RMX/86™ NUCLEUS, TERMINAL HANDLER, AND DEBUGGER REFERENCE MANUAL

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PREFACE

RMX/86 provides an operating system for Intel's iSBC 86/12 single board computers. It consists of a Nucleus, a Terminal Handler, a Debugger, and an input/output system (IOS).

The Nucleus, Terminal Handler, and Debugger Reference Manual is one of six manuals supporting the RMX/86 Operating System. The other manuals are:

Introduction to the RMX/86 Operating System	9803124
RMX/86 Installation Guide for ISIS-II Users	9803125
RMX/86 I/O System Reference Manual	9803123
RMX/86 System Programmer's Reference Manual	142721
RMX/86 Configuration Guide for ISIS-II Users	9803126

This manual is intended primarily as a source of Nucleus, Terminal Handler, and Debugger reference materials; it is only secondarily for instruction. We recommend reading the introductory manual prior to reading this manual.

The RMX/86 manual set is aimed at two classes of readers: application programmers and system programmers. Accordingly, reference information is separated by class. In particular, this manual and the I/O system manual are for application programmers, while systems-oriented features in both the Nucleus and the I/O System are described in the System Programmer's manual.

The following manuals provide valuable background information:

iSBC 86/12A Hardware Reference Manual	9803074
ISIS-II User's Guide	9800306
PL/M-86 Programming Manual	9800466
ISIS-II PL/M-86 Compiler Operator's Manual	9800478
The 8086 Family User's Manual	9800722

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Chapter 1. OVERVIEW

The RMX/86 Nucleus, Terminal Handler, and Debugger constitute a useful set of RMX/86 features for development purposes. The Nucleus is required in every application system. The Terminal Handler and Debugger are helpful during development but are frequently omitted thereafter.

NUCLEUS

The Nucleus is the core of every RMX/86 application system. Among the activities of the Nucleus are the following:

- Supplying timing functions.
- Controlling access of tasks to system resources.
- Providing for communication between tasks.
- Enabling the system to respond to external events.

TERMINAL HANDLER

The Terminal Handler provides a real-time, asynchronous interface between your terminal and tasks running under the supervision of the Nucleus. It can be used either with or without the Debugger. The Terminal Handler provides the following features:

- Line-editing.
- Control characters for suspending and resuming output at the terminal.
- A means of awakening the Debugger.

DEBUGGER

The Debugger is designed specifically for debugging and monitoring systems running under the supervision of the Nucleus. A special debugger is very helpful in debugging such systems, because their real-time and multi-tasking characteristics render inadequate many ordinary debugging techniques. The RMX/86 Debugger is sensitive to the data structures used by the Nucleus, and it can give "snapshots" of tasks at critical moments, while interfering minimally with the activities of the system being tested. It can also be used to alter the contents of memory.

If desired, the Debugger can be included in a debugged application system for troubleshooting in the field. If it is included, the Debugger requires only the support of the Nucleus.

Chapter 2. NUCLEUS OVERVIEW

INTRODUCTION

The RMX/86 Nucleus is one of two major software components of the RMX/86 Operating System. The other major component, the I/O System, is optional. The Nucleus, however, is required because it is the heart of the system.

The Nucleus provides the building blocks from which the I/O System and application systems are constructed. These building blocks are called objects and are classified into the following five categories called object types:

- Tasks
- Jobs
- Segments
- Mailboxes
- Semaphores

The following simplistic generalizations can be made regarding these types:

- Tasks are the active objects in a system. They do the work of the system.
- Jobs are the environments in which tasks do their work. An environment consists of tasks, the objects that tasks use, and a directory where tasks can catalog objects so as to make them available to other tasks in the job.
- Segments are pieces of memory, the medium that tasks use for communicating.
- Mailboxes are the objects to which tasks go to send or receive segments containing data.
- Semaphores enable tasks to send signals to other tasks.

The Nucleus does extensive record-keeping of objects. It keeps track of each object by means of one or more 16-bit value called tokens. The Nucleus provides a number of operators, called system calls, that tasks use to manipulate objects.

When using a system call, a task supplies parameter values, such as tokens, names, or other values, depending on the requirements of the system call. Some of the functions that tasks can perform with system calls are the following:

- Create objects.
- Delete objects.
- Send messages to other tasks.
- Receive messages from other tasks.
- Obtain information about objects.
- Catalog objects with descriptive names.
- Delete objects from catalogs.

OBJECTS

Each of the five object types has unique characteristics. These characteristics are discussed in detail in the following paragraphs.

TASKS

A task has two goals:

- Its primary goal is to do a specific piece of work.
- Its secondary goal is to obtain exclusive control of the processor so that it can progress toward its primary goal.

One of the main activities of the Nucleus is to arbitrate the competition that results when several tasks each want exclusive control over the processor. The Nucleus does this by maintaining, for each task, an execution state and a priority. The execution state for each task is, at any given time, either running, ready, asleep, suspended, or asleep-suspended. The running state is a special case of the ready state. The priority for each task is an integer value between 0 and 255, inclusive, with 0 being the highest priority.

The arbitration algorithm that the Nucleus uses is the following: The running task is the ready task with the highest (numerically lowest) priority. If two or more ready tasks each have the highest priority, the running task is the one which has been ready for the longest time.

As viewed by the Nucleus, a task is merely a set of values, some of which are the following:

- The task's priority.
- The task's execution state.
- A token for the job that contains the task.

When a task becomes the running task, the following events occur, in order:

- The values of the previously running task are saved by the Nucleus.
- The Nucleus sets the new running task's values.
- The new task begins executing.

The task continues to run until one of the following events occurs:

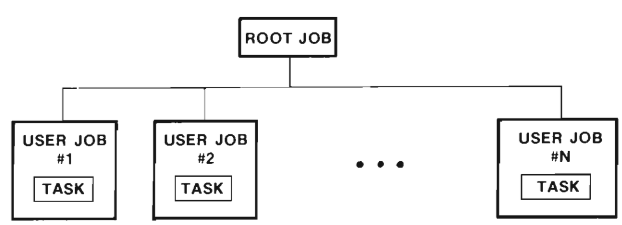
- The task removes itself from the ready state. For example, the task can suspend or delete itself; the task can attempt to receive an object that has not yet been sent, in which case it might elect to wait (in the asleep state).
- The task (task A) is preempted when a higher priority task (task B) becomes ready. An example of how this could happen is that task B might previously have gone into the asleep state for a specific period of time. When the time period has passed, task B becomes ready again. Because it is then the highest priority ready task, task B becomes the running task.

JOBS

A job consists of tasks and the resources they need.

The jobs in a system form a family tree, with each job, except the root job, obtaining its resources from its parent. The tasks in the user jobs can create additional objects. If they create additional jobs, this enlarges the job tree.

The job tree, right after the initializaton of a system, is as follows:



Associated with each job is an object directory. Objects are known to the Nucleus by their respective tokens, but often, in the code that is executed by tasks, the objects are known by symbolic names. The object directory for a job is a place in memory where a task can catalog an object under a name. Other tasks that know the name can then use the directory to access the object.

SEGMENTS

A fundamental resource that tasks need is memory. Memory is allocated to tasks in the form of segments. A task needing memory requests a segment of whatever size it requires. The Nucleus attempts to create a segment from the memory pool given to the task's job when the job was created.

If there is not enough memory available, the Nucleus will try to get the needed memory from ancestors of the job. In this respect, the tree-structured hierarchy of jobs is instrumental in resource distribution.

MAILBOXES

A mailbox is one of two types of objects that can be used for intertask communication. When task A wants to send an object to task B, task A must send the object to the mailbox, and task B must visit the mailbox, where it has the option of waiting for any desired length of time. Sending an object in this manner can achieve various purposes. It might be a segment that contains data needed by the waiting task. On the other hand, the segment might be blank, and sending it might constitute a signal to the waiting task. Another reason to send an object might be to point out the object to the receiving task.

SEMAPHORES

A semaphore is a custodian of abstract "units". It dispenses units to tasks that request them, and it accepts units from tasks.

An example of typical semaphore use is mutual exclusion. Suppose your application system contains one I/O device which is being used for output by multiple tasks. To ensure that only one of these tasks can use the device at a given time, you can establish a semaphore which has one unit and require that tasks obtain the unit before using the device. A task wanting to use the device would request the unit from the semaphore. When it gets the unit, it can use the device and then return the unit to the semaphore. Because the semaphore has no units while the task is using the device, other tasks are effectively excluded from using the device.

HANDLERS

Two kinds of events can be handled specially. The remainder of this chapter describes the handlers for these events.

EXCEPTION HANDLERS

Tasks occasionally make errors. If an error occurs during an RMX/86 system call, it causes an exceptional condition. The occurrence of an exceptional condition can, if desired, cause a transfer of control to the exception handler associated with the current task. The exception handler is a procedure that typically deals with the problem by one of the following methods:

- Correcting the cause of the problem and trying again.
- Merely logging the error.
- Deleting the task that caused the error.

In regard to exception handlers, the designer of an RMX/86-based system has two kinds of decisions that must be made for each task. The first decision concerns the choice of exception handlers. The task can have its own custom exception handler, it can use the exception handler for the job to which it belongs, or it can use the Intel-provided System Exception Handler. Second, there are two categories of exceptional conditions, programmer errors and environmental conditions. Each task can be set up so that control goes to an exception handler in case of

- programmer errors only,
- environmental conditions only,
- in both cases, or
- never.

If control is not directed to an exception handler, the responsibility for handling the exception falls upon the task.

INTERRUPT HANDLERS

To function effectively as a real-time system, an RMX/86 application system must be responsive to external events. An interrupt handler, one of which is required for each source of external events, is a procedure that is invoked by hardware or software for the purpose of responding to an asynchronous event. The handler takes control immediately and services the interrupt. When the interrupt handler is finished servicing the interrupt, it surrenders the processor, which returns to the interrupted procedure.

Chapter 3. JOB MANAGEMENT

A job is an environment in which RMX/86 objects such as tasks, mailboxes, semaphores, segments, and (offspring) jobs reside. In addition, a job has an object directory and a pool of memory. The job's memory pool provides the raw material from which objects can be created by the tasks in the job. Figure 3-1 illustrates the elements of a job.

Applications consist of one or more jobs. Jobs are independent but they may share resources. Each job has its own tasks and may have its own object directory. Objects may be shared between jobs, although each object is contained in only one job.

The programmer must decide whether tasks belong in the same job. In general, you should place tasks in the same job if:

- they have similar or related purposes
- they share many resources
- they have similar lifespans

JOB TREE AND RESOURCE SHARING

The jobs in a system are arranged in the form of a tree. The root is a job that is provided by the Nucleus. The remaining jobs, including jobs that are created dynamically while the system runs, are descendents of the root job. A job containing tasks that create other jobs is a parent job. A newly created job is a child of the job whose tasks created it.

Associated with each job is a set of limits. The limits of a job are as follows:

- the maximum allowable size of its object directory.
- the maximum and minimum allowable sizes of its memory pool.
- the maximum allowable number of simultaneously existing tasks that it can contain.
- the maximum allowable number of simultaneously existing objects that it can contain.
- the highest allowable priority of any task contained in it.

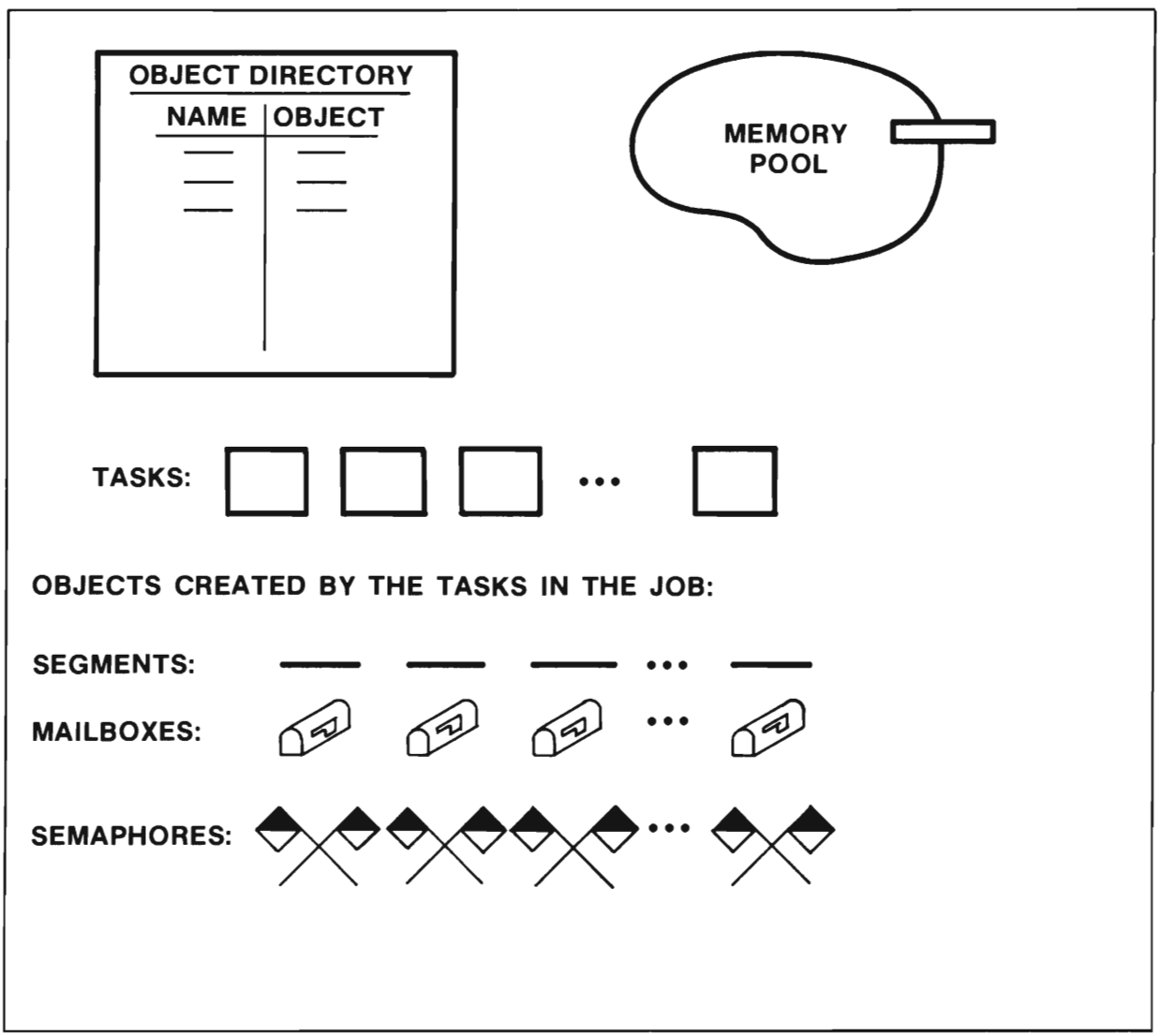


Figure 3-1. A Job

You must specify these limits whenever you create a job and the limits apply collectively to the job and all of its descendent jobs.

When job A creates job B:

- Sufficient memory to meet job B's minimum memory pool requirements is transferred from job A's memory pool to that of job B.
- The memory for job B's object directory is taken from job A's memory pool.
- The numbers of tasks and total objects that job A can contain are reduced by the corresponding values specified for job B.
- The specified maximum priority for tasks in job B cannot exceed the maximum priority for tasks in job A.

If job B is later deleted, its resources are returned to job A.

JOB CREATION

A job is created with one task. The functions of this task include doing some initializing for the new job. Initializing activities can include housekeeping and creating other objects in the new job.

When a task creates a job, it has the option of passing a token for a parameter object to the newly created job. The parameter object can be of any type and it can be used for any purpose. For example, the parameter object might be a segment containing data - arranged in a predefined format - needed by tasks in the new job. Tasks in the new job can obtain a token for the job's parameter object by means of the GET$TASK$TOKENS system call, described in Chapter 10.

JOB DELETION

Before a job can be deleted, all of its interrupt tasks (see Chapter 9) and descendent jobs must be deleted. By using the OFFSPRING system call, the deleting task can probe down the job tree and find all of the descendents. Then it can delete them, beginning with descendents that have no children and working up the tree. After all of the descendents have been deleted, the task can delete the target job.

SYSTEM CALLS FOR JOBS

The following system calls manipulate jobs:

- CREATE$JOB --- creates a job with a task and returns a token for the job; resources for the new job are drawn from the resources of the job to which the invoking task belongs.

- DELETE$JOB --- deletes a childless job that contains no interrupt tasks and returns the job's resources to its parent.

- OFFSPRING --- provides a segment containing tokens of the child jobs of the specified job.

Chapter 4. TASK MANAGEMENT

Tasks are the active objects in an RMX/86 system. Each task is part of a job and is restricted to the resources that its job provides. Tasks are written as PL/M-86 procedures, not as main modules.

The RMX/86 Nucleus maintains a set of attributes for each task. Among these attributes are the priority and execution state of the task. A task's priority is an integer value between 0 and 255, inclusive. The lower the priority number, the higher the priority of the task. A high priority task has favored status as it competes with other tasks for the CPU.

TASK STATES

A task is always in one of five execution states. The states are asleep, suspended, asleep-suspended, ready, and running.

THE ASLEEP STATE

A task is in the asleep state when it is waiting for a request to be granted. Also, a task can put itself to sleep for a specified amount of time by using the SLEEP system call.

THE SUSPENDED STATE

A task enters the suspended state when it is placed there by another task or when it suspends itself. Associated with each task is a suspension depth, which reflects the number of "suspends" outstanding against it. Each suspend operation must be countered with a resume operation before the task can leave the suspended state.

THE ASLEEP-SUSPENDED STATE

When a sleeping task is suspended, it enters the asleep-suspended state. In effect, it is then in both the asleep and suspended states. While asleep-suspended, the task's sleeping time might expire, putting it in the suspended state.

THE READY AND RUNNING STATES

A task is ready if it is not asleep, suspended, or asleep-suspended. For a task to become the running (executing) task, it must be the highest priority task in the ready state. In the event that multiple tasks each have the highest priority, the one that has been ready longest is the one that starts running.

TASK STATE TRANSITIONS

The Nucleus does not allocate the processor to tasks in a time-slicing manner. Instead, as an RMX/86 application system runs, events occur which cause tasks to pass from state to state. The RMX/86 Operating System is, therefore, event-driven. Figure 4-1 shows the paths of transition between states.

The following list describes, by number, the events that cause the transitions in Figure 4-1. In the list, the migrating task is called "the task":

(1) The task goes from non-existence to the ready state when it is created.

(2) The task goes from the ready state to the running state when one of the following occurs:

- The task has just become ready and has higher priority than does any other ready task.
- The task is ready, no other ready task has higher priority, no other task of equal priority has been ready for a longer time, and the previously running task has just left the running state by (4), (6), or (10).

(3) The task goes from the running state to the ready state when the task is preempted by a higher priority task that has just become ready.

(4) The task goes from the running state to the asleep state when one of the following occurs:

- the task puts itself to sleep (by the SLEEP system call.)
- The task makes a request (by the RECEIVE$MESSAGE, RECEIVE$UNITS, or LOOKUP$OBJECT system call) that cannot be granted immediately and expresses, in the request, its willingness to wait.

(5) The task goes from the asleep state to the ready state or from the asleep-suspended state to the suspended state when one of the following occurs:

- The task's designated waiting period expires without its request being granted.
- The task's request is granted (because another task called either the SEND$MESSAGE, SEND$UNITS, or CATALOG$OBJECT system call; these calls correspond to those mentioned in (4), above.)

(6) The task goes from the running state to the suspended state when the task suspends itself (by the SUSPEND$-TASK system call).

