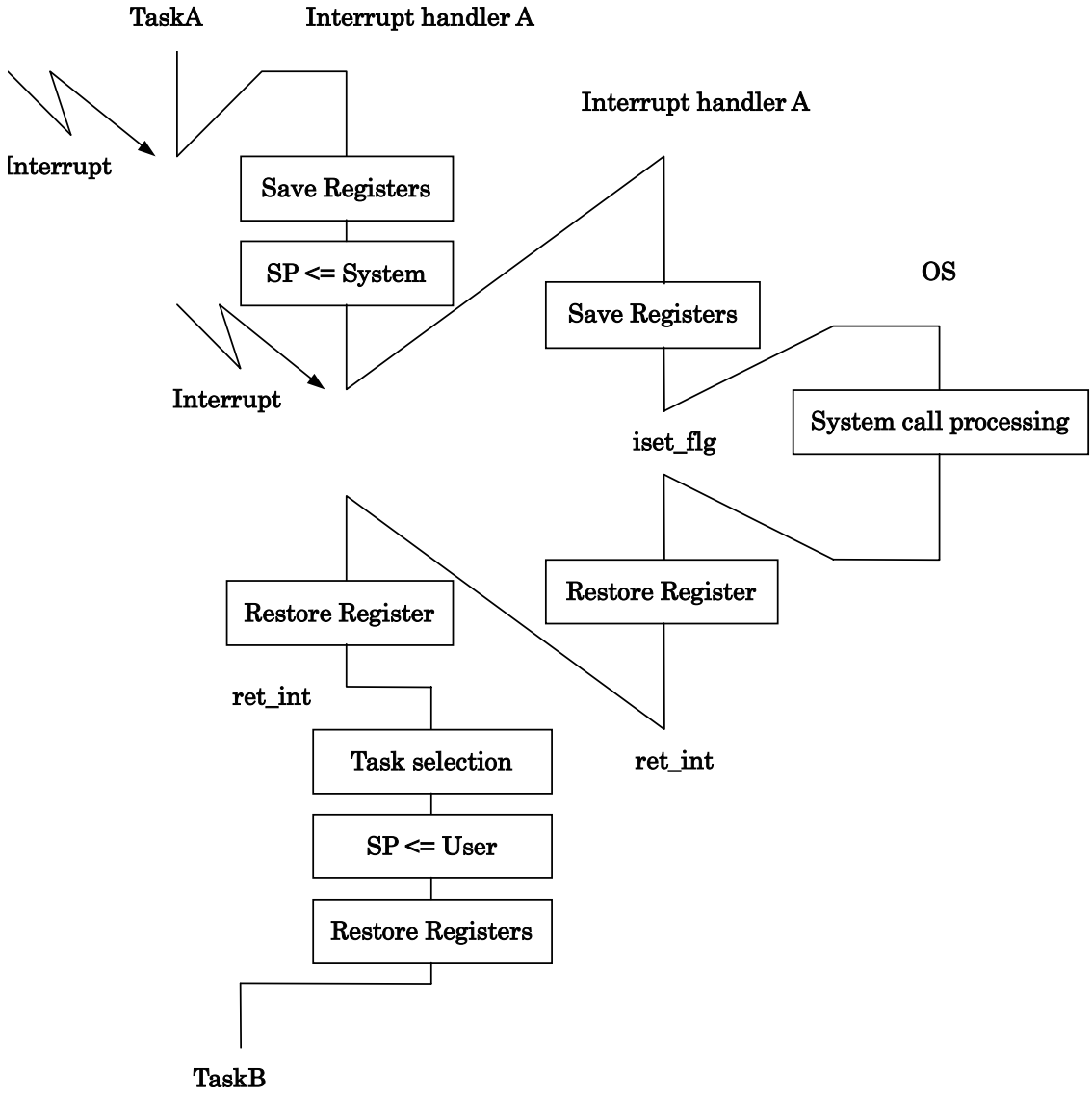


Figure 7.3 Processing Procedure for a service call from a Multiplex interrupt Handler

7.2 Stacks

7.2.1 System Stack and User Stack

The MR308 provides two types of stacks: system stack and user stack.

- User Stack
  One user stack is provided for each task. Therefore, when writing applications with the MR308, it is necessary to furnish the stack area for each task.

- System Stack
  This stack is used within the MR308 (during service call processing). When a service call is issued from a task, the MR308 switches the stack from the user stack to the system stack (See Figure 7.4).