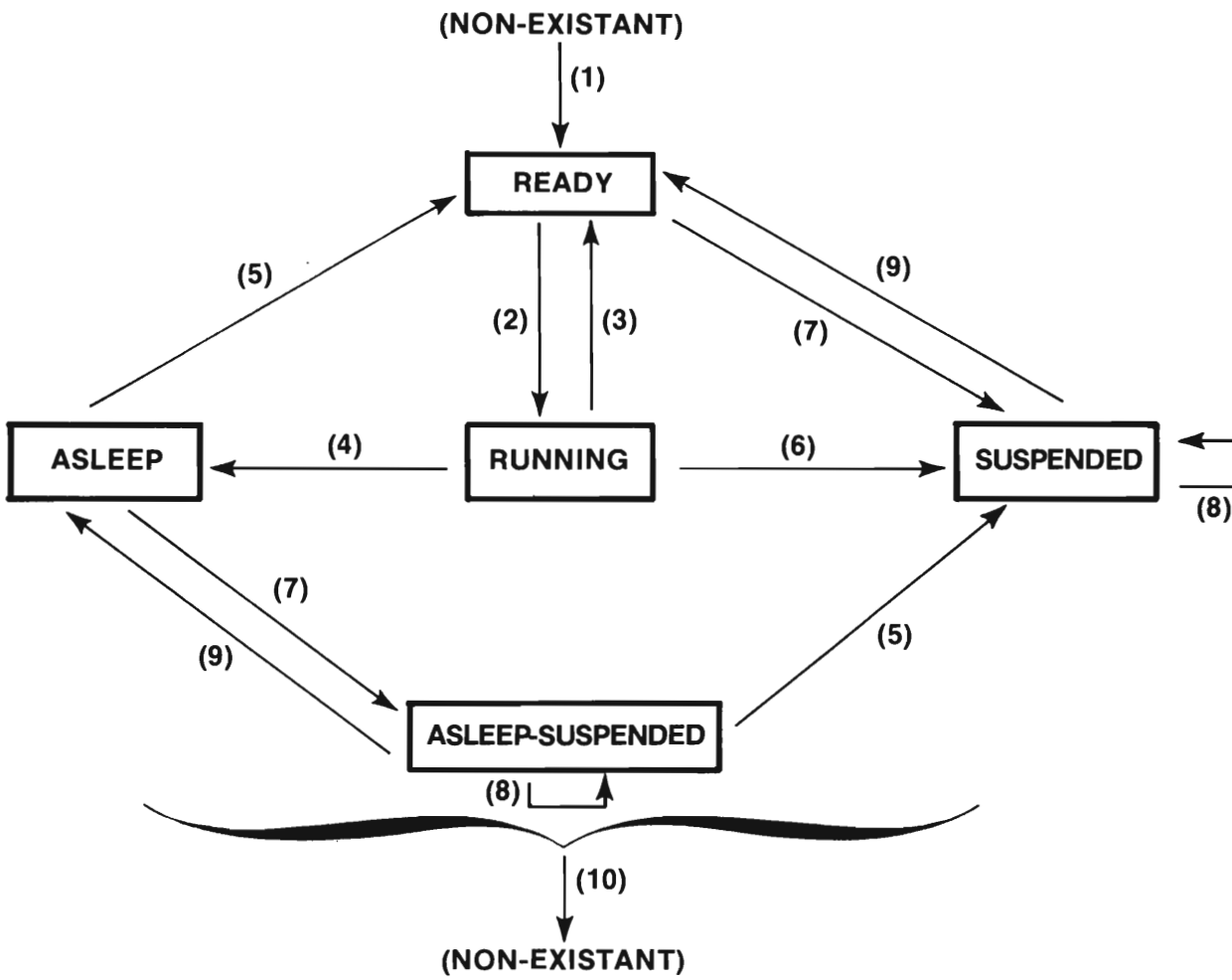


Figure 4-1. Task State Transition Diagram.

(7) The task goes from the ready state to the suspended state or from the asleep state to the asleep-suspended when the task is suspended by another task (by the SUSPEND$TASK system call).

(8) The task remains in the suspended state or the asleep-suspended state when one of the following occurs:

- (same as (7) or
- The task has a suspension depth greater than one and the task is resumed by another task (by the RESUME$-TASK system call).

(9) The task goes from the suspended state to the ready state or from the asleep-suspended state to the asleep state when the task has a suspension depth of one and the task is resumed by another task (by the RESUME$-TASK system call).

(10) The task goes from any state to non-existence when it is deleted (by the DELETE$TASK or DELETE$JOB system call).

ADDITIONAL TASK ATTRIBUTES

In addition to priority, execution state, and suspension depth, the Nucleus maintains current values of the following attributes for each existing task: containing job, its PL/M-86 register context, starting address of its exception handler (see Chapter 8), and exception mode (see Chapter 8).

TASK RESOURCES

When a task is created, the Nucleus takes any resources that it needs at that time (such as a segment) from the task's containing job.

SYSTEM CALLS FOR TASKS

The following system calls are provided for task manipulation:

- CREATE$TASK --- creates a task and returns a token for it.
- DELETE$TASK --- deletes a task from the system.
- SUSPEND$TASK --- increases a task's suspension depth by one; suspends the task if it is not already suspended.

- RESUME$TASK --- decreases a task's suspension depth by one; if the depth becomes zero and the task was suspended, it then becomes ready; if the depth becomes zero and the task was asleep-suspended, then it goes into the asleep state.

- SLEEP --- places the calling task in the asleep state for a specified amount of time.

- GET$TASK$TOKENS --- returns to the calling task a token for either itself, its job, its job's parameter object, or the root job, depending on which option is specified in the call.

- GET$PRIORITY --- returns the priority of the specified task.

Chapter 5. EXCHANGE MANAGEMENT

The RMX/86 Nucleus provides exchanges to facilitate intertask communication, synchronization, and mutual exclusion. When a task uses an exchange, it is always acting either as a sender or as a receiver. There are two kinds of exchanges: mailboxes and semaphores. If the exchange is a mailbox, one task will send an object to the mailbox; another task will go to the mailbox to receive the object. If the exchange is a semaphore, either a task is receiving units from the semaphore, or it is sending units to the semaphore.

MAILBOXES

The principal function of mailboxes is to support intertask communication. A sending task uses a mailbox to pass an object to another task. For example, the object might be that of a segment containing data needed by the receiving task.

MAILBOX QUEUES

Each mailbox is endowed with two queues, one for tasks that are waiting to receive objects, the other for objects that have been sent by tasks but have not yet been received. The Nucleus sees that waiting tasks receive objects as soon as they are available, so, at any given time, at least one of the mailbox's queues is empty.

MAILBOX MECHANICS

When a task sends a token to a mailbox, using the SEND$MESSAGE system call, one of two things happens. If no tasks are waiting at the mailbox, the object is placed at the rear of the object queue (which might be empty). Object queues are processed in a first-in-first-out manner, so the object remains in the queue until it makes its way to the front and is given to a task.

If, on the other hand, there are tasks waiting, the receiving task, which has been asleep, goes either from the asleep state to the ready state or from the asleep-suspended state to the suspended state.

NOTE

If the receiving task has a higher priority than the sending task, then the receiving task preempts the sender and becomes the running task.

When a task attempts to receive an object from a mailbox via the RECEIVE$MESSAGE system call, and the object queue at the mailbox is not empty, the task receives the object immediately and remains ready. However, if there are no objects at the mailbox there are two possibilities:

- If the task, in its request, elects to wait, it is placed in the mailbox's task queue and is put to sleep. If the designated waiting period elapses before the task gets an object, the task is made ready and receives an E$TIME exceptional condition (see Chapter 8).

- If the task is not willing to wait, it remains ready and receives an E$TIME exceptional condition.

A task has the option, when using the SEND$MESSAGE system call, of specifying that it wants acknowledgment from the receiving task. Thus, any task using the RECEIVE$MESSAGE system call should check to see if an acknowledgment has been requested. For details, see the description of the RECEIVE$MESSAGE system call in Chapter 10.

As stated earlier, the object queue for a mailbox is processed in a first-in-first-out manner. However, the task queue of a mailbox can be either first-in-first-out or priority-based, with higher-priority tasks toward the front of the queue. The queueing method to be used is specified for each mailbox at the time of its creation.

SYSTEM CALLS FOR MAILBOXES

The following system calls manipulate mailboxes:

- CREATE$MAILBOX --- creates a mailbox and returns a token for it.

- DELETE$MAILBOX --- deletes a mailbox from the system.

- SEND$MESSAGE --- sends an object to a mailbox.

- RECEIVE$MESSAGE --- sends the calling task to a mailbox for an object; the task has the option of waiting if no objects are present.

SEMAPHORES

A semaphore is a custodian of abstract units. A task uses a semaphore either by requesting a specific number of units from it via the RECEIVE$UNITS system call or by releasing a specific number of units to it via the SEND$UNITS system call. Although these operations do not support communication of data, they facilitate mutual exclusion, synchronization, and resource allocation.

SEMAPHORE QUEUE

Semaphores have only one queue - a task queue. As is the case with mailboxes, the task queue is either first-in-first-out or priority based. The queueing scheme to be used is specified for each semaphore at the time of its creation.

SEMAPHORE MECHANICS

A semaphore might simultaneously have both tasks in its queue and units in its custody. The allocation scheme used by semaphores is the reason for this. That scheme is best understood by imagining that the semaphore is trying, at all times, to satisfy the request of the task which is at the front of the semaphore's task queue. Only when it can provide as many units as the task requested does it award units, and then it does so immediately.

When a task uses the CREATE$SEMAPHORE system call, it must supply two values. One value specifies the initial number of units to be in the new semaphore's custody. The other value sets an upper limit on the number of units that the semaphore is allowed to keep at any given time. The lower limit is automatically zero.

When a task requests units from a semaphore via the RECEIVE$-UNITS system call, the request must be within the specified maximum for that semaphore; otherwise, the request is invalid and causes an E$LIMIT exceptional condition. If a task's request for units is valid and both

- the size of the request is within the semaphore's current supply of units and
- the task is - or would be if queued - at the front of the semaphore's task queue,

then the request is granted immediately and the task remains ready. Otherwise, one of the following applies:

- The task, in its request, elects to wait. It is placed in the semaphore's task queue and is put to sleep. If the designated waiting period elapses before the task gets its requested units, the task is made ready and receives an E$TIME exceptional condition.

- The task is not willing to wait. It remains ready and receives an E$TIME exceptional condition.

Suppose, for example, that two tasks, A and B, are waiting at a semaphore, with A at the front of the queue. The semaphore has no units, A wants 3 units, and B wants 1 unit. The following three separate cases illustrate the mechanics of the semaphore:

- If the semaphore is sent 2 units, both A and B remain asleep in the semaphore's queue. Note that B's modest request is not satisfied because A is ahead of B in the queue.

- If, instead, the semaphore is sent 3 units, A receives the units and awakens, while B remains asleep in the queue.

- If, instead, the semaphore is sent 4 units, A and B both receive their requested units and are awakened.

When a task sends units to a semaphore, the task remains ready. Sending units to a semaphore causes an E$LIMIT exceptional condition if it pushes the semaphore's supply above the designated maximum. The number of units in the custody of the semaphore remains unchanged.

NOTE

> It is possible that a task sending units to a semaphore can be preempted by a higher priority task becoming ready as a result of getting its requested units.

SYSTEM CALLS FOR SEMAPHORES

The following system calls manipulate semaphores:

- CREATE$SEMAPHORE --- creates a semaphore and returns a token for it.

- DELETE$SEMAPHORE --- deletes a semaphore from the system .

- SEND$UNITS --- adds a specific number of units to the supply of a semaphore.

- RECEIVE$UNITS --- asks for a specific number of units from a semaphore.

Chapter 6. MEMORY MANAGEMENT

Occasionally a task needs additional memory, that is, memory not yet allocated to its job. By using Nucleus system calls for allocating and deallocating memory, tasks can usually satisfy their memory needs.

SEGMENTS

Allocated memory is treated as a collection of segments. A segment is a contiguous sequence of 16 byte paragraphs, with its starting (base) address evenly divisible by 16. The Nucleus maintains, as attributes, the base address and the length in bytes of each segment.

When a task needs a segment, it can request one of the desired length via the CREATE$SEGMENT system call. If enough memory is available, the Nucleus returns a token for the segment.

NOTE

> The token of a segment can be used as the base portion of a pointer to the segment. Thus, the token can be used as a base address (as when writing a message in the segment) or as an object reference (as when sending the segment-with-message to a mailbox).

MEMORY POOLS

A memory pool is the amount of memory available to a job and its descendents. Each job has a memory pool. When a job is created, the memory for its pool is borrowed from the pool of its parent job. Thus, there is effectively a tree-structured hierarchy of memory pools, identical in structure to the hierarchy of jobs. Memory that a job borrows from its parent remains in the pool of the parent as well as being in the pool of the child. Such memory, however, is available for use by tasks in the child job, but not by tasks in the parent job. Figure 6-1 illustrates the relationship between the job and memory hierarchies. In the figure, the pool sizes shown are actually the maximum sizes of those pools.

CONTROLLING POOL SIZE

Two parameters, pool minimum and pool maximum, of the CREATE$-JOB system call, dictate the range of sizes (in paragraphs) of a new job's memory pool. Initially, the pool size is equal to pool minimum. Memory allocated to tasks in the job is still considered to be in the job's pool. A task needing to know

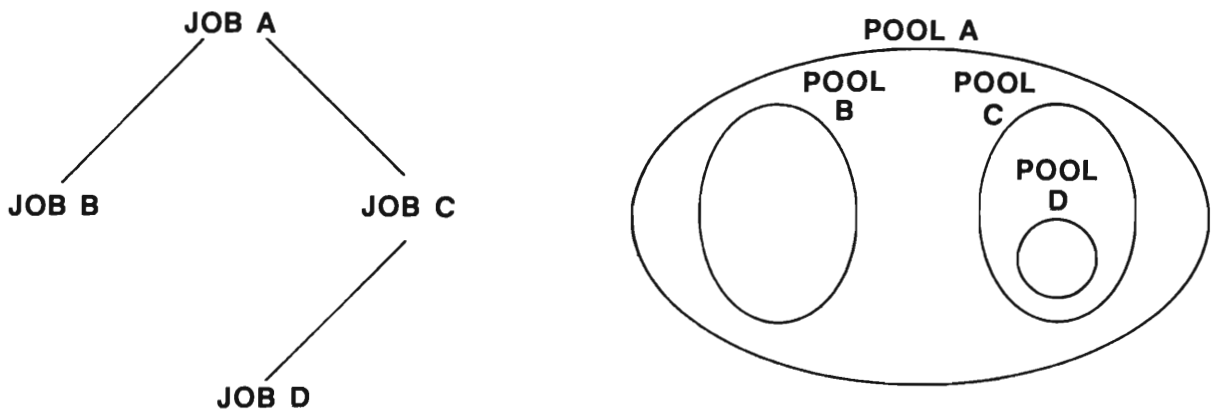


Figure 6-1. Comparison of Job and Memory Hierarchies

about its job's pool may use the GET$POOL$ATTRIBUTES system call to obtain pool minimum, pool maximum, initial pool size, number of bytes currently available, and number of bytes currently allocated.

A task may alter the pool minimum attribute for its job by means of the SET$POOL$MINIMUM system call; pool minimum must lie in the range from 0 to pool maximum. If a subsequent request for a segment increases the pool's minimum size, and the current pool size is less than the new minimum, no memory is borrowed immediately from the parent job. Rather, memory is automatically borrowed as it is requested by tasks in the job, until the new minimum is reached. At that time, the new value of the pool minimum attribute becomes a lower bound for the job's pool size.

MOVEMENT OF MEMORY BETWEEN JOBS

When a task requests a segment, and the unallocated part of its job's pool is not sufficient to satisfy the request, the Nucleus tries to borrow more memory from the job's parent (and

then, if necessary, from its parent's parent, and so on). Such borrowing increases the pool size of the borrowing job and is thus restricted by the pool maximum attribute of the borrowing job.

When a job is deleted, the memory in its pool becomes unallocated, and access to it is given back to the parent job. The smallest contiguous piece of memory that a job may borrow from its parent is a configuration parameter. The subject of configuration is covered in the RMX/86 Configuration Guide For ISIS-II Users.

Observe that, if a job has equal pool minimum and pool maximum attributes, then its pool is fixed at that common value. This means that, once it has this amount, the job may not borrow memory from its parent. A task in the job may, however, create a new job.

MEMORY ALLOCATION

The memory pool of a job consists of two classes of memory: allocated and unallocated. Memory in a job is allocated if it has been requested by tasks in the job or if it is on loan to a child job. Otherwise, it is unallocated.

When a task no longer needs a segment, it can return the segment to the unallocated part of the job's pool by using the DELETE$SEGMENT system call. Figure 6-2 shows how memory "moves."

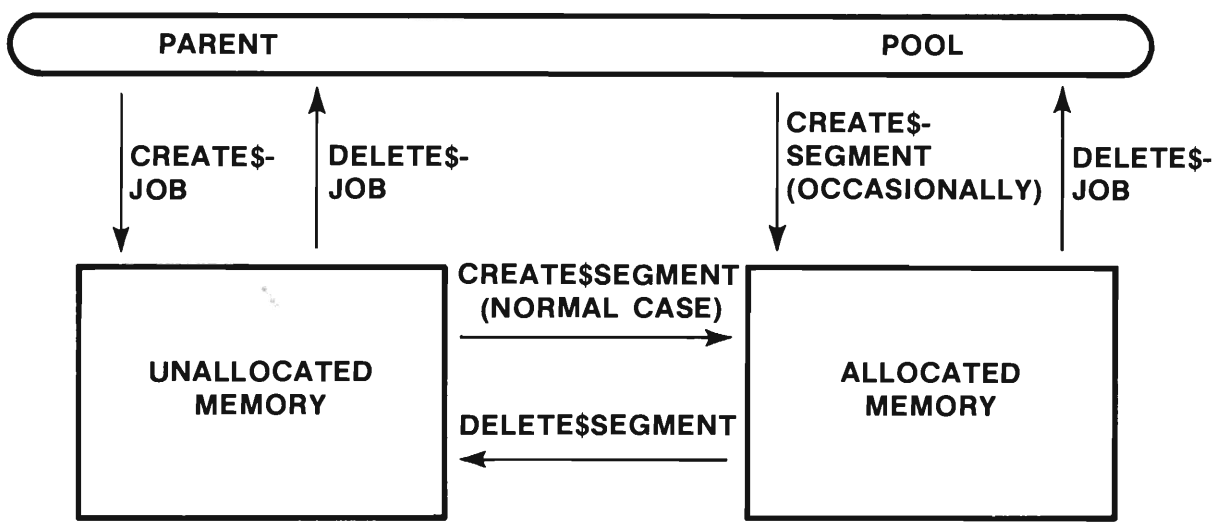


Figure 6-2. Memory Movement Diagram

MEMORY DEADLOCK PROBLEMS

Users who are planning to write tasks that do dynamic memory allocation (via the CREATE$SEGMENT system call) should be aware that deadlock is an inherent danger in any operatng system in which memory is allocated dynamically. Two tasks are said to be deadlocked when each one is requesting something that is held by the other and neither task will relinquish what the other task needs.

Deadlock is unusual and unpredictable. When it occurs it is usually in systems in which there is heavy use of the allocation and deallocation capabilities. When deadlock occurs, the best solution is not necessarily to add more memory. Instead, you can take precautions in the way in which you write tasks. The purpose of this section is to recommend some general methods of guarding against deadlock.

The following example serves both to illustrate the concept of deadlock and to emphasize the danger that RMX/86 tasks can face when they are requesting segments.

Suppose that the following circumstances exist for tasks A and B and the memory pool of their common job:

- A has low priority and B has high priority.
- A and B each want two segments of a given size. Each asks for the segments by calling the CREATE$SEGMENT system call repeatedly until both segments are acquired.
- The memory pool has only enough memory to satisfy two of the requests.
- B is asleep and A is running.

Now suppose that the following events occur in the order listed:

- A gets its first segment.
- B awakens and becomes the running task.
- B gets its first segment.

B remains ready and continues to ask for its second segment. Not only is each task unable to progress, but task B is consuming a great deal, perhaps all, of the processor time. Tasks A and B are deadlocked and the system's performance is seriously degraded.

This kind of memory allocation deadlock problem is particularly insidious because it probably would not occur during debugging. Note that the key event in the preceding example is

the waking of task B just after A's first call to the CREATE$-SEGMENT primitive and just before the second call. Such critical timing probably would occur only rarely, so what is confidently thought to be a "thoroughly debugged system" might suddenly, inexplicably fail. Analyzing this kind of problem can be very difficult.

Several precautions may be taken to prevent the deadlock in the previous examples:

- If either task needed memory for its own use, rather than needing a segment to send to another task, it might have been able to make do with its extra segment.

- Task B should not be asking endlessly for its second segment. As a general rule, a task should only try a predetermined number of times to obtain a segment.

- Each task could be stopped from preempting the other while the other is in the midst of its "allocation phase".

The following are two ways of achieving the mutual exclusion implied in the third precaution:

- Each task, instead of making multiple requests for memory, could ask for a single, large segment instead of asking for several small ones. This approach could be unsatisfactory for either or both of two reasons:

  - If the requesting task needs to send small segments to other tasks, a large segment will not suffice.

  - In general, requests for large segments are less apt to be successful because the memory in the pool might be fragmented, with no large, contiguous blocks remaining.

- The tasks could use an "allocation semaphore", which would be created with one unit. Each task, before requesting memory, would request one unit from the semaphore. When it gets the unit, the task can get all of its needed memory and then send the unit back to the semaphore. Doing this prevents deadlock, but it might cause a high priority task to be kept waiting for a long time by a low priority task that first obtained the unit from the semaphore and then was preempted by another, higher-priority task. There is no certain cure for this "blocking" of waiting tasks, but such incidents can be made somewhat rarer if the allocation semaphore has a priority-based task queue.

A fourth precaution against deadlock involves isolating tasks and memory pools so that tasks requesting memory are not directly or indirectly competing for the same memory. Tasks

compete directly when they are in the same job, so tasks that request memory should be in different jobs. (Perhaps each job contains a special purpose task which does all of the requesting of memory for its job.) Tasks can also compete (indirectly) when they are in different jobs, because their jobs might have to borrow memory from their ancestors in the job tree, and, in so doing, might borrow from the same job. However, if two tasks are in separate jobs and at least one of them is in a job whose pool$min and pool$max attributes are equal (and not zero), then that task's job cannot borrow and the deadlock problem is avoided. A disadvantage of isolating a job in this way is that it might then be unable to satisfy requests for memory, unless it is created with a substantial memory pool. In some cases, the requirement that memory pools be large may not be acceptable.