  The system stack use the interrupt stack(ISP).

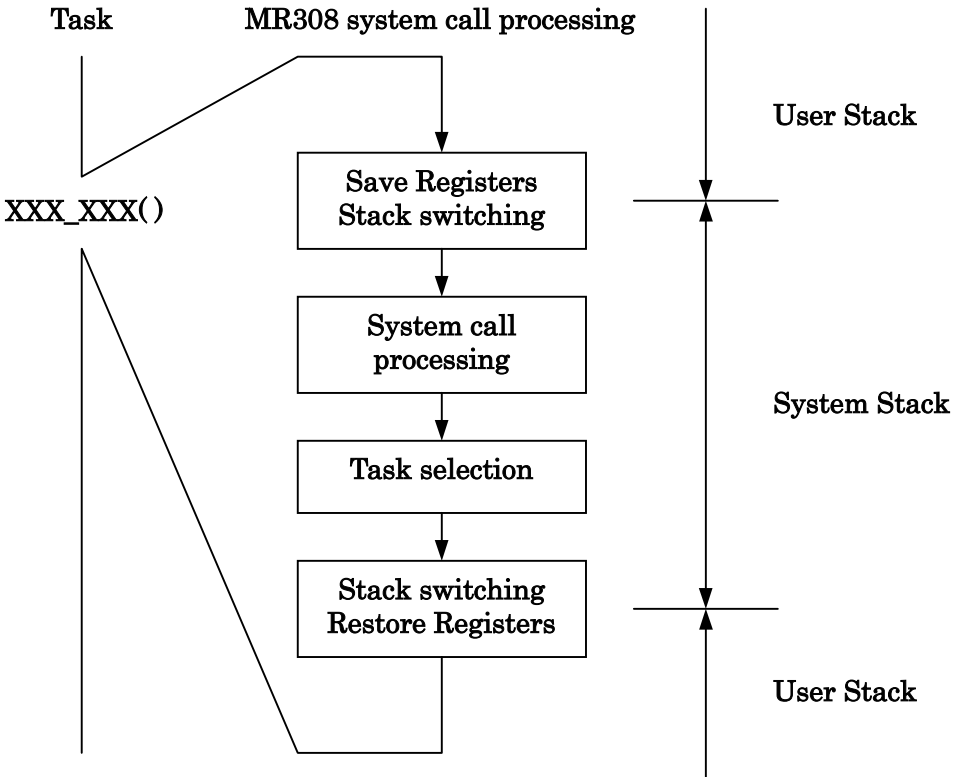


Figure 7.4 System Stack and User Stack

Switchover from user stack to system stack occurs when an interrupt of vector numbers 0 to 31 or 247 to 255 is generated. Consequently, all stacks used by the interrupt handler are the system stack.

Chapter 8 Sample Program Description

8.1 Overview of Sample Program

As an example application of MR308, the following shows a program that outputs a string to the standard output device from one task and another alternately.

Table 8.1 Functions in the Sample Program

Function Name	Type	ID No.	Priority	Description
main()	Task	1	1	Starts task1 and task2.
task1()	Task	2	2	Outputs "task1 running."
task2()	Task	3	3	Outputs "task2 running."
cyh1()	Handler	1		Wakes up task1().

The content of processing is described below.

- The main task starts task1, task2, and cyh1, and then terminates itself.
- task1 operates in order of the following.
  1. Gets a semaphore.
  2. Goes to a wakeup wait state.
  3. Outputs "task1 running."
  4. Frees the semaphore.
- task2 operates in order of the following.
  1. Gets a semaphore.
  2. Outputs "task2 running."
  3. Frees the semaphore.

cyh1 starts every 100 ms to wake up task1.