As was mentioned earlier, deadlock is a rare phenomenon. We recommend that you not worry excessively about it. However, it is a real hazard, so you would be wise to develop your system with deadlock prevention in mind.

SYSTEM CALLS FOR SEGMENTS

The following system calls manipulate segments:

- CREATE$SEGMENT --- creates a segment and returns a token for it.
- DELETE$SEGMENT --- returns a segment to the pool from which it was allocated.
- GET$SIZE --- returns the size, in bytes, of a segment.
- SET$POOL$MINIMUM --- enables a task to change the pool minimum attribute of its job's pool.
- GET$POOL$ATTRIBUTES --- returns the following memory pool attributes of the calling task's job: pool minimum, pool maximum, initial size, number of allocated bytes, and number of available bytes.

Chapter 7. OBJECT MANAGEMENT

There are a few RMX/86 Nucleus system calls that apply to all object types. One of these, the GET$TYPE system call, enables a task to present a token to the Nucleus and get an object's type code in return. (Type codes are listed in Appendix B.) This is useful, for example, when a task is expecting to receive objects of several different types. With the object's type code, the task can use the appropriate system calls for the object.

Other type-independent system calls have to do with object directories. Each job has its own object directory. An entry in an object directory consists of an object with an ASCII name. Such a feature is often needed because some tasks might only know some objects by their associated names.

By using the LOOKUP$OBJECT system call, a task can present the name of an object to the Nucleus. The Nucleus consults the object directory corresponding to the specified job and, if the object has been cataloged there, returns the token.

If the object has not yet been cataloged, and the task is not willing to wait, the task remains ready and receives an E$TIME exceptional condition. However, if the task is willing to wait, it is put to sleep; there are two possibilities:

- If the designated waiting period elapses before the task gets its requested token, the task is made ready and receives an E$TIME exceptional condition (see Chapter 8).

- If the task gets its requested token within the designated waiting period, it is made ready with no exceptional condition. This case is possible because another task can, while the requesting task is waiting, catalog the appropriate entry in the specified object directory.

The tasks in a job must maintain the job's object directory. When a task wants to share an object with the other tasks in a job (not necessarily its own job), it can use the CATALOG$-OBJECT system call to put the object in that job's object directory. Typically, this is done by the creator of the object. Likewise, entries can be removed from a directory by the UNCATALOG$OBJECT system call.

What is required, when using an object directory, is the token of the job whose directory is to be used. The root job's object directory, called the root object directory, is special in that any task can use it. Any task can call the GET$TASK$-TOKENS system call to obtain the token of the root job.

SYSTEM CALLS FOR ANY OBJECTS

The following system calls manipulate objects:

- CATALOG$OBJECT --- places an object in an object directory.
- UNCATALOG$OBJECT --- removes an object from an object directory.
- LOOKUP$OBJECT --- accepts a cataloged name of an object and returns a token for it.
- GET$TYPE --- accepts a token for an object and returns its type code.

Chapter 8. EXCEPTIONAL CONDITION MANAGEMENT

When a task invokes an RMX/86 system call, the results are sometimes not what the task is trying to achieve. For example, maybe the task requests memory that is not available, or it might use an invalid token as a parameter. In such cases, the system must inform the task that an error occurred. Whenever a task makes a system call, the means of communicating the success or failure of the call is the condition code.

TYPES OF EXCEPTIONAL CONDITIONS

Table 8-1 is a list of Nucleus conditions and their codes. The conditions that represent failure are called exceptional and are classified as programmer errors or environmental conditions. An exceptional condition that is preventable by the calling task is a programmer error. In contrast, exceptional conditions due to environmental circumstances of which the task could have no awareness are considered environmental conditions.

Table 8-1 lists the possible conditions, with their associated numeric codes and mnemonics. Values not used as numeric codes are reserved.

EXCEPTION HANDLERS

The RMX/86 Nucleus supports exception handlers. Their purpose is to deal with the errors that tasks make in making system calls. How an exception handler deals with an exceptional condition is a matter of programmer discretion. In general, a handler performs one of the following actions:

- Logs the error.
- Deletes the task that erred.
- Simply ignores the error. If this option is taken, the system continues as if no error had occurred.

An exception handler is written as a procedure with four parameters passed in the following order:

- the condition code (WORD).
- a code (BYTE) indicating which parameter, if any, was faulty in the call (1 for first, 2 for second, etc., 0 if none).

- a reserved (WORD) parameter.
- a reserved (WORD) parameter.

ASSIGNING AN EXCEPTION HANDLER

A task may use the SET$EXCEPTION$HANDLER system call to declare its own exception handler. Otherwise, the task inherits the exception handler of its job. A job can receive its own exception handler at the time of its creation. If it doesn't, the job inherits the system exception handler. Thus, the Nucleus can always find an exception handler for the running task.

A system exception handler is provided as part of the RMX/86 Operating System and deletes any task on whose behalf it is invoked. Users may provide their own system exception handlers.

Any task can have the Debugger as its exception handler; see the description in Chapter 10 of the SET$EXCEPTION$HANDLER system call for instructions on how to dynamically make such an assignment. Alternatively, the Debugger or any other routine can be made the system exception handler statically; see the RMX/86 Configuration Guide for ISIS-II users for information on how to do this.

INVOKING AN EXCEPTION HANDLER

When a task causes an exceptional condition, it need not have control passed to its exception handler. The factor that determines whether control passes to the exception handler is the task's exception mode. This attribute has four possible values, each of which specifies the circumstances under which the exception handler is to get control in the event of an exceptional condition. These circumstances are:

- Programmer errors only.
- Environmental conditions only.
- All exceptional conditions.
- No exceptional conditions.

When the Nucleus detects that a task has caused an exceptional condition in making a system call, it compares the type of the condition with the calling task's exception mode. If a transfer of control is indicated, the Nucleus passes control to the exception handler on behalf of the task. The exception handler then deals with the problem, after which control returns to the task, unless the exception handler deleted the task. While the exception handler is executing, the errant task is still regarded by the Nucleus to be the running task.

Table 8-1. Conditions and their Codes

CATEGORY/ MNEMONIC	MEANING	NUMERIC CODE HEX	DECIMAL
Normal			
E$OK	The most recent system call was successful.	0H	0
Exceptional			
Environmental Conditions			
E$TIME	A time limit (possibly a limit of zero time) expired without a task's request being satisfied.	1H	1
E$MEM	There is not sufficient memory available to satisfy a task's request.	2H	2
E$LIMIT	A task attempted an operation which, if it had been successful, would have violated a Nucleus-enforced limit.	4H	4
E$CONTEXT	A system call was issued out of context.	5H	5
E$EXIST	A token parameter has a value which is not the token of an existing object.	6H	6
E$STATE	A task attempted an operation which would have caused an impossible transition of a task's state.	7H	7
Programmer Errors			
E$ZERO$-DIVIDE	A task attempted to divide by zero.	8000H	32768
E$OVERFLOW	An overflow interrupt occurred.	8001H	32769
E$TYPE	A token parameter referred to an existing object that is not of the required type.	8002H	32770
E$BOUNDS	A task attempted to write beyond the end of a segment.	8003H	32771
E$PARAM	A parameter which is neither a token nor an offset has an illegal value.	8004H	32772

When a task is created, its exception mode is set to its job's default exception mode. The task can change its exception handler and exception mode attributes by using the SET$-EXCEPTION$HANDLER system call.

HANDLING EXCEPTIONS IN-LINE

If a task's exception mode attribute does not direct the Nucleus to transfer control to the task's exception handler, the responsibility for dealing with an error falls upon the task.

Each system call has as its last parameter a pointer to a WORD. After a system call, the Nucleus returns the resulting condition code to this WORD. By checking this WORD after each system call, a task can ascertain whether the call is successful. (See Table 8-1 for condition codes.) If the call is not successful, the task can learn which exceptional condition it caused. This information can sometimes enable the task to recover. In other cases more information is needed.

NOTE

> If an exceptional condition is caused by an invalid parameter, an exception handler, which is passed the parameter number of the first invalid parameter, should handle the condition.

SYSTEM CALLS FOR EXCEPTION HANDLERS

The following system calls manipulate exception handlers:

- SET$EXCEPTION$HANDLER --- sets the exception handler and exception mode attributes of the calling task.
- GET$EXCEPTION$HANDLER --- returns to the calling task the current values of its exception handler and exception mode attributes.

Chapter 9. INTERRUPT MANAGEMENT

Interrupts and interrupt processing are central to real-time computing. External events occur asynchronously with respect to the internal workings of a RMX/86 application system. An interrupt, signalling the occurrence of an external event, triggers an implicit "call" to a specific location in a section of memory known as the interrupt vector table. From there, control is redirected to a PL/M-86 interrupt procedure called an interrupt handler. At this point, one of two things happens. If handling the interrupt takes little time and requires no system calls, other than certain interrupt-related system calls, the interrupt handler processes the interrupt. Otherwise, the interrupt handler invokes an interrupt task which deals with the interrupt. After the interrupt has been serviced, control returns to the application task with highest priority.

INTERRUPT MECHANISMS

There are three major concepts in interrupt processing: the interrupt vector table, interrupt levels, and disabling interrupt levels.

THE INTERRUPT VECTOR TABLE

The interrupt vector table is composed of 256 vectors. The vectors are numbered 0 to 255. A number of the interrupt vectors are reserved and therefore are not available to be defined by user tasks. The vectors are allocated as follows:

```
  0- 55:  reserved
 56- 63:  available for external interrupts
 64-223:  reserved
224-255:  described in the RMX/86 System Programmer's
          Reference Manual.
```

INTERRUPT LEVELS

External interrupts are funneled through hardware which can manage interrupts from up to eight external sources. The eight sources are associated with eight interrupt levels.

The interrupt levels, numbered 0 to 7, correspond to interrupt vectors 56 to 63, respectively. Interrupt levels with low numbers have high priority. As a rule, all levels except level 2 are available for user devices. Level 2 is reserved for the system clock.

DISABLING INTERRUPTS

Occasionally you want to prevent interrupt signals from causing an immediate interrupt. For example, it is desirable to prevent low priority interrupts from interfering with the servicing of a high priority interrupt. In the RMX/86 Operating System, each interrupt level can be disabled. In some circumstances, described later, the Nucleus disables levels. Tasks can also disable and enable levels by means of the DISABLE and ENABLE system calls. Level 2, which is reserved for the system clock, should not be disabled.

If an interrupt signal arrives at a level that is enabled, the interrupt is recognized by the processor and control goes immediately to the interrupt handler for that level. Otherwise, the level is disabled and the interrupt signal is blocked until the level is enabled, at which time the signal is recognized by the CPU. However, if the signal is no longer emanating from its source, it is not recognized and the interrupt is not handled.

There are two ways in which an interrupt level can be disabled. A task can mask a level by using the DISABLE system call; later the level can be unmasked by the ENABLE system call. The second disabling agent is the Nucleus itself. When the running task is of high priority, the Nucleus disables certain interrupt levels. The relationship between task priorities and disabled levels is given in Table 9-1.

Table 9-1. Interrupt Levels Disabled For Running Task

Task Priority	Disabled Levels
0-16	0-7
17-32	1-7
33-48	2-7
49-64	3-7
65-80	4-7
81-96	5-7
97-112	6-7
113-128	7
129-255	None

INTERRUPT HANDLERS AND INTERRUPT TASKS

Whether an interrupt level is to be serviced by an interrupt handler alone or by having an interrupt handler invoke an interrupt task depends on two conditions. First, interrupt handlers cannot make most system calls. Only EXIT$INTERRUPT, GET$LEVEL, and SIGNAL$INTERRUPT can be called from an interrupt handler. If other system calls are required, they must be made by an interrupt task. Second, an interrupt handler should call an interrupt task unless it can service interrupts quickly because an interrupt signal disables all interrupts, and interrupts remain disabled until the interrupt handler is finished processing. Invoking an interrupt task, on the other hand, allows higher priority interrupts to be accepted.

USING AN INTERRUPT HANDLER

Interrupt handlers are written as PL/M-86 interrupt procedures.

An interrupt handler that does not call an interrupt task must perform the following functions in the following order:

Service the interrupt.
Make an EXIT$INTERRUPT system call.

The call to the EXIT$INTERRUPT causes an end-of-interrupt signal to be sent to the hardware.

The SET$INTERRUPT system call binds an interrupt handler and, optionally, an interrupt task to an interrupt level. SET$INTERRUPT places the starting address of an interrupt handler in the interrupt vector table. If the interrupt$-task$flag parameter is set to 1, then the task calling SET$-INTERRUPT becomes the interrupt task for the specified level. Otherwise, interrupt$task$flag is 0 and there is no interrupt task for the level.

When an RMX/86 application system starts up, all interrupt levels are disabled. When SET$INTERRUPT binds an interrupt handler but not an interrupt task to a level, the level is enabled. If, instead, there is an interrupt task, the level is not enabled until that task makes a WAIT$INTERRUPT system call (described in the next section.)

The RESET$INTERRUPT system call cancels the bond between an interrupt level and its interrupt handler. The call also disables the specified level. If there is an interrupt task for the level, RESET$INTERRUPT deletes it. DELETE$TASK and DELETE$JOB do not delete interrupt tasks.

USING AN INTERRUPT TASK

If there is both an interrupt handler and an interrupt task associated with a level, the interrupt handler invokes the interrupt task by making a SIGNAL$INTERRUPT system call. If a level has only an interrupt handler, however, the handler may not call SIGNAL$INTERRUPT.

If an interrupt handler calls an interrupt task, the handler must perform the following functions in the following order:

Optionally, service the interrupt without system calls.
Call SIGNAL$INTERRUPT.

The call to SIGNAL$INTERRUPT starts up the interrupt task and enables interrupts.

An interrupt task must perform the following functions in the following order, although the first two functions may be interchanged:

```
Call SET$INTERRUPT.
Do initialization.
Do forever;
   Call WAIT$INTERRUPT.
   Service the interrupt (system calls allowed).
End;
```

An interrupt handler executes in the environment of the interrupted task. An interrupt task has its own environment.

An interrupt task, once initialized, is always in one of two modes. Either it is servicing an interrupt or it is waiting for notification of an interrupt.

When a task becomes an interrupt task by calling SET$INTERRUPT, the Nucleus assigns a priority to it, according to the level that the task is to service. Table 9-2 shows the relationship between levels and interrupt task priorities.

NOTES

The priority that the Nucleus assigns to an interrupt task might exceed the maximum priority attribute of the job that contains that task. If this occurs, you get an exceptional condition. To overcome this problem, recreate the job with a higher maximum priority attribute.

Because an interrupt vector is initialized by SET$INTERRUPT, the NOINTVECTOR control should be used when compiling the interrupt task.

Figure 9-1 illustrates the two interrupt servicing patterns and their relationships.

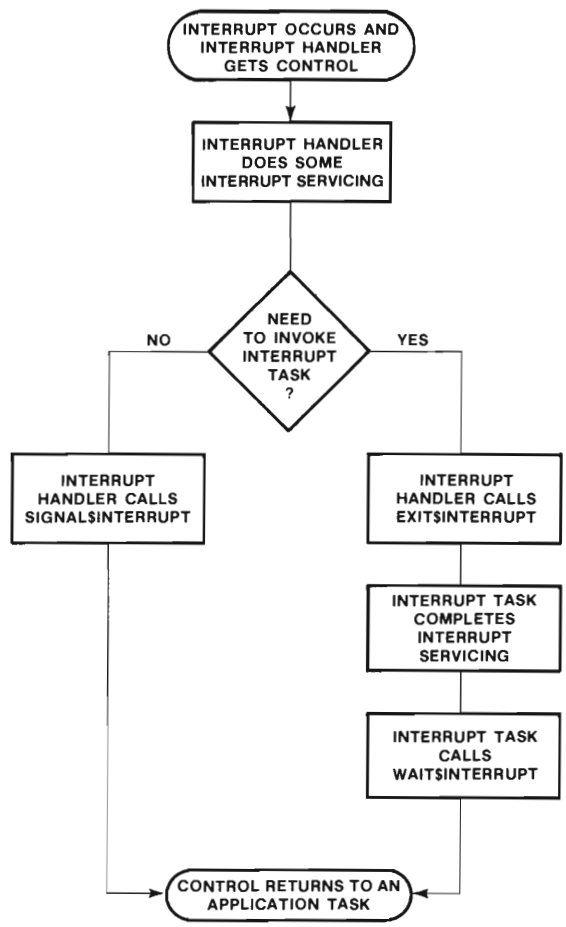


Figure 9-1.

Table 9-2. The Relationship Between External Levels and Internal Task Priorities

LEVEL	INTERRUPT TASK PRIORITY
0	18
1	34
2	50
3	66
4	82
5	98
6	114
7	130

HANDLING LEVEL 7 INTERRUPTS

Occasionally, spurious signals can trigger a level 7 interrupt. An interrupt handler for level 7 should begin by sampling port CO. If the BYTE value obtained there does not have a 1 in the high-order bit, then the interrupt is a false alarm and should not be handled. In PL/M-86, the following lines perform this check when placed at the beginning of the interrupt handler:

```
OUTPUT (OCOH) = OBH;

IF ((INPUT (OCOH)) AND  80H) = 0

     THEN RETURN;
```

EXAMPLES OF INTERRUPT SERVICING

To help you understand the major points already described, tables 9-3 and 9-4 are provided. Each table outlines the turning points in a scenario where an interrupt handler is assigned to level 4, an interrupt arrives at that level and is serviced, and finally the assignment of an interrupt handler is cancelled. Table 9-3 shows a case where the interrupt handler deals with the interrupt. Table 9-4 treats the case where the interrupt handler calls an interrupt task.

In the right-hand column of each of tables 9-3 and 9-4, the phrase "interrupt levels necessarily disabled" alludes to the fact that the events of the example cause certain levels to be enabled or disabled. Other events, outside the scope of the example, might cause other levels to be disabled as well.

Table 9-3. An Example Of Interrupt Handling Without An Interrupt Task

EVENTS IN SEQUENCE	EXPLANATION	INTERRUPT LEVELS NECESSARILY DISABLED
-	No interrupt handler assigned to level 4.	4
RQSETINTERRUPT (LEVEL$4,0,...);	A task assigns an interrupt handler to level 4.	NONE
Level 4 device interrupts	An interrupt arrives at level 4.	0-7
. . .	The interrupt is serviced by the interrupt handler.	0-7
RQ$EXIT$INTERRUPT (LEVEL$4,...);	Interrupt hardware reset by the interrupt handler.	0-7
Interrupt handler returns	Interrupts are re-enabled.	NONE
RQ$RESET$INTERRUPT- (LEVEL$4,...);	A task cancels the assignment of an interrupt handler to level 4.	4

Table 9-4. An Example Of Interrupt Handling With An Interrupt Task

EVENTS IN SEQUENCE	EXPLANATION	INTERRUPT LEVELS NECESSARILY DISABLED
—	No interrupt handler assigned to level 4.	4
RQSETINTERRUPT (LEVEL$4, 1, ...);	A task assigns an interrupt handler to level 4 and it assigns itself to be the interrupt task for that level.	4
RQ$WAIT$INTERRUPT (LEVEL$4,...);	The interrupt task begins to wait for an interrupt.	NONE
Level 4 device interrupts	An interrupt arrives at level 4. The interrupt handler gets control and optionally, does some servicing.	0-7
RQ$SIGNAL$INTERRUPT (LEVEL$4,...);	The interrupt handler invokes the interrupt task.	4-7
. . .	The interrupt is serviced by the interrupt task.	4-7
RQ$WAIT$INTERRUPT (LEVEL$4,...);	The interrupt task finishes and begins to wait for another level 4 interrupt. Control passes back to the interrupt handler and then back to an application task.	NONE

SYSTEM CALLS FOR INTERRUPTS

The following system calls manipulate interrupts:

- SET$INTERRUPT --- assigns an interrupt handler and, if desired, an interrupt task to an interrupt level.
- RESET$INTERRUPT --- cancels the assignment made to a level by SET$INTERRUPT and, if applicable, deletes the interrupt task for that level.
- EXIT$INTERRUPT --- used by interrupt handlers to send an end-of-interrupt signal to hardware.
- SIGNAL$INTERRUPT ---used by interrupt handlers to invoke interrupt tasks.
- WAIT$INTERRUPT --- puts the calling interrupt task to sleep until it is called into service by an interrupt handler.
- ENABLE --- enables an external interrupt level.
- DISABLE --- disables an external interrupt level.
- GET$LEVEL --- returns the interrupt level of highest priority for which an interrupt handler has started but has not yet finished processing.

Chapter 10. NUCLEUS SYSTEM CALLS

This chapter contains the calling sequences and other information about the system calls to the Nucleus. The system calls are listed in alphabetical order. Names of the calls are written in white on a dark background in the upper outside corner of each page. The calling sequence for each call is that for the PL/M-86 interface. The information for each system call is organized into the following categories, in the following order:

- A brief sketch of the effects of the call.
- The format of the call.
- Definitions of the input parameters, if any.
- Definitions of the output parameters, if any.
- A complete description of the effects of the call.
- The condition codes that can result from using the call, with a description of the possible causes of each condition.

Throughout the chapter, RMX/86 data types, such as BYTE, STRING are used. They are always capitalized and their definitions are found in Appendix A.

Between this introduction and the details of the system calls is a command dictionary, in which the calls are grouped according to type. This dictionary, which includes short descriptions and page numbers of the complete descriptions in this chapter, is provided as an alternate way of indexing the system calls.

COMMAND DICTIONARY

CALLS FOR JOBS

CALLS FOR TASKS

CALLS FOR MAILBOXES

COMMAND DICTIONARY (continued)

CALLS FOR SEMAPHORES

CALLS FOR SEGMENTS AND MEMORY POOLS

CALLS FOR ALL OBJECTS

COMMAND DICTIONARY (continued)

CATALOG OBJECT

CATALOG$OBJECT places an entry for an object in an object directory.

```
CALL RQ$CATALOG$OBJECT (job, object, name, except$ptr);
```

INPUT PARAMETERS

job — A WORD which,

- if zero, indicates that the object is to be cataloged in the object directory of the job to which the calling task belongs.
- if not zero, contains the token for the job in whose object directory the object is to be cataloged.

object — A WORD containing a token for the object to be cataloged.

name — A POINTER to a STRING containing the ASCII name under which the object is to be cataloged. The name itself must not exceed 12 ASCII characters in length.

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The CATALOG$OBJECT system call places an entry for an object in the object directory of a specific job. The entry consists of both an ASCII name and the object. There may be several such entries for a single object in a directory, because the object may have several ASCII names. (However, in a given object directory, only one object may be cataloged under a given name.) If another task is waiting, via the LOOKUP$OBJECT system call, for the object to be cataloged, that task is awakened when the entry is cataloged.

CONDITION CODES

E$OK — No exceptional conditions.

E$CONTEXT — The entry that is being cataloged is already in the designated object directory.

CATALOG OBJECT (continued)

CONDITION CODES (continued)

E$EXIST	Either the job parameter (which is not zero) or the object parameter is not a token for an existing object.
E$LIMIT	The designated object directory is full.
E$PARAM	The first BYTE of the STRING pointed to by the name parameter contains a value greater than 12 or a value of 0.
E$TYPE	The job parameter is a token for an object which is not a job.

CREATE$JOB creates a job with a single task.

```
job = RQ$CREATE$JOB (directory$size, param$obj, pool$min,
      pool$max, max$objects, max$tasks, max$priority,
      except$handler, job$flags, task$priority, start$-
      address, data$seg, stack$ptr, stack$size, task$flags,
      except$ptr);
```

INPUT PARAMETERS

directory$size — A WORD containing the maximum allowable number of entries in the created job's object directory.

param$obj — A WORD which,

- if zero, indicates that the new job has no parameter object.
- if not zero, contains a token for the new job's parameter object.

pool$min — A WORD which contains the minimum allowable size of the new job's pool, in 16 byte paragraphs. The pool$min parameter is also the initial size of the new job's pool. If the stack$ptr parameter has a base value of 0, pool$min should be at least 32. Otherwise, pool$min should be at least 32 plus the value of stack$size in 16 byte paragraphs. If pool$min is less than 32, an E$PARAM exceptional condition occurs.

pool$max — A WORD which contains the maximum allowable size of the new job's memory in 16 byte paragraphs. If pool$max is smaller than pool$min, an E$PARAM error occurs.

max$objects — A WORD which,

- if not OFFFFH, contains the maximum number of objects, created by tasks in the new job, that can exist simultaneously.
- if OFFFFH, indicates that there is no limit to the number of objects that tasks in the new job can create.

CREATE JOB (continued)
INPUT PARAMETERS (continued)

max$tasks — A WORD which,

- if not OFFFFH, contains the maximum number of tasks that can exist simultaneously in the new job.
- if OFFFFH, indicates that there is no limit to the number of tasks that tasks in the new job can create.

max$priority — A BYTE which,

- if not zero, contains the maximum allowable priority of tasks in the new job. If max$priority exceeds the maximum priority of the parent job, an E$LIMIT error occurs.
- if zero, indicates that the new job is to inherit the maximum priority attribute of the job to which the calling task belongs.

except$handler — A POINTER to a structure of the following form:

```
STRUCTURE(
     EXCEPTION$HANDLER$OFFSET      WORD,
     EXCEPTION$HANDLER$BASE        WORD,
     EXCEPTION$MODE                BYTE);
```

If exception$handler$base is not zero, then it and exception$handler$offset form a POINTER to the first instruction of the new job's own exception handler. If exception$handler$base is zero, the new job's exception handler is the system default exception handler. In both cases, the exception handler for the new task is the default exception handler for the job. Exception$mode indicates when control is to be passed to the new task's exception handler. It is encoded as follows:

Value	When Control Passes To Exception Handler
0	Never
1	On programmer errors only
2	On environmental conditions only
3	On all exceptional conditions

INPUT PARAMETERS (continued)

job$flags — A WORD reserved for future use. It should be set to 0.

task$priority — A BYTE which,

- if not zero, contains the priority of the new job's initial task. If the task$priority parameter is greater (numerically smaller) than the new job's maximum priority attribute, an E$PARAM error occurs.
- if zero, indicates that the new job's initial task is to have a priority equal to the new job's maximum priority attribute.

start$address — A POINTER to the first instruction of the new job's initial task.

data$seg — A WORD which,

- if not zero, contains a token for the data segment of the new job's initial task.

  This can be set up by the following PL/M statement:

```
DECLARE BEGIN WORD;  /*   A   DUMMY
                     VARIABLE  WHICH
                     IS  THE  FIRST
                     DECLARED
                     VARIABLE */

DECLARE DATA$PTR POINTER;

DECLARE DATA$ADDRESS STRUCTURE (

      OFFSET WORD,

      BASE WORD) AT (@DATA$PTR);
                     /* THIS MAKES
                     ACCESSIBLE THE
                     TWO HALVES OF
                     THE     POINTER
                     DATA$PTR */
```

CREATE JOB (continued)

INPUT PARAMETERS
data$seg (continued)

```
DATA$PTR = @BEGIN;    /*  PUTS  THE
                          WHOLE  ADDRESS
                          OF  THE  DATA
                          SEGMENT  INTO
                          DATA$PTR  AND
                          DATA$ADDRESS */

DS$BASE = DATA$ADDRESS.BASE;

CALL RQ$SET$INTERRUPT (...,DS$BASE);
```

- if zero, indicates that the new job's initial task has no data segment.

stack$ptr — A POINTER which,

- if the base portion is not zero, points to the base of the stack of the new job's initial task.
- if the base portion is zero, indicates that the Nucleus should allocate a stack segment to the new job's initial task. The length of the allocated segment is equal to the value of the stack$size parameter.

stack$size — A WORD containing the size, in bytes, of the stack segment of the new job's initial task. Stack$size must specify at least 16 bytes. The Nucleus decreases specified values that are not multiples of 16 up to the next higher multiple of 16.

Stack$size should be at least 512 bytes if the new task is going to make system calls.

task$flags — A WORD reserved for future use. It should be set to 0.

OUTPUT PARAMETERS

job — A WORD containing a token for the new job.

OUTPUT PARAMETERS (continued)

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The CREATE$JOB system call creates a job with an initializing task and returns a token for the job. The new job's parent is the calling task's job. The new job counts as one against the parent job's object limit. The new task counts as one against the new job's object and task limits. If a stack segment is created for the new task, it counts as one against the new job's object limit. The new job's resources come from the parent job, as described in the chapter on job management.

CONDITION CODES

E$OK — No exceptional conditions.

E$CONTEXT — The job containing the calling task is partially deleted.

E$EXIST — Param$obj is not zero and is not a token for an existing object.

E$LIMIT — At least one of the following is true:

- pool$min is larger than the available memory space in the memory pool of the calling task's job.
- max$objects is larger than the unused portion of the object allotment in the calling task's job.
- max$tasks is larger than the unused portion of the task allotment in the calling task's job.
- max$priority is larger than the maximum allowable task priority in the calling task's job.
- the new job and task would exceed the object limit in the calling task's job.

CREATE JOB (continued)

CONDITION CODES
E$LIMIT (continued)

- the new task would exceed the task limit in the calling task's job.

E$MEM — At least one of the following is true:

- the memory available to the calling task's job is not sufficient to create a task.
- the token part of the stack$ptr parameter is zero, and the memory available to the calling task's job is not sufficient to create a segment of the size indicated by the stack$size parameter.

E$PARAM — At least one of the following is true:

- pool$min is less than 32.
- pool$min is greater than pool$max.
- task$priority is greater (numerically smaller) than max$priority.
- stack$size is less than 16.

CREATE$MAILBOX creates a mailbox.

```
mailbox = RQ$CREATE$MAILBOX (mailbox$flags, except$ptr);
```

INPUT PARAMETERS

mailbox$flags — A WORD containing information about the new mailbox. The low-order bit determines the queueing scheme for the new mailbox's task queue:

Value	Queueing Scheme
0	First-in-first-out
1	Priority Based

The remaining bits in mailbox$flags are reserved for future use and should be set to 0.

OUTPUT PARAMETERS

mailbox — A WORD containing a token for the new mailbox.

except$ptr — A POINTER to a WORD to which the condition code for the call is returned.

DESCRIPTION

The CREATE$MAILBOX system call creates a mailbox and returns a token for it. The new mailbox counts as one against the object limit of the calling task's job.

CONDITION CODES

E$OK — No exception conditons.

E$LIMIT — The requested mailbox would exceed the job object limit.

E$MEM — The memory available to the calling task's job is not sufficient to create a mailbox.

CREATE SEGMENT

CREATE$SEGMENT creates a segment.

```
segment = RQ$CREATE$SEGMENT (size, except$ptr);
```

INPUT PARAMETER

size — A WORD which,

- if not zero, contains the size, in bytes, of the requested segment. If the size parameter is not a multiple of 16, it will be rounded up to the nearest higher multiple of 16 before the request is processed by the Nucleus.
- if zero, indicates that the size of the request is 65536 (64K) bytes.

OUTPUT PARAMETERS

segment — A WORD which,

- if not OFFFFH, contains a token for the newly created segment.
- if OFFFFH, indicates that an exceptional condition resulted from the call.

except$ptr — A POINTER to a WORD to which the condition code for the call is returned.

DESCRIPTION

The CREATE$SEGMENT system call creates a segment and returns the token for it. The memory for the segment is taken from the free portion of the memory pool of the calling task's job, unless borrowing from the parent job is both necessary and possible. The new segment counts as one against the object limit of the calling task's job.

CONDITION CODES

E$OK	No exceptional conditions.
E$LIMIT	The requested segment would exceed the job object limit.
E$MEM	The memory available to the calling task's job is not sufficient to create a segment.

CREATE$SEMAPHORE creates a semaphore.

```
semaphore = RQCREATE$SEMAPHORE (initial$value, max$value,
                                semaphore$flags, except$ptr);
```

INPUT PARAMETERS

initial$value — A WORD containing the initial number of units to be in the custody of the new semaphore.

max$value — A WORD containing the maximum number of units over which the new semaphore is to have custody at any given time. If max$value is zero, an E$PARAM error occurs.

semaphore$flags — A WORD containing information about the new semaphore. The low-order bit determines the queueing scheme for the new semaphore's task queue:

Value	Queueing Scheme
0	First-in-first-out
1	Priority based

The remaining bits in semaphore$flags are reserved for future use and should be set to 0.

OUTPUT PARAMETERS

semaphore — A WORD containing a token for the new semaphore.

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The CREATE$SEMAPHORE system call creates a semaphore and returns a token for it. The semaphore thus created counts as one against the object limit of the calling task's job.

CREATE SEMAPHORE (continued)

CONDITION CODES

E$OK	No exceptional conditions.
E$LIMIT	The requested semaphore would exceed the job object limit.
E$MEM	The memory available to the calling task's job is not sufficient to create a semaphore.
E$PARAM	At least one of the following is true: • the initial$value parameter is larger than the maximum$value parameter or • the maximum$value parameter is 0.

CREATE$TASK creates a task.

```
task = RQ$CREATE$TASK (priority, start$address, data$seg,
            stack$ptr, stack$size, task$flags, except$ptr);
```

INPUT PARAMETERS

priority — A BYTE which,

- if not zero, contains the priority of the new task. The priority parameter must not exceed the maximum allowable priority of the calling task's job. If it does, an E$PARAM error occurs.
- if zero, indicates that the new task's priority is to equal the maximum allowable priority of the calling task's job.

start$address — A POINTER to the first instruction of the new task.

data$seg — A WORD which,

- if not zero, contains a token for the new task's data segment.

  This can be set up by the following PL/M statement:

```
DECLARE BEGIN WORD;  /*   A   DUMMY
                     VARIABLE  WHICH
                     IS   THE   FIRST
                     DECLARED
                     VARIABLE */

DECLARE DATA$PTR POINTER;

DECLARE DATA$ADDRESS STRUCTURE (

      OFFSET WORD,

      BASE WORD) AT (@DATA$PTR);
                     /*  THIS  MAKES
                     ACCESSIBLE  THE
                     TWO  HALVES  OF
                     THE     POINTER
                     DATA$PTR */
```

CREATE TASK (continued)

INPUT PARAMETERS
data$seg (continued)

```
DATA$PTR = @BEGIN;   /*  PUTS  THE
                         WHOLE  ADDRESS
                         OF  THE  DATA
                         SEGMENT  INTO
                         DATA$PTR  AND
                         DATA$ADDRESS */

DS$BASE = DATA$ADDRESS.BASE;

CALL RQ$SET$INTERRUPT (...,DS$BASE);
```

- if zero, indicates that the new task has no data segment.

stack$ptr — A POINTER which,

- if the base portion is not zero, points to the base of the new task's stack.
- if the base portion is zero, indicates that the Nucleus should allocate a stack segment to the new task. The length of the allocated segment is equal to the value of the stack$size parameter.

stack$size — A WORD containing the size, in bytes, of the new task's stack segment. Stack$size must specify at least 16 bytes. The Nucleus decreases specified values that are not multiples of 16 up to the next higher multiple of 16.

Stack$size should be at least 512 bytes if the new task is going to make system calls.

task$flags — A WORD reserved for future use. It should be set to 0.

OUTPUT PARAMETERS

task — A WORD containing a token for the new task.

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The CREATE$TASK system call creates a task and returns a token for it. The new task counts as one against the object and task limits of the calling task's job. Attributes of the new task are initialized upon creation as follows:

- priority: as specified in the call.
- execution state: ready.
- suspension depth: 0.
- containing job: the job which contains the calling task.
- exception handler: the exception handler of the containing job.
- exception mode: the exception mode of the containing job.

CONDITION CODES

E$OK — No exceptional conditions.

E$LIMIT — The new task would exceed the system object limit, the object limit of the calling task's job, or the task limit of the calling task's job.

E$MEM — At least one of the following is the case:

- The memory available to the calling task's job is not sufficient to create a task.
- The base part of the stack$ptr parameter is zero, and the memory available to the calling task's job is not sufficient to create a segment of the size indicated by the stack$size parameter.

CREATE TASK (continued)

CONDITION CODES (continued)

E$PARAM	At least one of the following is the case: • The priority parameter is greater (numerically smaller) than the maximum allowable priority for tasks in the calling task's job. • The stack$size parameter is less than 16.

DELETE$JOB deletes a job.

```
CALL RQ$DELETE$JOB (job, except$ptr);
```

INPUT PARAMETER

job	A WORD containing a token for the job to be deleted.

OUTPUT PARAMETERS

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DELETE$JOB system call deletes from the system the specified job, as well as all objects created by tasks in it. Exceptions are that jobs, interrupt tasks, and extension objects (see the RMX/86 System Programmer's Reference Manual) created by tasks in the target job must be deleted prior to the call to DELETE$JOB. Information concerning the descendents of a job is obtained via the OFFSPRING system call. During deletion, all resources that the target job had borrowed from its parent are returned.

Deleting a job causes a credit of one toward the object total of the parent job.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	There are undeleted jobs, interrupt tasks, or extension objects (see the RMX/86 System Programmer's Reference Manual) which have been created by tasks in the target job.
E$EXIST	The job parameter is not a token for an existing object.
E$MEM	The job to be deleted contains undeleted composite objects (see the RMX/86 System Programmer's Reference Manual), and there is not sufficient memory for the Nucleus to send deletion messages to the appropriate deletion mailboxes.
E$TYPE	The job parameter is a token for an object that is not a job.

DELETE MAILBOX

DELETE$MAILBOX deletes a mailbox.

```
CALL RQ$DELETE$MAILBOX (mailbox, except$ptr);
```

INPUT PARAMETER

mailbox	A WORD containing a token for the mailbox to be deleted.

OUTPUT PARAMETERS

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DELETE$MAILBOX system call deletes the specified mailbox from the system. If any tasks are queued at the mailbox at the moment of deletion, they are awakened with an E$EXIST exceptional condition. If there is a queue of object tokens at the moment of deletion, the queue is discarded. Deleting the mailbox counts as a credit of one toward the object total of the containing job.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The mailbox parameter is not a token for an existing object.
E$TYPE	The mailbox parameter is a token for an object which is not a mailbox.

DELETE$SEGMENT deletes a segment.

```
CALL RQ$DELETE$SEGMENT (segment, except$ptr);
```

INPUT PARAMETER

segment	A WORD containing a token for the segment that is to be deleted.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DELETE$SEGMENT system call returns the specified segment to the memory pool from which it was allocated. The deleted segment counts as a credit of one toward the object total of the containing job.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The segment parameter is not a token for an existing object.
E$TYPE	The segment parameter is a token for an object that is not a segment.

DELETE SEMAPHORE

DELETE$SEMAPHORE deletes a semaphore.

```
CALL RQ$DELETE$SEMAPHORE (semaphore, except$ptr);
```

INPUT PARAMETER

semaphore	A WORD containing a token for the semaphore that is to be deleted.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DELETE$SEMAPHORE system call deletes the specified semaphore. If there are tasks in the semaphore's queue at the moment of deletion, they are awakened with an E$EXIST exceptional condition. The deleted semaphore counts as a credit of one toward the object total of the containing job.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The semaphore parameter is not a token for an existing object.
E$TYPE	The semaphore parameter is a token for an object that is not a semaphore.

DELETE$TASK deletes a task.

```
CALL RQ$DELETE$TASK (task, except$ptr);
```

INPUT PARAMETER

task	A WORD which, • if not zero, contains a token for the task that is to be deleted. • if zero, indicates that the calling task is to be deleted.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DELETE$TASK system call deletes the specified task from the system and from any queues in which the task was waiting. Deleting the task counts as a credit of one toward the object total of the containing job. It also counts as a credit of one toward the containing job's task total. Interrupt tasks cannot be deleted by DELETE$TASK; instead, interrupt tasks are deleted by RESET$INTERRUPT.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	The task parameter is a token for an interrupt task.
E$EXIST	The task parameter is not a token for an existing object.
E$TYPE	The task parameter is a token for an object which is not a task.

DISABLE

DISABLE disables an interrupt level.

```
CALL RQ$DISABLE (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level that is encoded as follows (bit 15 is the high-order bit):

Bits	Value
15-7	0
6-4	The interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The DISABLE system call disables the specified interrupt level. It has no effect on other levels. Level 2, which is reserved for the system clock, should not be disabled.

CONDITION CODES

E$OK — No exceptional conditions.

E$CONTEXT — The level indicated by the level parameter is already disabled.

E$PARAM — The level parameter is invalid.

ENABLE enables an interrupt level.

```
CALL RQ$ENABLE (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level that is encoded as follows (bit 15 is the high-order bit):

Bits	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The ENABLE system call enables the specified interrupt level. The level must have an interrupt handler assigned to it.

CONDITION CODES

E$OK — No exceptional conditions.

E$CONTEXT — At least one of the following is true:

- The level indicated by the level parameter is already unmasked.
- There is not an interrupt handler assigned to the specified level.

E$PARAM — The level parameter is invalid.

EXIT INTERRUPT

EXIT$INTERRUPT is used by interrupt handlers that don't call interrupt tasks; this call sends an end-of-interrupt signal to hardware.

```
CALL RQ$EXIT$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level that is encoded as follows (bit 15 is the high-order bit):

Bits	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The EXIT$INTERRUPT system call sends an end-of-interrupt signal to hardware. This sets the stage for re-enabling interrupts. The re-enabling actually occurs when control passes from the interrupt handler to an application task. The specified level must be disabled or an E$CONTEXT exceptional condition results from the call.

CONDITION CODES

E$OK	No exceptional conditions.
E$PARAM	The level parameter is invalid.

GET$EXCEPTION$HANDLER returns information about the calling task's exception handler.