8.2 Program Source Listing

```
 1 /************************************************************************
 2 *                       MR308  smaple program
 3 *
 4 * COPYRIGHT(C) 2003(2005) RENESAS TECHNOLOGY CORPORATION
 5 * AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 6 *
 7 *
 8 *     $Id: demo.c,v 1.2 2005/06/15 05:29:02 inui Exp $
 9 ************************************************************************/
10
11 #include <itron.h>
12 #include <kernel.h>
13 #include "kernel_id.h"
14 #include <stdio.h>
15
16
17 void main( VP_INT stacd )
18 {
19     sta_tsk(ID_task1,0);
20     sta_tsk(ID_task2,0);
21     sta_cyc(ID_cyh1);
22 }
23 void task1( VP_INT stacd )
24 {
25     while(1){
26             wai_sem(ID_sem1);
27             slp_tsk();
28             printf("task1 running\n");
29             sig_sem(ID_sem1);
30     }
31 }
32
33 void task2( VP_INT stacd )
34 {
35     while(1){
36             wai_sem(ID_sem1);
37             printf("task2 running\n");
38             sig_sem(ID_sem1);
39     }
40 }
41
42 void cyh1( VP_INT exinf )
43 {
44     iwup_tsk(ID_task1);
45 }
46
```

8.3 Configuration File

```
 1 //************************************************************************
 2 //
 3 //   COPYRIGHT(C) 2003,2005 RENESAS TECHNOLOGY CORPORATION
 4 //   AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 5 //
 6 //      MR308 System Configuration File.
 7 //        "$Id: smp.cfg,v 1.5 2005/06/15 05:41:54 inui Exp $"
 8 //
 9 //************************************************************************
10
11 // System Definition
12 system{
13        stack_size      = 1024;
14      priority        = 10;
15        system_IPL      = 4;
16      task_pause      = NO;
17      timeout         = YES;
18      tic_nume        = 1;
19      tic_deno        = 1;
20      message_pri     = 255;
21 };
22 //System Clock Definition
23 clock{
24      mpu_clock               = 20MHz;
25        timer                 = A0;
26        IPL                   = 4;
27 };
28 //Task Definition
29 //
30 task[]{
31      entry_address   = main();
32      name            = ID_main;
33        stack_size      = 100;
34      priority        = 1;
35      initial_start   = ON;
36 };
37 task[]{
38      entry_address   = task1();
39      name            = ID_task1;
40        stack_size      = 500;
41      priority        = 2;
42 };
43 task[]{
44      entry_address   = task2();
45      name            = ID_task2;
46      stack_size      = 500;
47      priority        = 3;
48 };
49
50 semaphore[]{
51      name            = ID_sem1;
52      max_count       = 1;
53      initial_count   = 1;
54      wait_queue      = TA_TPRI;
55 };
56
57
58
59 cyclic_hand [1] {
60      name                    = ID_cyh1;
61      interval_counter        = 100;
62      start                   = OFF;
63      phsatr                  = OFF;
64      phs_counter             = 0;
65      entry_address           = cyh1();
66      exinf                   = 1;
67 };
```

Chapter 9 Separate ROMs

9.1 How to Form Separate ROMs

This chapter describes how to form the MR308's kernel and application programs into separate ROMs.

Figure 9.1 shows an instance in which the sections common to two different applications together with the kernel are allocated in the kernel ROM and the applications are allocated in separate ROMs.

Here is how to divide a ROM based on this example.

1. System configuration

Here you set up a system configuration of application programs.

Here, descriptions are given on the supposition that the system configuration of two application programs is as shown below.

	Application 1	Application 2
The number of Tasks	4	5
The number of Eventflags	1	3
The number of Semaphores	4	2
The number of Mailboxes	3	5
The number of Fixed-size memory pools	3	1
The number of Cyclic handlers	3	3

2. Preparing configuration files

You prepare configuration files based on the result brought by setting up the system configuration. In this instance, you need to make the following two items you set in the maxdefine definition division common to two configuration files. You specify the greater of the two numbers of definitions as to the respective applications for a value to be set in the maxdefine definition division.

e.g.

```
maxdefine{
        max_task        = 5;
        max_flag        = 3;
        max_sem         = 4;
        max_mbx         = 5;
        max_mpl         = 3;
        max_cyh         = 3;
};
```

Other definitions, though different from each other between two configuration files, raise no problem.

3. Changing the processor mode register

You change the processor mode register for a startup program in compliance with the system.

4. Preparing application programs

You prepare two application programs.

5. Locating respective sections

Programs to be located in the kernel ROM and in the application ROM are given below.