```
CALL RQ$GET$EXCEPTION$HANDLER (exception$info$ptr, except$ptr);
```

INPUT PARAMETER

exception$info$ptr — A POINTER to a structure of the following form:

```
STRUCTURE (

   EXCEPTION$HANDLER$OFFSET   WORD,
   EXCEPTION$HANDLER$BASE     WORD,
   EXCEPTION$MODE             BYTE);
```

where, after the call,

- exception$handler$offset contains the offset of the first instruction of the exception handler.
- exception$handler$base contains a base for the segment containing the first instruction of the exception handler.
- exception$mode contains an encoded indication of the calling task's current exception mode. The value is interpreted as follows:

Value	When to Pass Control to Exception Handler
0	Never
1	On programmer errors only
2	On environmental conditions only
3	On all exceptional conditons

OUTPUT PARAMETERS

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

GET EXCEPTION HANDLER (continued)

DESCRIPTION

The GET$EXCEPTION$HANDLER system call returns both the address of the calling task's exception handler and the current value of the task's exception mode.

CONDITION CODE

E$OK	No exceptional conditions.

GET$LEVEL returns the number of the level of the interrupt being serviced.

```
level = RQ$GET$LEVEL (except$ptr);
```

INPUT PARAMETERS

none

OUTPUT PARAMETERS

level — A WORD whose value is interpreted as follows (bit 15 is the high-order bit):

Bit	Value	Interpretation
15-8		undefined
7	0	some level is being serviced and bits 6-4 are significant
	1	no level is being serviced and bits 6-4 are not significant
6-4		an interrupt level (0-7)
3-0		undefined

except$ptr — A POINTER to a WORD to which the condition code for the call is to be retured.

DESCRIPTION

The GET$LEVEL system call returns to the calling task the highest (numerically lowest) level which an interrupt handler has started servicing but has not yet finished. To strip away unwanted one bits, logically AND the returned value with 00F0H.

CONDITION CODES

E$OK — No exceptional conditions.

GET POOL ATTRIBUTES

GET$POOL$ATTRIBUTES returns information about the memory pool of the calling task's job.

```
CALL RQ$GET$POOL$ATTRIBUTES (attrib$ptr, except$ptr);
```

INPUT PARAMETER

attrib$ptr A POINTER to a data structure of the following form:

```
STRUCTURE(
    POOL$MAX            WORD,
    POOL$MIN            WORD,
    INITIAL$SIZE        WORD,
    ALLOCATED           WORD,
    AVAILABLE           WORD);
```

where, after the call,

- pool$max contains the maximum allowable size of the memory pool of the calling task's job.
- pool$min contains the minimum allowable size of the memory pool of the calling task's job.
- initial$size contains the original value of the pool$min attribute.
- allocated contains the number of bytes currently allocated from the memory pool of the calling task's job.
- available contains the number of bytes currently available in the memory pool of the calling task's job.

OUTPUT PARAMETER

except$ptr A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The GET$POOL$ATTRIBUTES system call returns information regarding the memory pool of the call task's job. The data returned comprises the allocated and available portions of the pool, as well as its initial, minimum, and maximum sizes.

CONDITION CODE

E$OK	No exceptional conditions.

GET PRIORITY

GET$PRIORITY returns the priority of a task.

```
priority = RQ$GET$PRIORITY (task, except$ptr);
```

INPUT PARAMETER

task	A WORD which, • if not zero, contains a token for the task whose priority is being requested. • if zero, indicates that the calling task is asking for its own priority.

OUTPUT PARAMETERS

priority	A BYTE containing the priority of the task indicated by the task parameter.
except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The GET$PRIORITY system call returns the priority of the specified task.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The task parameter is not a token for an existing object.
E$TYPE	The task parameter is a token for an object that is not a task.

GET$SIZE returns the size, in bytes, of a segment.

```
size = RQ$GET$SIZE (segment, except$ptr);
```

INPUT PARAMETER

segment	A WORD containing a token for a segment.

OUTPUT PARAMETERS

size	A WORD which, • if not zero, contains the size, in bytes, of the segment indicated by the segment parameter. • if zero, indicates that the size of the segment is 65536 (64K) bytes.
except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The GET$SIZE system call returns the size, in bytes, of a segment.

CONDITION CODES

E$OK	No exceptional conditons.
E$EXIST	The segment parameter is not a token for an existing object.
E$TYPE	The segment parameter is a token for an object that is not a segment.

GET TASK TOKENS

GET$TASK$TOKENS returns the token requested by the calling task.

```
token = RQ$GET$TASK$TOKENS (selection, except$ptr);
```

INPUT PARAMETER

selection — A BYTE containing the request, encoded as follows:

Value	Object for which a Token is Requested
0	The calling task.
1	The calling task's job.
2	The parameter object of the calling task's job.
3	The root job.

OUTPUT PARAMETERS

token — A WORD containing the requested token.

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The GET$TASK$TOKENS system call returns a token for either the calling task, the calling task's job, the calling task's parameter object, or the root job, depending on the encoded request.

CONDITION CODES

E$OK — No exceptional conditions.

E$PARAM — The selection parameter is greater than 3.

GET$TYPE returns the encoded type of an object.

```
type$code = RQ$GET$TYPE (object, except$ptr);
```

INPUT PARAMETER

object	A WORD containing the token for an object.

OUTPUT PARAMETERS

type$code	A WORD which, • if not OFFFFH, contains the encoded type of the specified object. The types are encoded as follows:

Value	Type
1	job
2	task
3	mailbox
4	semaphore
6	segment

• if OFFFFH, indicates that the object parameter is not a valid object token and that an E$EXIST exceptional condition has occurred.

except$ptr	A POINTER to a WORD to which the condition code for the call is returned.

DESCRIPTION

The GET$TYPE system call returns a type code for an object.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The object parameter is not a token for an existing object.

LOOKUP OBJECT

LOOKUP$OBJECT returns a token for a cataloged object.

```
object = RQ$LOOKUP$OBJECT (job, name, time$limit, except$ptr);
```

INPUT PARAMETERS

job — A WORD which,

- if not zero, contains a token for the job whose object directory is to be searched.
- if zero, indicates that the object directory to be searched is that of the calling task's job.

name — A POINTER to a STRING which contains the ASCII name under which the object is cataloged.

time$limit — A WORD which,

- if zero, indicates that the calling task is not willing to wait.
- if OFFFFH, indicates that the task will wait as long as is necessary.
- if between 0 and OFFFFH, indicates that the task is willing to wait only that many 1/100 second time units.

OUTPUT PARAMETERS

object — A WORD containing the requested token.

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The LOOKUP$OBJECT system call returns the token for the specified object after searching for its ASCII name in the specified object directory. Because it is possible that the object is not cataloged at the time of the call, the calling task has the option of waiting, either indefinitely or for a specific period of time, for another task to catalog the object.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	The specified job has an object directory of size 0.
E$EXIST	The job parameter (which is not zero) is not a token for an existing object.
E$LIMIT	The specified object directory is full.
E$PARAM	The first byte of the string pointed to by the name parameter contains a value greater than 12 or equal to zero.
E$TIME	Either • the calling task indicated its willingness to wait a certain amount of time, then waited without satisfaction or • the task was not willing to wait, and the entry indicated by the name parameter is not in the specified object directory.
E$TYPE	The job parameter is a token for an object that is not a job.

OFFSPRING

OFFSPRING returns a token for each child (job) of a job.

```
token$list = RQ$OFFSPRING (job, except$ptr);
```

INPUT PARAMETER

job	A WORD containing a token for the job whose offspring are desired.

OUTPUT PARAMETER

token$list	A WORD which, • if not zero, contains a token for a segment. The first word in the segment contains the number of words in the remainder of the segment. Subsequent words contain the tokens for jobs which are the children of the specified job. • if zero, indicates that the specified job has no children.
except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The OFFSPRING system call returns the token for a segment. The segment contains a token for each child of the specified job. By repeated use of this call, tokens can be obtained for all descendents of a job; this information is needed by a task which is attempting to delete a job.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The job parameter is not a token for an existing object.
E$LIMIT	The required segment, if allocated, would exceed the job object limit.
E$MEM	There is not sufficient memory available to create the required segment.
E$TYPE	The job parameter is not a token for an existing object.

RECEIVE$MESSAGE delivers the calling task to a mailbox, where it waits for an object token to be returned.

```
object = RQ$RECEIVE$MESSAGE (mailbox, time$limit,
                             response$ptr, except$ptr);
```

INPUT PARAMETERS

mailbox	A WORD containing a token for the mailbox at which the calling task expects to receive an object token.
time$limit	A WORD which, • if zero, indicates that the calling task is not willing to wait. • if OFFFFH, indicates that the task will wait as long as is necessary. • if between 0 and OFFFFH, indicates that the task is willing to wait only that many 1/100 second time units.

OUTPUT PARAMETERS

object	A WORD containing the token for the object being received.
response$ptr	A POINTER to a WORD which, • if not zero, contains a token for the exchange to which a response is to be sent. • if zero, indicates that no response has been requested by the sending task.
except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The RECEIVE$MESSAGE system call causes the calling task either to get the token for an object or to wait for the token in the task queue of the specified mailbox. If the object queue at the mailbox is not empty, then the calling task immediately gets the token at the head of the queue and remains ready. Otherwise, the calling task goes into

RECEIVE MESSAGE (continued)

DESCRIPTION (continued)

the task queue of the mailbox and goes to sleep, unless the task is not willing to wait. In the latter case, or if the task's waiting period elapses without a token arriving, the task is awakened with an E$TIME exceptional condition.

If the sending task needs a response from the receiving task, a token for the requested response exchange is returned in the word to which the response$ptr parameter is pointing. The nature of the response must be aggreed upon by the writers of the two tasks.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The mailbox parameter is not a token for an existing object.
E$TIME	Either • the calling task was not willing to wait and there was not a token available, or • the task waited in the task queue and its designated waiting period elapsed before the task got the desired token.
E$TYPE	The mailbox parameter is a token for an object that is not a mailbox.

RECEIVE$UNITS delivers the calling task to a semaphore, where it waits for units.

```
value = RQ$RECEIVE$UNITS (semaphore, units, time$limit,
                                                except$ptr);
```

INPUT PARAMETERS

semaphore — A WORD containing a token for the semaphore from which the calling task hopes to receive units.

units — A WORD containing the number of units that the calling task is requesting.

time$limit — A WORD which,

- if zero, indicates that the calling task is not willing to wait.
- if OFFFFH, indicates that the task will wait as long as is necessary.
- if between 0 and OFFFFH, indicates that the task is willing to wait only that many 1/100 second time units.

OUTPUT PARAMETERS

value — A WORD containing the number of units remaining in the custody of the semaphore after the calling task's request is satisfied.

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The RECEIVE$UNITS system call causes the calling task either to get the units that it is requesting or to wait for them in the semaphore's task queue. If the units are available and the task is at the front of the queue, then the task receives them and remains ready. Otherwise, the task is placed in the semaphore's task queue and goes to sleep, unless the task is not willing to wait. In the latter case, or if the task's waiting period elapses before the requested units are available, the task is awakened with an E$TIME exceptional condition.

RECEIVE UNITS (continued)

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The semaphore parameter is not a token for an existing object.
E$LIMIT	The units parameter is greater than the maximum value that had been specified for the semaphore when it was created.
E$TIME	Either • the calling task was not willing to wait and the requested units were not available or • the task waited in the task queue and its designated waiting period elapsed before the requested units were available.
E$TYPE	The semaphore parameter is a token for an object that is not a semaphore.

RESET$INTERRUPT cancels the assignment of an interrupt handler to a level.

```
CALL RQ$RESET$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level which is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The RESET$INTERRUPT system call cancels the assignment of the current interrupt handler to the specified interrupt level. If an interrupt task had also been assigned to the level, the interrupt task is deleted. RESET$INTERRUPT also disables the level.

Level 2 should not be reset and is considered invalid.

CONDITION CODES

E$OK — No exceptional conditions.

E$CONTEXT — There is not an interrupt handler assigned to the specified level.

E$PARAM — The level parameter is invalid.

RESUME·TASK

RESUME$TASK decreases by one the suspension depth of a task.

```
CALL RQ$RESUME$TASK (task, except$ptr);
```

INPUT PARAMETER

task	A WORD containing a token for the task whose suspension depth is to be decremented.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The RESUME$TASK system call decreases by one the suspension depth of the specified non-interrupt task. The task should be in either the suspended or asleep-suspended state, so its suspension depth should be at least one. If the suspension depth is still positive after being decremented, the state of the task is not changed. If the depth becomes zero, and the task is in the suspended state, then it is placed in the ready state. If the depth becomes zero, and the task is in the asleep-suspended state, then it is placed in the asleep state.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The task parameter is not a token for an existing object.
E$STATE	The task indicated by the task parameter was not suspended when the call was made.
E$TYPE	The task parameter is a token for an object that is not a task.

SEND$MESSAGE sends an object token to a mailbox.

```
CALL RQ$SEND$MESSAGE (mailbox, object, response, except$ptr);
```

INPUT PARAMETERS

mailbox	A WORD containing a token for the mailbox to which an object token is to be sent.
object	A WORD containing an object token which is to be sent.
response	A WORD which, • if not zero, contains a token for the desired response mailbox or semaphore. • if zero, indicates that no response is requested.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SEND$MESSAGE system call sends the specified object token to the specified mailbox. If there are tasks in the task queue at that mailbox, the task at the head of the queue is awakened and is given the token. Otherwise, the object token is placed at the tail of the object queue of the mailbox. The sending task has the option of specifying a mailbox or semaphore at which it will wait for a response from the task that receives the object. The nature of the response must be agreed upon by the writers of the two tasks.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	One or more of the input parameters is not a token for an existing object.
E$TYPE	Either • the mailbox parameter is a token for an object that is not a mailbox or • the response parameter is a token for an object that is neither a mailbox nor a semaphore.

SEND UNITS

SEND$UNITS sends units to a semaphore.

```
CALL RQ$SEND$UNITS (semaphore, units, except$ptr);
```

INPUT PARAMETERS

semaphore	A WORD containing a token for the semaphore to which the units are to be sent.
units	A WORD containing the number of units to be sent.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SEND$UNITS system call sends the specified number of units to the specified semaphore. If the transmission would cause the semaphore's supply of units to exceed its maximum allowawble supply, then an E$LIMIT exceptional condition occurs. Otherwise, the transmission is successful and the Nucleus attempts to satisfy the requests of the tasks in the semaphore's task queue, beginning at the head of the queue.

CONDITION CODES

E$OK	No exceptional conditons.
E$EXIST	The semaphore parameter is not a token for an existing object.
E$LIMIT	The number of units that the calling task is trying to send would cause the semaphore's supply of units to exceed its maximum allowable supply.
E$TYPE	The semaphore parameter is a token for an object that is not a semaphore.

SET EXCEPTION HANDLER

SET$EXCEPTION$HANDLER assigns an exception handler to the calling task.

```
CALL RQ$SET$EXCEPTION$HANDLER (exception$info$ptr, except$ptr);
```

INPUT PARAMETER

exception$info$ptr — A POINTER to a structure of the following form:

```
STRUCTURE(
   EXCEPTION$HANDLER$OFFSET   WORD,
   EXCEPTION$HANDLER$BASE     WORD,
   EXCEPTION$MODE             BYTE);
```

where

- exception$handler$offset contains the offset of the first instruction of the exception handler.
- exception$handler$base contains a token for the segment containing the first instruction of the exception handler.
- exception$mode contains an encoded indication of the calling task's intended exception mode. The value is interpreted as follows:

Value	When to Pass Control To Exception Handler
0	Never
1	On programmer errors only
2	On environmental conditions only
3	On all exceptional conditions

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

SET EXCEPTION HANDLER (continued)

DESCRIPTION

The SET$EXCEPTION$HANDLER system call enables a task to set its exception handler and exception mode attributes. If you want to designate the Debugger as the exception handler, the following code sets up the needed structure in PL/M-86 (except in the SMALL case):

```
DECLARE   X   STRUCTURE (OFFSET   WORD,
                         BASE     WORD,
                         MODE     BYTE);

DECLARE   Y   POINTER;

DECLARE YSTRUCT STRUCTURE (OFFSET   WORD,
                           BASE     WORD) AT (@Y);

DECLARE EXCEPTION WORD;
DECLARE EXCEPT$PTR POINTER;
EXCEPT$PTR = @EXCEPTION;

Y = @RQDEBUGGEREX;
X.BASE = YSTRUCT.BASE;
X.OFFSET = YSTRUCT.OFFSET;
X.MODE = ZERO$ONE$TWO$OR$THREE;
CALL  RQ$SET$EXCEPTION$HANDLER (@X, EXCEPT$PTR);
```

CONDITION CODES

E$OK	No exceptional conditions.
E$PARAM	The exception$mode parameter is greater than 3.

SET$INTERRUPT assigns an interrupt handler to an interrupt level and, optionally, makes the calling task the interrupt task for the level.

```
CALL RQ$SET$INTERRUPT (level, interrupt$task$flag,
  interrupt$handler, interrupt$handler$ds, except$ptr);
```

INPUT PARAMETERS

level — A WORD containing an interrupt level that is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

interrupt$task$flag — A BYTE which,

- if one, indicates that the calling task is to be the interrupt task that will be invoked by the interrupt handler being set. The priority of the calling task is set by the Nucleus. The priority is derived from the level, according to the following table:

Level	Priority
0	18
1	34
2	50
3	66
4	82
5	98
6	114
7	130

Be certain that priorities set in this manner do not violate the max$priority attribute of the containing job.

SET INTERRUPT (continued)

- if zero, indicates that no interrupt task is to be associated with the special level and that the new interrupt handler will not call SIGNAL INTERRUPT.

- if greater than one, causes an E$PARAM exceptional condition.

interrupt$handler — A POINTER to the first instruction of the interrupt handler.

interrupt$handler$ds — A WORD which,

- if not zero, contains the address of the interrupt handler's data segment.
  This can be set up by the following PL/M statements:

```
DECLARE BEGIN WORD;  /*  A  DUMMY
                         VARIABLE  WHICH
                         IS  THE  FIRST
                         DECLARED
                         VARIABLE */

DECLARE DATA$PTR POINTER;

DECLARE DATA$ADDRESS STRUCTURE (

      OFFSET WORD,

      BASE WORD) AT (@DATA$PTR);
                         /*  THIS  MAKES
                         ACCESSIBLE  THE
                         TWO  HALVES  OF
                         THE     POINTER
                         DATA$PTR */

DATA$PTR = @BEGIN;   /*  PUTS  THE
                         WHOLE  ADDRESS
                         OF  THE  DATA
                         SEGMENT  INTO
                         DATA$PTR  AND
                         DATA$ADDRESS */

DS$BASE = DATA$ADDRESS.BASE;

CALL RQ$SET$INTERRUPT (...,DS$BASE);
```

- if zero, indicates that the interrupt handler does not have a data segment.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SET$INTERRUPT system call is used to inform the Nucleus that the specified interrupt handler is to service interrupts which come in at the specified level. In a call to SET$INTERRUPT, a task must indicate whether the interrupt handler will invoke an interrupt task and whether the interrupt handler has its own data segment. If there is to be an interrupt task, the calling task is that interrupt task. If there is no interrupt task, SET$INTERRUPT also enables the specified level, which must be disabled at the time of the call.

CONDITION CODES

ESOK	No exceptional conditions.
E$CONTEXT	Either • the specified level already has an interrupt handler assigned to it or • the job containing the calling task is partially deleted.
E$PARAM	Either • the level parameter is invalid or would cause the task to have a priority not allowed by its job. • the interrupt$task$flag parameter is greater than one.

SET POOL MINIMUM

SET$POOL$MINIMUM sets a job's pool$min attribute.

```
CALL RQ$SET$POOL$MINIMUM (new$min, except$ptr);
```

INPUT PARAMETER

new$min — A WORD which,

- if OFFFFH, indicates that the pool$min attribute of the calling task's job is to be set equal to that job's pool$max attribute.
- if less than OFFFFH, contains the new value of the pool$min attribute of the calling task's job. This new value must not exceed that job's pool$max attribute.

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SET$POOL$MINIMUM system call sets the pool$min attribute of the calling task's job. The new value must not exceed that job's pool$max attribute. When the pool$min attribute is made larger than the current pool size, the pool is not enlarged until the additional memory is needed.

CONDITION CODES

E$OK — No exceptional conditions.

E$LIMIT — The new$min parameter is not OFFFFH, yet is greater than the pool$max attribute of the calling task's job.

SIGNAL$INTERRUPT is used by an interrupt handler to activate an interrupt task.

```
CALL RQ$SIGNAL$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level which is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

An interrupt handler uses SIGNAL$INTERRUPT to start up its associated interrupt task. The interrupt task runs in its own environment with interrupts enabled, whereas the interrupt handler runs in the environment of the interrupted task with all interrupts disabled.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	There is not an interrupt task assigned to the specified level.
E$PARAM	The level parameter is invalid.

SLEEP

SLEEP puts the calling task to sleep.

```
CALL RQ$SLEEP (time$limit, except$ptr);
```

INPUT PARAMETER

time$limit — A WORD which,

- if not zero and not OFFFFH, causes the calling task to go to sleep for that many 1/100 second time units, after which it will be awakened.
- if zero, causes the calling task to be placed on the list of ready tasks, immediately behind all tasks of the same priority. If there are no such tasks, there is no effect.
- if OFFFFH, is invalid.

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SLEEP system call has two uses. One use places the calling task in the asleep state for a specific amount of time. The other use allows the calling task to defer to the other ready tasks with the same priority. When a task defers in this way it is placed on the list of ready tasks, immediately behind those other tasks of equal priority.

CONDITION CODES

E$OK	No exceptional conditions.
E$PARAM	The time$limit parameter contains the invalid value OFFFFH.

SUSPEND$TASK increases by one the suspension depth of a task.

```
CALL RQ$SUSPEND$TASK (task, except$ptr);
```

INPUT PARAMETER

task	A WORD which, • if not zero, contains a token for the task whose suspension depth is to be incremented. • if zero, indicates that the calling task is suspending itself.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTIONS

The SUSPEND$TASK system call increases by one the suspension depth of the specified task. If the task is already in either the suspended or asleep-suspended state, its state is not changed. If the task is in the ready or running state, it enters the suspended state. If the task is in the asleep state, it enters the asleep-suspended state.

SUSPEND$TASK cannot be used to suspend interrupt tasks.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The task parameter is not a token for an existing object.
E$LIMIT	The suspension depth for the specified task is already at the maximum of 255.
E$TYPE	The task parameter is a token for an object that is not a task.

UNCATALOG OBJECT

UNCATALOG$OBJECT removes an entry for an object from an object directory.

```
CALL RQ$UNCATALOG$OBJECT (job, name, except$ptr);
```

INPUT PARAMETERS

job — A WORD which,

- if not zero, is a token for the job from whose object directory the specified entry is to be deleted.
- if zero, indicates that the entry is to be deleted from the object directory of the calling task's job.

name — A POINTER to a STRING containing the ASCII name of the object whose entry is to be deleted.

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The UNCATALOG$OBJECT system call deletes an entry from the object directory of the specified job.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	The specified object directory does not contain an entry with the designated name.
E$EXIST	The job parameter is neither zero nor a token for an existing object.
E$PARAM	The first byte of the STRING pointed to by the name parameter contains a value greater than 12 or equal to 0.
E$TYPE	The job parameter is a token for an object that is not a job.

WAIT INTERRUPT

WAIT$INTERRUPT is used by an interrupt task to signal its readiness to service an interrupt.

```
CALL RQ$WAIT$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level which is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The WAIT$INTERRUPT system call is used by interrupt tasks immediately after initializing and immediately after servicing interrupts. Such a call places an interrupt task in the asleep state until reawakened by the interrupt handler for the same level. Each call (except the first) that an interrupt task makes to WAIT$INTERRUPT sends an end-of-interrupt signal to hardware.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	The calling task is not the interrupt task for the given level.
E$PARAM	The level parameter is invalid.

CHAPTER 11. TERMINAL HANDLER

GENERAL INFORMATION

The Terminal Handler supports real-time, asynchronous I/O between an operator's terminal and tasks running under the RMX/86 Nucleus. It is intended for use in applications which require only limited I/O through a terminal, and it generally is used in applications that do not include the RMX/86 I/O System. The features of the Terminal Handler include the following:

- Line editing capabilities.
- Keystroke control over output, including output suspension and resumption, and deletion of data being sent by tasks to the terminal.
- Echoing of characters as they are entered into the Terminal Handler's line buffer.

An output-only version of the Terminal Handler is available for use in applications in which tasks send output to a terminal but do not receive input from the terminal.

The remainder of this chapter is divided into two parts. The first part, Using a Terminal with the RMX/86 Operating System, provides the information that is needed by an operator of the terminal. The second part, Programming Considerations, contains the information that a programmer needs to write tasks that send data to, or receive data from, the terminal. In the first part, there are a few references to the mailboxes that tasks use to communicate with the terminal. If you are puzzled by such a reference, look in the second part for an explanation.

USING A TERMINAL WITH THE RMX/86 OPERATING SYSTEM

While using a terminal that is under control of the Terminal Handler, an operator either reads an output message from the terminal's display or enters characters by striking keys on the terminal's keyboard. Normal input characters are destined for input messages that are sent to tasks. Special input characters direct the Terminal Handler to take special actions. The special characters are RUBOUT, Carriage Return, Line Feed, ESCape, control-C, control-D, control-O, control-Q, control-R, control-S, control-X, and control-Z. The output-only version of the Terminal Handler does not support any of the special

characters. In the remainder of this section, the handling of these two types is discussed, and the significance of each of the special characters is explained.

HOW NORMAL CHARACTERS ARE HANDLED

The destination of a normal character, when entered, depends on whether there is an input request message at the Terminal Handler's input request mailbox. If there is an input request message, the character is echoed to the terminal's display and goes into the input request message. If there is not an input request message, the character is deleted.

HOW SPECIAL CHARACTERS ARE HANDLED

Table 11-1 lists the special characters and summarizes the effects of each of them. The following text comprises complete descriptions of the effects of the special characters. In these descriptions, there are several references to "the current line." The current line is the contents of the MESSAGE CONTENT field of the input request message currently being processed.

Table 11-1. Special Character Summary

SPECIAL CHARACTER	EFFECT
RUBOUT	Deletes previously entered character.
Carriage Return	Signals end of line.
Line Feed	Signals end of line.
ESCape	Signals end of line.
control-C	Aborts an application program.
control-O	Kills or restarts output.
control-Q	Resumes suspended output.
control-R	Displays current line with editing.
control-S	Suspends output.
control-X	Deletes the current line.
control-Z	Sends empty message.

The following descriptions concern the special characters needed when entering data at the terminal. Most of these characters are for line-editing. Each description is divided into two parts: internal effects and external effects. The difference is that external effects are immediately shown on the terminal's display, whereas internal effects are those that are not directly visible.

Rubbing Out a Previously-Typed Character (RUBOUT)

Internal Effects: Causes the most recently entered but not yet deleted character to be deleted from the current line. If the current line is empty, there is no internal effect.

External Effects: If the current line is empty, the BEL character (07H) is sent to the terminal. Otherwise, the character is "rubbed out" in accordance with one of two available rubout modes. In the copying mode, the character being deleted from the current line is re-echoed to the display. For example, entering "CAT" and then striking RUBOUT three times results in the display "CATTAC". In the blanking mode, the deleted character is replaced on the CRT screen with the blanking character. For example, entering "CAT" and then striking RUBOUT three times deletes all three characters from the display. The copy mode is the default mode. The default blanking character for the blanking mode is a space (20H). If you wish to change either of these defaults, refer to the RMX/86 Configuration Guide for ISIS-II Users (Manual order number 9803126) or talk to someone who knows about configuration.

Displaying the Current Line (control-R)

Internal Effects: None.

External Effects: Sends a carriage return and line feed to the terminal, followed by the current line. If the current line is empty, the previous line is sent to the display, where it can be line edited and submitted as a new input message.

Deleting the Current Line (control-X)

Internal Effects: Empties the current line.

External Effects: Causes the sequence (#, Carriage Return, Line Feed) to be sent to the terminal.

Sending an Empty Message (control-Z)

Internal Effects: Puts a zero in the ACTUAL field of the input request message currently being processed. The message is then sent to the appropriate response mailbox.

External Effects: None.

Signalling the End of a Line of Input (Carriage Return, Line Feed, or ESCape)

Internal Effects: Puts either the ASCII end-of-transmission character (0AH in the case of Carriage Return or Line Feed) or the ESCape character (1BH) in the current line. Each of these characters signals the end of a message, so the input request message currently being constructed is sent to the appropriate response mailbox.

External Effects: If the end-of-line indicator is either Carriage Return or Line Feed, both Carriage Return and Line Feed are sent to the terminal. If the indicator is ESCape, however, there is no effect on the display.

OUTPUT CONTROL

Output request messages that are sent to output mailbox RQTHNORMOUT can be processed in three ways:

- They can be output as described later under Programming Considerations.
- They can be queued at RQTHNORMOUT where they remain until an operator at the terminal takes action to permit processing of the messages.
- They can be discarded.

In the descriptions that follow, these methods of dealing with normal output requests are called the normal mode, the queueing mode, and the suppression mode, respectively. Initially, output is in the normal mode.

Suspending Output (control-S)

Puts normal output in the queueing mode.

Resuming Output (control-Q)

Negates the effects of control-S by allowing output requests that are queued at RQTHNORMOUT to be displayed.

Deleting or Restarting Output (control-O)

If output is in the normal mode, control-O puts it in the suppression mode. If output is in the suppression mode, control-O restores it to the normal mode. If output is in the queueing mode, control-O has no effect.

PROGRAM CONTROL

Aborting an Application (control-C)

Control-C invokes a user-written procedure called RQ$ABORT$AP. This procedure can perform any actions that suit the application. However, control-C is normally used to abort an application. For example, you might want to halt a compilation if you realize that your program contains a serious error. Control-C also causes the effects produced by control-Z; that is, it returns the current input request message with its ACTUAL field set to zero.

SETTING A BAUD RATE

The Terminal Handler can be set to operate at any of the following baud rates:

110
150
300
600
1200
2400
4800
9600
19200

The rate is set during software configuration, when an RMX/86 system variable, RQRATE, is assigned one of the previously mentioned baud rate values.

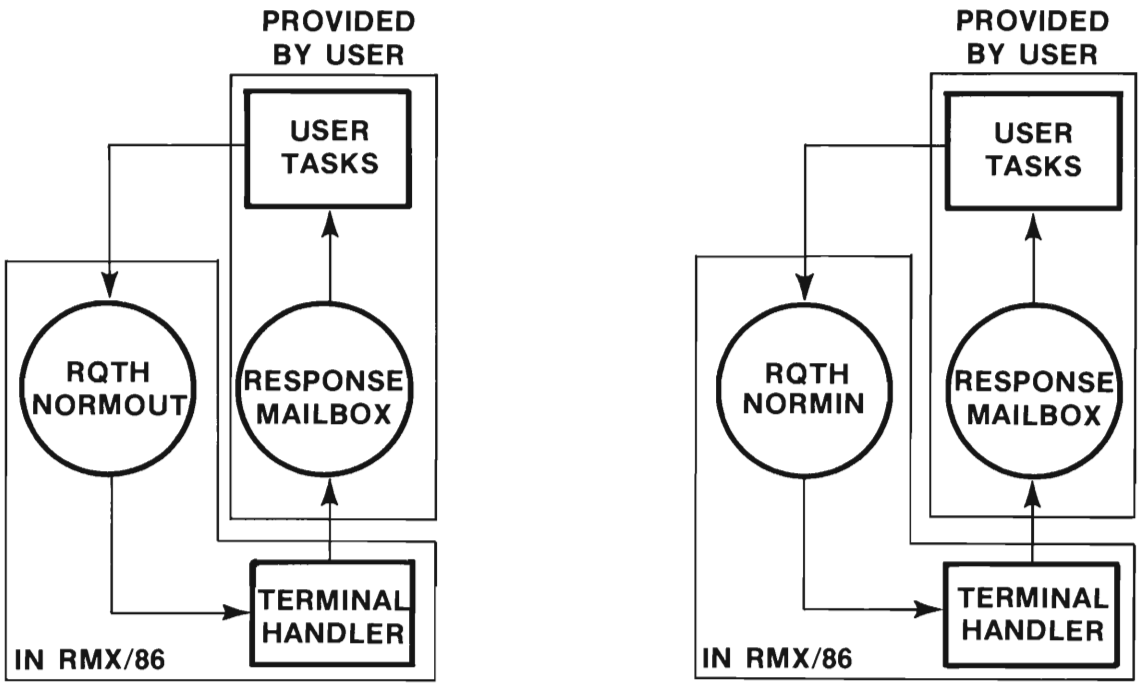


Figure 11-1. Input and Output Mailbox Interfaces.

PROGRAMMING CONSIDERATIONS

The RMX/86 Terminal Handler supports terminal input and output by providing mailbox interfaces. Figure 11-1 shows the mailboxes that are used typically. In the figure, an arrow pointing from a task to a mailbox represents a SEND$MESSAGE system call. An arrow pointing from a mailbox to a task indicates a RECEIVE$MESSAGE system call.

The protocol that tasks observe is much the same for input and output. In each case, the task initiates I/O by sending a request message to a mailbox. An input request mailbox, RQTHNORMIN, and an output request mailbox, RQTHNORMOUT, are provided. The Terminal Handler processes the request and then sends a response message back to the requesting task. The task waits at a response mailbox for the message. Thus, when a task does either input or output, it sends and then receives. The full details of the input and output protocols are described later in this section.

For both input and output, the medium is the message segment sent by a task to the Terminal Handler. The format of a request message is depicted in Figure 11-2. The numbers in that figure are offsets, in bytes, from the beginning of the segment. The field names have different meanings for input and for output. For both input and output, the first four fields are WORD values. The MESSAGE CONTENT field can be up to 132 bytes in length for input and up to 65527 bytes in length for output.

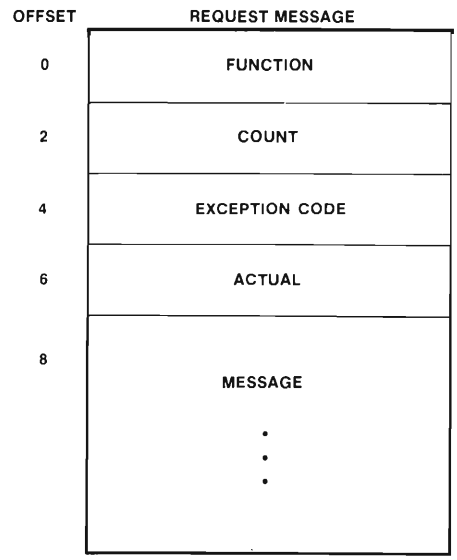


Figure 11-2. Request Message Format.

In the following discussions, the names F$WRITE and F$READ literal names for the particular WORD values 5 and 1, respectively.

OUTPUT

The first thing a task does when transmitting output is prepare an output request message. The task must fill in the following fields prior to sending the message:

FUNCTION --- F$WRITE.

COUNT --- the number of bytes (not to exceed 65527) in the MESSAGE CONTENT field.

MESSAGE CONTENT --- the bytes that are to be output.

Having prepared the message segment, the task must send it to the output request mailbox RQTHNORMOUT. Messages sent to this mailbox are processed in a first-in-first-out manner. Processing a message involves sending the characters in the MESSAGE CONTENT field to the terminal until a total of COUNT characters have been sent. There is one exception; when the Terminal Handler encounters the end-of-transmission character (OAH), it sends a Carriage Return and a Line Feed to the terminal.

When sending the output request message, the task specifies a user-supplied response mailbox. If no response mailbox is specified, the Terminal Handler will delete the segment that contained the message. In addition to transmitting the message

to the terminal, the Terminal Handler fills in the remaining fields in the output request message. The requesting task can wait at the response mailbox (that is, it can call the RECEIVE$MESSAGE system call with a time limit of OFFFFH) immediately after sending the output request. By observing this protocol, the task can learn of the success or failure of the output attempt. The fields that provide this information are the following:

- EXCEPTION CODE --- the encoded result of the output operation:
  - E$OK --- the operation was successful.
  - E$PARAM --- the FUNCTION field in the message did not contain F$WRITE.
  - E$BOUNDS --- the COUNT field in the message is too big for the segment, that is, COUNT + 8 is greater than the length of the segment containing the message.
- ACTUAL --- the actual number of bytes output.

In summary, the protocol observed by tasks doing output is as follows:

- Prepare the output request message segment, filling in the FUNCTION, COUNT, and MESSAGE CONTENT fields.
- Send the segment, via the SEND$MESSAGE system call, to RQTHNORMOUT. It is advisable, but not necessary, to specify a response mailbox in the system call.
- Wait indefinitely, via the RECEIVE$MESSAGE system call, at the response mailbox. When received, the message contains the results of the transmission in the EXCEPTION CODE and ACTUAL fields.

INPUT

The protocol for obtaining input is much the same as that for outputting. A message is prepared and sent to a request mailbox, then the message is received at a response mailbox. There is a significant difference, however. The input is contained in the message segment at the response mailbox, so designating a response mailbox and then waiting there is required.

CAUTION

When multiple tasks use the same mailbox for input from the terminal, there is a chance that a task will get input that is intended for another task.

The first thing a task needing input does is prepare an input request message. It must fill in the FUNCTION and COUNT fields prior to sending its request. The FUNCTION field must contain F$READ. The COUNT field reflects the maximum possible number of input characters in the input message. The value of COUNT must not exceed 132; moreover, COUNT + 8 must not exceed the length of the input request message segment.

When sending the input request message, the task must specify the response mailbox in its call to the SEND$MESSAGE system call. The Terminal Handler obtains characters from the terminal and places them in the MESSAGE CONTENT field. The message is terminated by an end of line character (Carriage Return, Line Feed, or ESCape). The lone exception is when the end-of-line character has been "normalized" by being preceded by a control-P; then the end-of-line character is treated as a normal character.

NOTE

If more than COUNT characters are entered prior to the end-of-line character, the extra characters are ignored, and the terminal beeps at the operator.

After the message is complete, the Terminal Handler fills in the EXCEPTION CODE and ACTUAL fields as follows:

- EXCEPTION CODE --- the encoded result of the input operation, which is one of the following:
  - E$OK --- the operation was successful.
  - E$PARAM --- either the FUNCTION field in the message did not contain F$READ or the COUNT field was greater than 132.
  - E$BOUNDS --- COUNT + 8 is greater than the length of the message segment.
- ACTUAL --- the number of bytes actually entered and placed in the MESSAGE CONTENT field.

The requesting task must wait (that is, it must make a RECEIVE$OBJECT system call with a time limit of OFFFFH) at the designated response mailbox immediately after sending the input request.

In summary, the input protocol is as follows:

- Prepare the input request message segment, filling in the FUNCTION and COUNT fields.

- Send the segment, via the SEND$MESSAGE system call, to RQTHNORM$IN. In the call, specify a response mailbox.

- Wait indefinitely, via the RECEIVE$MESSAGE system call, at the response mailbox. When received, the message segment will contain the results of the input operation in the MESSAGE CONTENT, EXCEPTION CODE, and ACTUAL fields.

Chapter 12. DEBUGGER

GENERAL INFORMATION

The development of almost every software application requires debugging. To aid in the development of RMX/86 application systems, Intel provides three debugging tools. One, the RMX/86 Debugger, is a powerful tool which is sensitive to the data structures that the Nucleus maintains. The other debugging tools are the ICE-86 In-Circuit Emulator and the monitor in the iSBC 86/12A Single Board Computer.

The Debugger supplies its own Terminal Handler, which includes all of the capabilities described in Chapter 11. If your application includes the Debugger, then you may use its Terminal Handler, rather than linking in the Terminal Handler module.

DEBUGGER CAPABILITIES

The RMX/86 Debugger enables you to do the following:

- View RMX/86 system lists, including the lists of the jobs, the tasks, the ready tasks, the suspended tasks, the task queues at exchanges, the object queues at mailboxes, and the exchanges.
- Inspect jobs, tasks, exchanges, and segments.
- Inspect absolute memory locations.
- Set, change, view, and delete breakpoints.
- View the list of tasks that have incurred breakpoints and remove tasks from it.
- Declare a task to be the breakpoint task.
- Find out as to which task is the breakpoint task.
- Inspect and alter the breakpoint task's register values.
- Alter the contents of absolute memory locations.
- Set, change, view, and delete special variables for debugging.
- View the list of special debugging variables.
- Deactivate the Debugger.

DEBUGGING CAPABILITIES IN THE ICE-86 EMULATOR

The ICE-86 In-Circuit Emulator provides several debugging capabilities. In particular, an ICE-86 emulator lets you:

- Get closer to the hardware level by examining the contents of input pins and input ports. You can also change the values at output ports.
- Set breakpoints.
- Use memory in your Intel Microcomputer Development System as if it were on your prototype board.
- Look at the most recent 80 to 150 assembly language instructions executed.

To learn more about the ICE-86 Emulator, consult the ICE-86 In-Circuit Emulator Operating Instructions for ISIS-II Users, manual order number 9800714.

DEBUGGING CAPABILITIES IN THE iSBC 86/12A MONITOR

The iSBC 86/12A monitor has several capabilities that can aid you in debugging. With the monitor, you can do the following:

- View and modify the contents of 8086 registers and absolute memory locations.
- Set breakpoints.
- Single step program execution.
- Do I/O to and from ports.
- Move or compare blocks of memory.

INVOKING THE DEBUGGER

The Debugger is invoked when you enter control-D at the terminal. The Debugger responds with its sign-on message, "RMX/86 DEBUGGER V1.0", and its prompt character, an asterisk.