- Programs to be located in the kernel ROM
  - ♦ Startup program (MR_KERNEL section)
  - ♦ MR308's kernel(MR_KERNEL section)
  - ♦ Programs common to two applications(program section)
  - ♦ Fixed interrupt vector area(FIX_INTERRUPT_VECTOR section)

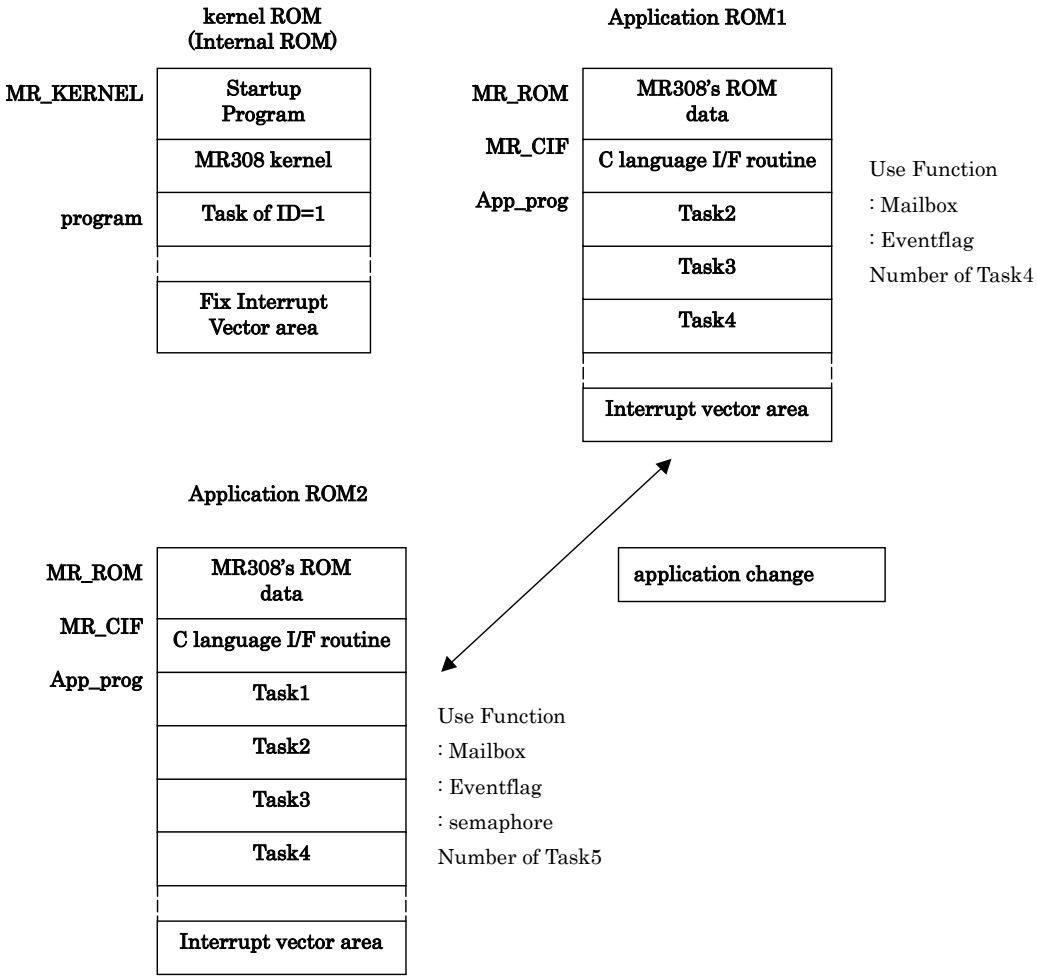


Figure 9.1 ROM separate

- Programs to be located in the application ROM
  - MR308's ROM data (the MR_ROM section)
  - C language I/F routines (the MR_CIF section)
  - Application programs (the app_prog section)
  - Interrupt vector area (the INTERRUPT_VECTOR section)

- How to locate individual programs is given below.
  - Changing the section name of user program

  In dealing with application programs written in C language, you change the section name of the programs to be located in the application ROM by use of #pragma SECTION as shown below. In NC308WA, the section name of user program, if not given, turns to program section. So you need to assign a different section name to the task you locate in the application ROM.[64]

```
#pragma SECTION program app_prog/* Changing section of program */
/* The section names of task2 and task3 turn to app_prog */
void task2(void){
                :
}

void task3(void){
                :
}
```

  - Locating sections

[64] You need not change the names of sections for tasks to be located int the kernel ROM.

Here you change the section files (c_sec.inc, asm_sec.inc), and set addresses of programs you locate in the application ROM. In this instance, the respective first addresses of the sections given below must agree with each other between two applications. Also, you need to invariably locate the MR_ROM section at the beginning of the application ROM. The sequence of other sections are free of restrictions.