In addition to the functions the Debugger can perform when it has been invoked, there are two services it can perform at any time, even when not invoked. First, if a task encounters a breakpoint, the Debugger responds as described later in this chapter.

Second, if a task has the Debugger as its exception handler and the task causes an exceptional condition, then the Debugger displays a message to that effect at the terminal. A task gets

the Debugger as its exception handler either by using the SET$EXCEPTION$HANDLER system call or when the task is created by means of either CREATE$TASK or CREATE$JOB. An example of code setting up such a call is the following:

```
DECLARE EXCEPT$BLOCK STRUCTURE (

   EXCEPT$PROC          POINTER,
   EXCEPT$MODE          BYTE);
   .
   .
   .

EXCEPT$BLOCK.EXCEPT$PROC = @RQ$DEBUGGER$EX;
EXCEPT$BLOCK.EXCEPT$MODE = ZERO$ONE$TWO$OR$THREE;
   .
   .
   .

RQ$SYSTEM$CALL (...,@EXCEPT$BLOCK,...);
```

DEBUGGER INPUT AND OUTPUT

The Debugger obtains input one line at a time from its Terminal Handler. The end-of-line indicators are Carriage Return, Line Feed, and ESCape. When either Carriage Return or Line Feed is entered, the current input line is sent to the Debugger; when ESCape is entered, the current input line is discarded and a prompt is displayed.

The Debugger generates display at the terminal by sending output messages to its Terminal Handler. To suppress output from application tasks during a debugging session, type control-S. If control-S is not entered, any output from tasks is interspersed with output from the Debugger. To allow resumption of output from tasks, type control-Q. Control-S and control-Q have no effect on output from the Debugger.

SYNTAX OF DEBUGGER COMMANDS

When using the RMX/86 Debugger, you sit at a terminal and type commands. This section describes the syntactical standards for commands to the Debugger, and it introduces notational conventions that are used throughout this chapter.

Debugger commands fall into families. The syntax for each family is described in detail later in this chapter.

The first one or two characters of a command constitute a key sequence for the command:

- Most Debugger commands are specified by one or two letters. The key letters or pairs of letters are BL, BT, D, DB, G, I, L, M, Q, R, V, and Z.

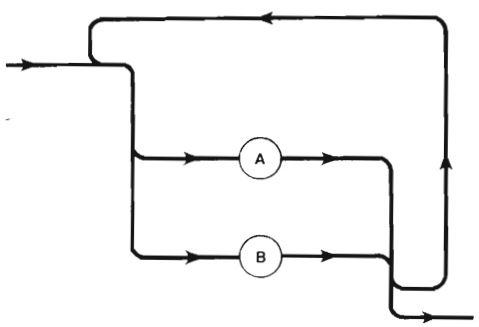
- In a few cases, a command is specified by beginning the command with a name. A name, for the Debugger, must consist of a period followed by a variable name of the PL/M-86 variety.

After the key initial sequence, a command may be followed by one or more parameters or additional specifiers. Blanks are used as delimiters between elements of a command; they are mandatory except

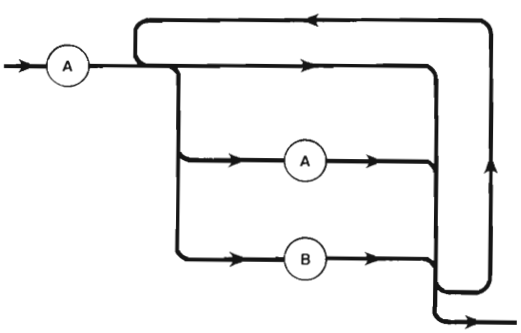
- immediately after a command key that is not a name and
- between a letter or digit and a non-letter, non-digit. The legal characters of the latter type are the following: ; @ = / \ : ( ) * + - ,

PICTORIAL REPRESENTATION OF SYNTAX

In this chapter, a schematic device illustrates the syntax of commands. The schematic consists of what looks like an aerial view of a model railroad setup, with syntactic entities scattered along the track. Imagine that a train enters the system at the upper left, drives around as much as it can or wants to (sharp turns and backing up are not allowed), and finally departs at the lower right. The command it generates in so doing consists, in order, of the syntactic entities that it encounters on its journey. For example, a string of A's and B's, in any order, would be depicted as



If such a string has to begin with an A, the schematic could be drawn as



In the second drawing, it is necessary to represent the letter A twice because A is playing two roles: It is the first symbol (necessarily) and it is a symbol that may (optionally) be used after the first symbol. Note that a train could avoid the second A but cannot avoid the first A. The arrows are not necessary and henceforth are omitted.

SPECIAL SYMBOLS FOR THE DEBUGGER

The entities that will be used in the remainder of this chapter, as A and B were used in the previous paragraph, are the following:

- CONSTANT. Constants are always hexadecimal. Unlike such constants in PL/M-86, they do not require an H as the last character. H's may be used if desired. Leading zeroes are not necessary unless they help to distinguish between constants and other things. For example, AH is a register in the 8086, but 0AH is a constant.

  NOTE

  If more than four hexadecimal digits compose a constant, only the low order four digits are used. Binary, octal, and decimal constants are not understood by the Debugger.

- NAME. A name is a period followed by up to 31 alphabetic or numeric characters, the first of which must be alphabetic.

  Examples:

  ```
  .task

  .mailbox7
  ```

- EXPRESSION. As in algebra, an expression is either a term or is the result of adding and subtracting terms. Also as in algebra, a term is a product; each factor in the product is either a constant, a name, a parenthetical expression, or one of the registers AX, BX, CX, DX, DS, ES, SS, CS, IP, FL, SI, DI, BP, and SP. Graphically, term and expression are shown in Figure 12-1:

  NOTE

  If the computed value of an expression is too large to fit into four hexadecimal digits, then only the low order four digits are used.

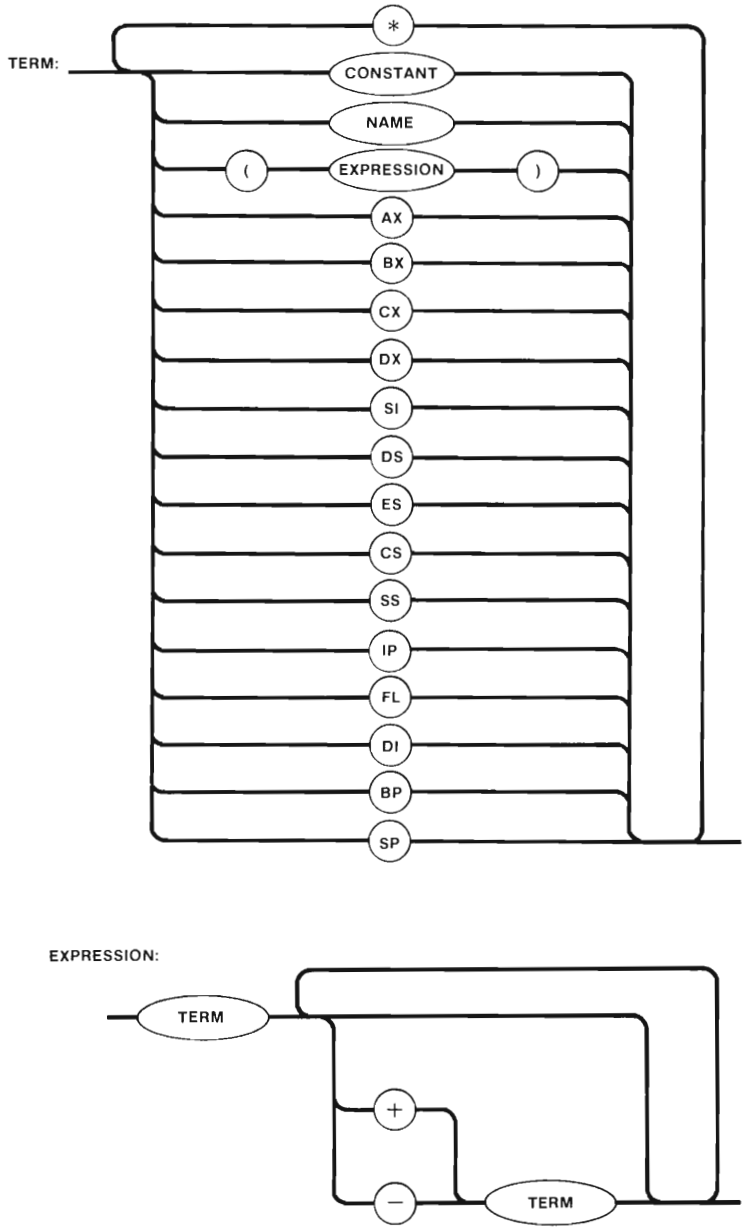


Figure 12-1. Syntax Diagrams for Term and Expression

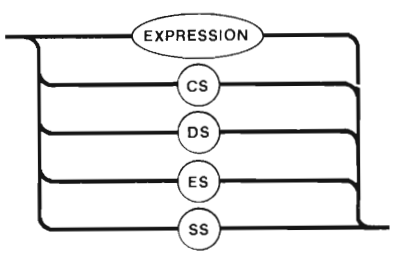


Figure 12-2. Syntax Diagram for Item

- ITEM. An item is either an expression or one of the segment registers of the 8086 microprocessor. The values of items are used variously as tokens and as offsets in Debugger commands. Graphically, an item is defined in Figure 12-2.

DEBUGGER COMMANDS

This section presents the details of the Debugger commands. The commands fall into two groups, those relating to breakpoints and those that enable you to observe or change the contents of memory.

BREAKPOINT CONTROL

The Debugger provides you with the ability to set, change, view, or delete breakpoints. You set a breakpoint by defining an act which a task can perform. When a task performs the act, it incurs the breakpoint. The Debugger supports three kinds of breakpoints:

- Execution breakpoint. A task incurs an execution breakpoint when it executes an instruction that is at a previously specified location in memory.

- Exchange breakpoint. A task incurs an exchange breakpoint when it performs a previously specified type of operation (send or receive) at a previously specified exchange.

- Exception breakpoint. A task incurs an exception breakpoint if its exception handler has been declared to be the Debugger and the task causes an exceptional condition of the type that invokes its exception handler.

When a task incurs a breakpoint (of any type), three things occur automatically:

- The task is suspended. Moreover, depending on the breakpoint, the tasks in the containing job might also be suspended.

- The suspended task (or tasks) is (are) placed on a Debugger-maintained list called the breakpoint list. You can resume a task on the breakpoint list or you can remove it from the list.

- At the terminal, a display informs you that a breakpoint has been incurred. It also provides information about the event.

Each task on the breakpoint list is assigned a breakpoint state, which reflects the kind of breakpoint last incurred by the task. The states are as follows:

X --- The task incurred an execution breakpoint.

E --- The task incurred an exchange breakpoint.

Z --- The task incurred an exception breakpoint.

N --- The task was placed on the breakpoint list by the BT command (described later), rather than by incurring a breakpoint.

You set an execution or exchange breakpoint with the DB command by defining a breakpoint variable and assigning it a breakpoint request. The request specifies to the Debugger the nature of the breakpoint, and the variable provides you with a convenient means of talking to the Debugger about the breakpoint. Using the breakpoint variable, you can cancel the breakpoint or replace it with a new one.

The Debugger displays information when a task incurs a breakpoint. The format of the display depends on the kind of breakpoint incurred:

- The display format for an execution breakpoint is

  bp-var: E, TASK=jjjjJ/ttttq, CS=cccc, IP=iiii

  where

bp-var	The name of the breakpoint variable.
jjjj	A token for the task's job.
tttt	A token for the task.
q	Either T (for task) or * (indicating that the task has overflowed its stack).
cccc	The base of the segment in which the breakpoint was set.
iiii	The offset of the breakpoint within its segment.

- The display format for an exchange breakpoint is

  bp-var: a, EXCH=jjjjJ/xxxxe, TASK=jjjjJ/ttttq, ITEM=item

where

bp-var	The name of the breakpoint variable.
a	Indicates which kind of operation (S for send or R for receive) caused the breakpoint to be incurred.
jjjj	A token for the job containing the exchange or task whose token follows.
xxxx	A token for the exchange.
e	Indicates the type of the exchange (M for mailbox, S for semaphore).
tttt	A token for the task.
item	One of the following: A pair of tokens, jjjjJ/oooot, with oooo being a token for the object being sent or received, t indicating the type of the object (J for job, T for task, M for mailbox, S for semaphore, and G for segment), and jjjj being a token for the object's containing job, if the exchange is a mailbox. If the kind of operation was receive, but no object was there to be received, item is 0000. The number of units held by the exchange, if it is a semaphore.

- The display format for an exception breakpoint is

EXCEPTION: jjjjJ/ttttT, CS=cccc, IP=iiii, TYPE=wwww, PARAM=vvvv

where

jjjj	A token for the job which contains the task that caused the exception condition.
tttt	A token for the task that caused the exceptional conditon.
cccc and iiii	Respectively, the contents of the 8086 CS and IP registers when the exceptional condition occurred.

wwww	The numerical value of the exception code; reflects the nature of the exceptional condition. Chapter 8 contains the mnemonic condition codes and their numerical equivalents.
vvvv	The number (0001 for first, 0002 for second, etc.) of the parameter that caused the exceptional condition. If no parameter was at fault, vvvv is 0000.

Exception breakpoints differ from execution and exchange breakpoints in several respects:

- It is not possible to set, change, view, or delete exception breakpoints by using the commands of the Debugger. Instead, each task can set an exception breakpoint by declaring the Debugger to be its exception handler. The task can subsequently delete the breakpoint by declaring a different exception handler.

- An exception breakpoint is set for a particular task. Execution and exchange breakpoints are set for no particular task; any task can incur such a breakpoint.

- Exception breakpoints are set for a "kind" of event, namely the occurrence of an exceptional condition when the task that set the breakpoint makes a system call. An execution or exchange breakpoint, on the other hand, is set at a "place."

- An exception breakpoint is not known to the Debugger by a breakpoint variable name.

If you want to monitor a particular task, you can designate it to be the breakpoint task. If the task is not already on the breakpoint list when you do this, it is suspended and is placed on the breakpoint list with a null breakpoint state. After designating a breakpoint task, you can examine its registers or alter them. You can also ascertain the breakpoint state of the task. When ready, you can easily resume the task and remove it from the breakpoint list.

The handling of exception breakpoints is significantly different from that of execution and exchange breakpoints. For example, exception breakpoints cannot be viewed, but the other breakpoints can be. Wherever this distinction applies, this chapter points it out.

Establishing a Breakpoint --- The DB Command

Syntax

The syntax for the DB command is given in figure 12-3.

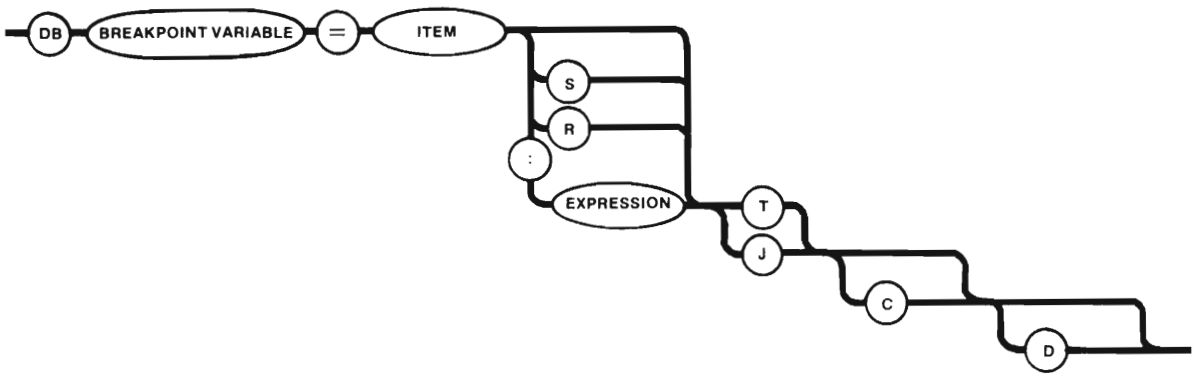


Figure 12-3. Syntax Diagram for Establishing a Breakpoint

Explanation of Syntax

BREAKPOINT VARIABLE	A Debugger name. If the Debugger's symbol table already contains this name, an error message will appear on the terminal's display.
ITEM	If followed by ":" and an EXPRESSION, you are setting an execution breakpoint, and ITEM must contain a token for a segment, while EXPRESSION must contain an offset. Otherwise, you are setting an exchange breakpoint, and ITEM must contain a token for an exchange.
S and R	To be used only when setting an exchange breakpoint. S means that the exchange breakpoint is for senders only, while R means that it is for receivers only. If you want to set an exchange breakpoint for both senders and receivers, omit both S and R, as well as both ":" and EXPRESSION.
T and J	Indicate which tasks are to be put on the breakpoint list when a breakpoint is incurred. T indicates only the task that incurred the breakpoint, while J indicates all of the tasks in that task's job.

C	Directs the Debugger not to suspend tasks that incur the breakpoint, and not to put them on the breakpoint list.
D	Directs the Debugger to delete the breakpoint when it is first incurred by a task. The D option does not suppress the display that results when a task incurs a breakpoint.

Effects

The DB command sets a breakpoint of the type indicated in the remainder of the command line. The name designated as the breakpoint variable can be used to alter or delete the breakpoint.

Changing a Breakpoint

Syntax

The syntax for this command is given in Figure 12-4.

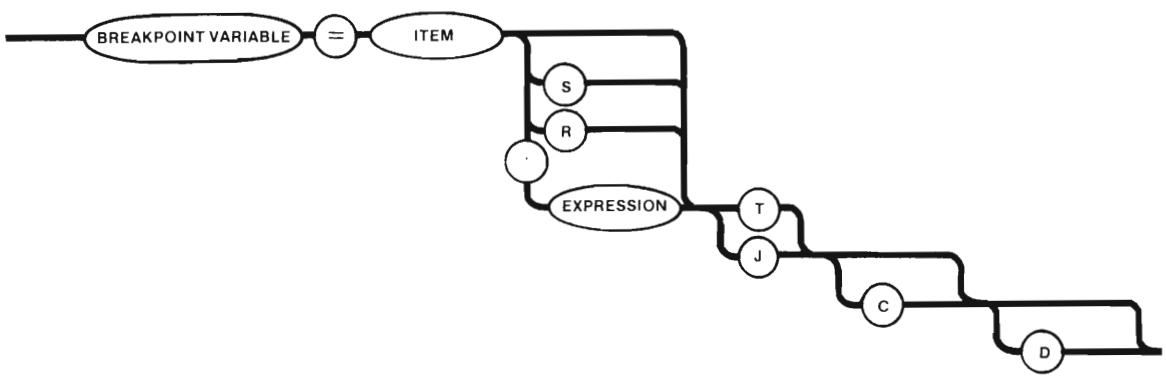


Figure 12-4. Syntax Diagram for Changing a Breakpoint

Explanation of Syntax

BREAKPOINT VARIABLE	A Debugger name. If the Debugger's symbol table already contains this name, an error message will appear on the terminal's display.

ITEM	If followed by ":" and an EXPRESSION, you are setting an execution breakpoint, and ITEM must contain a token for a segment, while EXPRESSION must contain an offset. Otherwise, you are setting an exchange breakpoint, and ITEM must contain a token for an exchange.
S and R	To be used only when setting an exchange breakpoint. S means that the exchange breakpoint is for senders only, while R means that it is for receivers only. If you want to set an exchange breakpoint for both senders and receivers, omit both S and R, as well as both ":" and EXPRESSION.
T and J	Indicate which tasks are to be put on the breakpoint list when a breakpoint is incurred. T indicates only the task that incurred the breakpoint, while J indicates all of the tasks in that task's job.
C	Directs the Debugger not to suspend tasks that incur the breakpoint, and not to put them on the breakpoint list.
D	Directs the Debugger to delete the breakpoint when it is first incurred by a task. The D option does not suppress the display that results when a task incurs a breakpoint.

Effects

This command deletes the breakpoint that was associated with the breakpoint variable name and replaces it with a new breakpoint, as specified in the command. The breakpoint variable name can be used to delete or change the breakpoint.

Deleting a Breakpoint --- The Z Command

Syntax

The syntax for the Z command is given in Figure 12-5.

Figure 12-5. Syntax Diagram for Deleting a Breakpoint

Explanation of Syntax

BREAKPOINT VARIABLE — A Debugger name. If the Debugger's symbol table does not contain the name, or if it does contain the name but the name is not stored as a breakpoint variable, an error message is displayed.

Effects

The Z command deletes the specified breakpoint and removes the breakpoint variable name from the Debugger's symbol table.

Examining a Breakpoint

Syntax

The syntax for this command is given in Figure 12-6.

Figure 12-6. Syntax Diagram for Examining a Breakpoint

Explanation of Syntax

BREAKPOINT VARIABLE — The name of the breakpoint to be examined.