- MR308's ROM data(MR_ROM section)
- C language I/F routine(MR_CIF section)
- Interrupt vector area(INTERRUPT_VECTOR section)

Settings of the section files are given below.

```
.section MR_ROM,ROMDATA          ; MR308's ROM data
.org    0fe0000H                 ; The address common to two applications

.section MR_CIF,CODE             ; C language I/F routine

.section app_prog,CODE           ; Use Program

.section INTERRUPT_VECTOR        ; Interrupt Vector
.org    0fefd00H                 ; The address common to two applications
```

The memory map turns to give below.(See Figure 9.2)

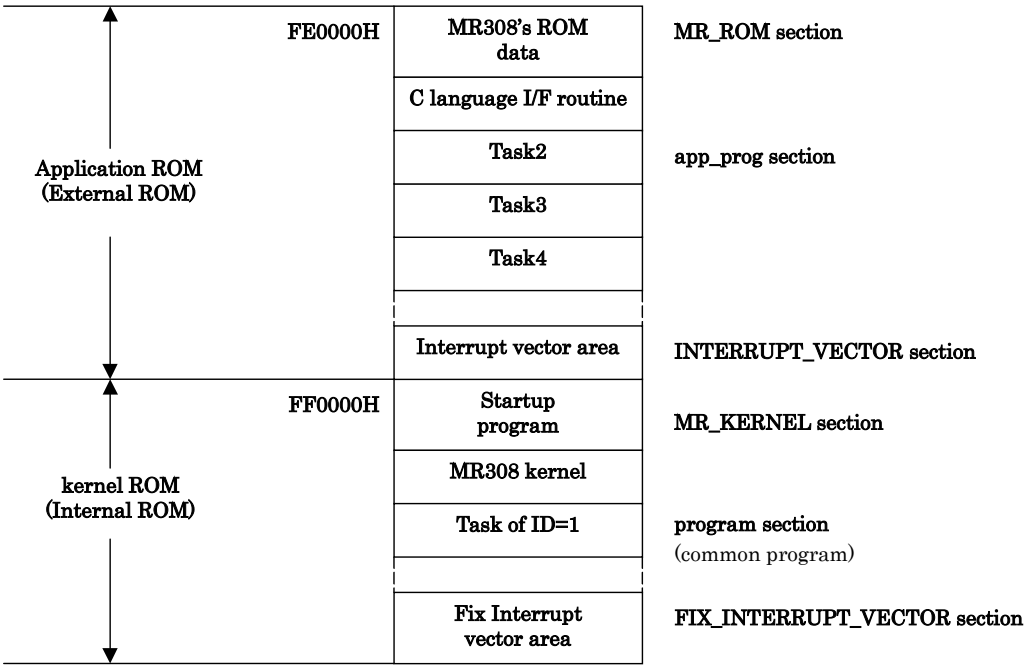


Figure 9.2 Memory map

6. Executing the configurator cfg308.

7. Editing makefile.

You specify an argument for mr308tbl held in makefile. You specify the argument for two directories in which each application is held.

An example is given here in which the directory /product/app1 is used for application 1 is and the directory /product/app2 is used for application 2.

```
e.g.

            mr308tbl \product\app1 \product\app2
```

8. Generating a system

You execute the make command to generate a system.[65]

9. Carrying out steps 4 through 8 with respect to application 2 allows you to generate the system for application 2.

The steps given above allows you to form the separate ROMs.

[65] If the file mrtable.a30 is not held in the current directory, execute make command to generate a system.

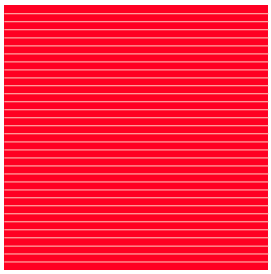
Real-time OS for M16C/70,80,M32C/80 Series
M3T-MR308/4 User's Manual

Publication Date: Nov. 1, 2005 Rev.2.00

Published by: Sales Strategic Planning Div.
Renesas Technology Corp.

Edited by: Application Engineering Department 1
Renesas Solutions Corp.

M3T-MR308/4
User's Manual



Renesas Technology Corp.
2-6-2, Ote-machi, Chiyoda-ku, Tokyo, 100-0004, Japan