Effects

If the designated breakpoint is an execution breakpoint, the following display is sent to the terminal:

```
bp-var=xxxx:yyyy  z op op
```

where

bp-var	The name of the breakpoint variable.
xxxx	The base of the segment containing theinstruction at which the breakpoint is set.
yyyy	The offset of the instruction within the segment.
z	Indicates whether a task (T) or all tasks in a job (J) are to be suspended and placed on the breakpoint list when the breakpoint is incurred.

op	If present, is C (for Continue task) or D (for Delete breakpoint).

If the breakpoint is an exchange breakpoint, the following display is sent to the terminal:

bp-var=xxxx a ops r

where

bp var	The name of the breakpoint variable.
xxxx	A token for the exchange at which the breakpoint is set.
a	Indicated the kind of activity at the exchange, either S (for send), R (for receive), or SR (for both).
ops	If any are present, can be C (for continue task) and/or D (for delete breakpoint).
r	indicates whether a task (T) or all tasks in a job (J) are to be suspended and placed on the breakpoint list when the breakpoint is incurred.

You cannot examine an exception breakpoint.

Viewing the Breakpoint List --- The BL Command

Syntax

The syntax for the BL command is given in Figure 12-7.

Figure 12-7. Syntax Diagram for Viewing the Breakpoint List.

Effects

The Debugger responds to this command by displaying the entire breakpoint list as follows:

BL=jjjjJ/ttttT(s) jjjjJ/ttttT(s) ... jjjjJ/ttttT(s)

where

jjjj	A token for the job containing the task whose token follows.
tttt	A token for a task.
s	The breakpoint state of a task. Possible values are X (for execution), E (for exchange), Z (for exception), and blank (for null).

Viewing the Breakpoint Parameters --- The B Command

Syntax

The syntax for the B command is given in Figure 12-8.

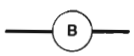


Figure 12-8. Syntax Diagram for Viewing the Breakpoint Parameters

Effects

The B command has two principal effects. The first is to display the breakpoint list as

BL=jjjjJ/ttttT(s) jjjjJ/ttttT(s) ... jjjjJ/ttttT(s)

where

jjjj	A token for the job containing the task whose token follows.
tttt	A token for a task.
s	The breakpoint state of a task. Possible values are X (for execution), E (for exchange), Z (for exception), and blank (for null).

The second effect of the B command is to display the breakpoint task to be displayed as

BT=jjjjJ/ttttT(s)

where

jjjj	A token for the job containing the breakpoint task.

op	If present, is C (for Continue task) or D (for Delete breakpoint).

If the breakpoint is an exchange breakpoint, the following display is sent to the terminal:

bp-var=xxxx a ops r

where

bp var	The name of the breakpoint variable.
xxxx	A token for the exchange at which the breakpoint is set.
a	Indicated the kind of activity at the exchange, either S (for send), R (for receive), or SR (for both).
ops	If any are present, can be C (for continue task) and/or D (for delete breakpoint).
r	indicates whether a task (T) or all tasks in a job (J) are to be suspended and placed on the breakpoint list when the breakpoint is incurred.

You cannot examine an exception breakpoint.

Viewing the Breakpoint List --- The BL Command

Syntax

The syntax for the BL command is given in Figure 12-7.

Figure 12-7. Syntax Diagram for Viewing the Breakpoint List.

Effects

The Debugger responds to this command by displaying the entire breakpoint list as follows:

BL=jjjjJ/ttttT(s) jjjjJ/ttttT(s) ... jjjjJ/ttttT(s)

ITEM	If followed by ":" and an EXPRESSION, you are setting an execution breakpoint, and ITEM must contain a token for a segment, while EXPRESSION must contain an offset. Otherwise, you are setting an exchange breakpoint, and ITEM must contain a token for an exchange.
S and R	To be used only when setting an exchange breakpoint. S means that the exchange breakpoint is for senders only, while R means that it is for receivers only. If you want to set an exchange breakpoint for both senders and receivers, omit both S and R, as well as both ":" and EXPRESSION.
T and J	Indicate which tasks are to be put on the breakpoint list when a breakpoint is incurred. T indicates only the task that incurred the breakpoint, while J indicates all of the tasks in that task's job.
C	Directs the Debugger not to suspend tasks that incur the breakpoint, and not to put them on the breakpoint list.
D	Directs the Debugger to delete the breakpoint when it is first incurred by a task. The D option does not suppress the display that results when a task incurs a breakpoint.

Effects

This command deletes the breakpoint that was associated with the breakpoint variable name and replaces it with a new breakpoint, as specified in the command. The breakpoint variable name can be used to delete or change the breakpoint.

Deleting a Breakpoint --- The Z Command

Syntax

The syntax for the Z command is given in Figure 12-5.

Figure 12-5. Syntax Diagram for Deleting a Breakpoint

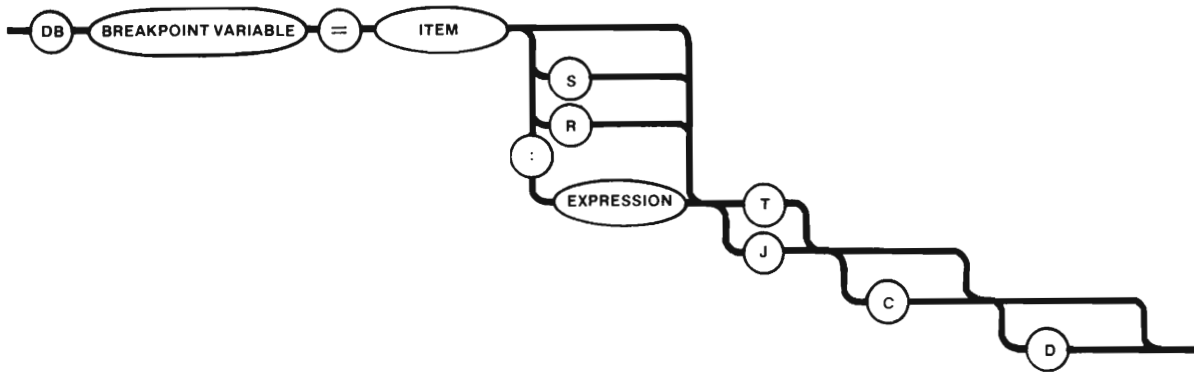


Figure 12-3. Syntax Diagram for Establishing a Breakpoint

Explanation of Syntax

BREAKPOINT VARIABLE	A Debugger name. If the Debugger's symbol table already contains this name, an error message will appear on the terminal's display.
ITEM	If followed by ":" and an EXPRESSION, you are setting an execution breakpoint, and ITEM must contain a token for a segment, while EXPRESSION must contain an offset. Otherwise, you are setting an exchange breakpoint, and ITEM must contain a token for an exchange.
S and R	To be used only when setting an exchange breakpoint. S means that the exchange breakpoint is for senders only, while R means that it is for receivers only. If you want to set an exchange breakpoint for both senders and receivers, omit both S and R, as well as both ":" and EXPRESSION.
T and J	Indicate which tasks are to be put on the breakpoint list when a breakpoint is incurred. T indicates only the task that incurred the breakpoint, while J indicates all of the tasks in that task's job.

where

bp-var	The name of the breakpoint variable.
a	Indicates which kind of operation (S for send or R for receive) caused the breakpoint to be incurred.
jjjj	A token for the job containing the exchange or task whose token follows.
xxxx	A token for the exchange.
e	Indicates the type of the exchange (M for mailbox, S for semaphore).
tttt	A token for the task.
item	One of the following: A pair of tokens, jjjjJ/oooot, with oooo being a token for the object being sent or received, t indicating the type of the object (J for job, T for task, M for mailbox, S for semaphore, and G for segment), and jjjj being a token for the object's containing job, if the exchange is a mailbox. If the kind of operation was receive, but no object was there to be received, item is 0000. The number of units held by the exchange, if it is a semaphore.

- The display format for an exception breakpoint is

```
EXCEPTION:  jjjjJ/ttttT, CS=cccc, IP=iiii, TYPE=wwww, PARAM=vvvv
```

where

jjjj	A token for the job which contains the task that caused the exception condition.
tttt	A token for the task that caused the exceptional conditon.
cccc and iiii	Respectively, the contents of the 8086 CS and IP registers when the exceptional condition occurred.

- ITEM. An item is either an expression or one of the segment registers of the 8086 microprocessor. The values of items are used variously as tokens and as offsets in Debugger commands. Graphically, an item is defined in Figure 12-2.

DEBUGGER COMMANDS

This section presents the details of the Debugger commands. The commands fall into two groups, those relating to breakpoints and those that enable you to observe or change the contents of memory.

BREAKPOINT CONTROL

The Debugger provides you with the ability to set, change, view, or delete breakpoints. You set a breakpoint by defining an act which a task can perform. When a task performs the act, it incurs the breakpoint. The Debugger supports three kinds of breakpoints:

- Execution breakpoint. A task incurs an execution breakpoint when it executes an instruction that is at a previously specified location in memory.

- Exchange breakpoint. A task incurs an exchange breakpoint when it performs a previously specified type of operation (send or receive) at a previously specified exchange.

- Exception breakpoint. A task incurs an exception breakpoint if its exception handler has been declared to be the Debugger and the task causes an exceptional condition of the type that invokes its exception handler.

When a task incurs a breakpoint (of any type), three things occur automatically:

- The task is suspended. Moreover, depending on the breakpoint, the tasks in the containing job might also be suspended.

- The suspended task (or tasks) is (are) placed on a Debugger-maintained list called the breakpoint list. You can resume a task on the breakpoint list or you can remove it from the list.

- At the terminal, a display informs you that a breakpoint has been incurred. It also provides information about the event.

In the second drawing, it is necessary to represent the letter A twice because A is playing two roles: It is the first symbol (necessarily) and it is a symbol that may (optionally) be used after the first symbol. Note that a train could avoid the second A but cannot avoid the first A. The arrows are not necessary and henceforth are omitted.

SPECIAL SYMBOLS FOR THE DEBUGGER

The entities that will be used in the remainder of this chapter, as A and B were used in the previous paragraph, are the following:

- CONSTANT. Constants are always hexadecimal. Unlike such constants in PL/M-86, they do not require an H as the last character. H's may be used if desired. Leading zeroes are not necessary unless they help to distinguish between constants and other things. For example, AH is a register in the 8086, but 0AH is a constant.

  NOTE

  If more than four hexadecimal digits compose a constant, only the low order four digits are used. Binary, octal, and decimal constants are not understood by the Debugger.

- NAME. A name is a period followed by up to 31 alphabetic or numeric characters, the first of which must be alphabetic.

  Examples:

  ```
  .task

  .mailbox7
  ```

- EXPRESSION. As in algebra, an expression is either a term or is the result of adding and subtracting terms. Also as in algebra, a term is a product; each factor in the product is either a constant, a name, a parenthetical expression, or one of the registers AX, BX, CX, DX, DS, ES, SS, CS, IP, FL, SI, DI, BP, and SP. Graphically, term and expression are shown in Figure 12-1:

  NOTE

  If the computed value of an expression is too large to fit into four hexadecimal digits, then only the low order four digits are used.

the Debugger as its exception handler either by using the SET$EXCEPTION$HANDLER system call or when the task is created by means of either CREATE$TASK or CREATE$JOB. An example of code setting up such a call is the following:

```
DECLARE EXCEPT$BLOCK STRUCTURE (

   EXCEPT$PROC          POINTER,
   EXCEPT$MODE          BYTE);
   .
   .
   .

EXCEPT$BLOCK.EXCEPT$PROC = @RQ$DEBUGGER$EX;
EXCEPT$BLOCK.EXCEPT$MODE = ZERO$ONE$TWO$OR$THREE;
   .
   .
   .

RQ$SYSTEM$CALL (...,@EXCEPT$BLOCK,...);
```

DEBUGGER INPUT AND OUTPUT

The Debugger obtains input one line at a time from its Terminal Handler. The end-of-line indicators are Carriage Return, Line Feed, and ESCape. When either Carriage Return or Line Feed is entered, the current input line is sent to the Debugger; when ESCape is entered, the current input line is discarded and a prompt is displayed.

The Debugger generates display at the terminal by sending output messages to its Terminal Handler. To suppress output from application tasks during a debugging session, type control-S. If control-S is not entered, any output from tasks is interspersed with output from the Debugger. To allow resumption of output from tasks, type control-Q. Control-S and control-Q have no effect on output from the Debugger.

SYNTAX OF DEBUGGER COMMANDS

When using the RMX/86 Debugger, you sit at a terminal and type commands. This section describes the syntactical standards for commands to the Debugger, and it introduces notational conventions that are used throughout this chapter.

Debugger commands fall into families. The syntax for each family is described in detail later in this chapter.

The first one or two characters of a command constitute a key sequence for the command:

- Most Debugger commands are specified by one or two letters. The key letters or pairs of letters are BL, BT, D, DB, G, I, L, M, Q, R, V, and Z.

Chapter 12. DEBUGGER

GENERAL INFORMATION

The development of almost every software application requires debugging. To aid in the development of RMX/86 application systems, Intel provides three debugging tools. One, the RMX/86 Debugger, is a powerful tool which is sensitive to the data structures that the Nucleus maintains. The other debugging tools are the ICE-86 In-Circuit Emulator and the monitor in the iSBC 86/12A Single Board Computer.

The Debugger supplies its own Terminal Handler, which includes all of the capabilities described in Chapter 11. If your application includes the Debugger, then you may use its Terminal Handler, rather than linking in the Terminal Handler module.

DEBUGGER CAPABILITIES

The RMX/86 Debugger enables you to do the following:

- View RMX/86 system lists, including the lists of the jobs, the tasks, the ready tasks, the suspended tasks, the task queues at exchanges, the object queues at mailboxes, and the exchanges.
- Inspect jobs, tasks, exchanges, and segments.
- Inspect absolute memory locations.
- Set, change, view, and delete breakpoints.
- View the list of tasks that have incurred breakpoints and remove tasks from it.
- Declare a task to be the breakpoint task.
- Find out as to which task is the breakpoint task.
- Inspect and alter the breakpoint task's register values.
- Alter the contents of absolute memory locations.
- Set, change, view, and delete special variables for debugging.
- View the list of special debugging variables.
- Deactivate the Debugger.

The first thing a task needing input does is prepare an input request message. It must fill in the FUNCTION and COUNT fields prior to sending its request. The FUNCTION field must contain F$READ. The COUNT field reflects the maximum possible number of input characters in the input message. The value of COUNT must not exceed 132; moreover, COUNT + 8 must not exceed the length of the input request message segment.

When sending the input request message, the task must specify the response mailbox in its call to the SEND$MESSAGE system call. The Terminal Handler obtains characters from the terminal and places them in the MESSAGE CONTENT field. The message is terminated by an end of line character (Carriage Return, Line Feed, or ESCape). The lone exception is when the end-of-line character has been "normalized" by being preceded by a control-P; then the end-of-line character is treated as a normal character.

NOTE

If more than COUNT characters are entered prior to the end-of-line character, the extra characters are ignored, and the terminal beeps at the operator.

After the message is complete, the Terminal Handler fills in the EXCEPTION CODE and ACTUAL fields as follows:

- EXCEPTION CODE --- the encoded result of the input operation, which is one of the following:
  - E$OK --- the operation was successful.
  - E$PARAM --- either the FUNCTION field in the message did not contain F$READ or the COUNT field was greater than 132.
  - E$BOUNDS --- COUNT + 8 is greater than the length of the message segment.
- ACTUAL --- the number of bytes actually entered and placed in the MESSAGE CONTENT field.

The requesting task must wait (that is, it must make a RECEIVE$OBJECT system call with a time limit of OFFFFH) at the designated response mailbox immediately after sending the input request.

In summary, the input protocol is as follows:

- Prepare the input request message segment, filling in the FUNCTION and COUNT fields.

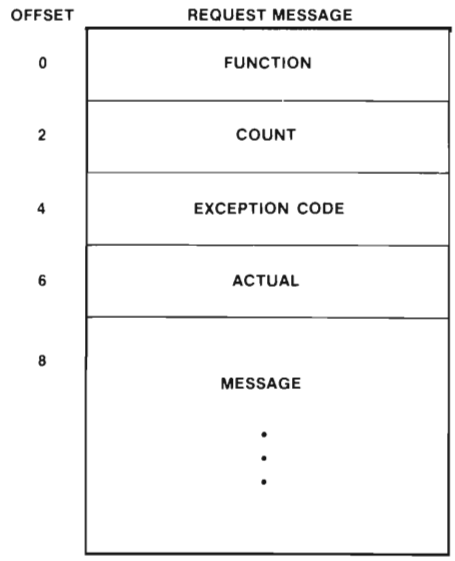


Figure 11-2. Request Message Format.

In the following discussions, the names F$WRITE and F$READ literal names for the particular WORD values 5 and 1, respectively.

OUTPUT

The first thing a task does when transmitting output is prepare an output request message. The task must fill in the following fields prior to sending the message:

FUNCTION --- F$WRITE.

COUNT --- the number of bytes (not to exceed 65527) in the MESSAGE CONTENT field.

MESSAGE CONTENT --- the bytes that are to be output.

Having prepared the message segment, the task must send it to the output request mailbox RQTHNORMOUT. Messages sent to this mailbox are processed in a first-in-first-out manner. Processing a message involves sending the characters in the MESSAGE CONTENT field to the terminal until a total of COUNT characters have been sent. There is one exception; when the Terminal Handler encounters the end-of-transmission character (OAH), it sends a Carriage Return and a Line Feed to the terminal.

When sending the output request message, the task specifies a user-supplied response mailbox. If no response mailbox is specified, the Terminal Handler will delete the segment that contained the message. In addition to transmitting the message

Resuming Output (control-Q)

Negates the effects of control-S by allowing output requests that are queued at RQTHNORMOUT to be displayed.

Deleting or Restarting Output (control-O)

If output is in the normal mode, control-O puts it in the suppression mode. If output is in the suppression mode, control-O restores it to the normal mode. If output is in the queueing mode, control-O has no effect.

PROGRAM CONTROL

Aborting an Application (control-C)

Control-C invokes a user-written procedure called RQ$ABORT$AP. This procedure can perform any actions that suit the application. However, control-C is normally used to abort an application. For example, you might want to halt a compilation if you realize that your program contains a serious error. Control-C also causes the effects produced by control-Z; that is, it returns the current input request message with its ACTUAL field set to zero.

SETTING A BAUD RATE

The Terminal Handler can be set to operate at any of the following baud rates:

110
150
300
600
1200
2400
4800
9600
19200

The rate is set during software configuration, when an RMX/86 system variable, RQRATE, is assigned one of the previously mentioned baud rate values.

The following descriptions concern the special characters needed when entering data at the terminal. Most of these characters are for line-editing. Each description is divided into two parts: internal effects and external effects. The difference is that external effects are immediately shown on the terminal's display, whereas internal effects are those that are not directly visible.

Rubbing Out a Previously-Typed Character (RUBOUT)

Internal Effects: Causes the most recently entered but not yet deleted character to be deleted from the current line. If the current line is empty, there is no internal effect.

External Effects: If the current line is empty, the BEL character (07H) is sent to the terminal. Otherwise, the character is "rubbed out" in accordance with one of two available rubout modes. In the copying mode, the character being deleted from the current line is re-echoed to the display. For example, entering "CAT" and then striking RUBOUT three times results in the display "CATTAC". In the blanking mode, the deleted character is replaced on the CRT screen with the blanking character. For example, entering "CAT" and then striking RUBOUT three times deletes all three characters from the display. The copy mode is the default mode. The default blanking character for the blanking mode is a space (20H). If you wish to change either of these defaults, refer to the RMX/86 Configuration Guide for ISIS-II Users (Manual order number 9803126) or talk to someone who knows about configuration.

Displaying the Current Line (control-R)

Internal Effects: None.

External Effects: Sends a carriage return and line feed to the terminal, followed by the current line. If the current line is empty, the previous line is sent to the display, where it can be line edited and submitted as a new input message.

Deleting the Current Line (control-X)

Internal Effects: Empties the current line.

External Effects: Causes the sequence (#, Carriage Return, Line Feed) to be sent to the terminal.

CHAPTER 11. TERMINAL HANDLER

GENERAL INFORMATION

The Terminal Handler supports real-time, asynchronous I/O between an operator's terminal and tasks running under the RMX/86 Nucleus. It is intended for use in applications which require only limited I/O through a terminal, and it generally is used in applications that do not include the RMX/86 I/O System. The features of the Terminal Handler include the following:

- Line editing capabilities.
- Keystroke control over output, including output suspension and resumption, and deletion of data being sent by tasks to the terminal.
- Echoing of characters as they are entered into the Terminal Handler's line buffer.

An output-only version of the Terminal Handler is available for use in applications in which tasks send output to a terminal but do not receive input from the terminal.

The remainder of this chapter is divided into two parts. The first part, Using a Terminal with the RMX/86 Operating System, provides the information that is needed by an operator of the terminal. The second part, Programming Considerations, contains the information that a programmer needs to write tasks that send data to, or receive data from, the terminal. In the first part, there are a few references to the mailboxes that tasks use to communicate with the terminal. If you are puzzled by such a reference, look in the second part for an explanation.

USING A TERMINAL WITH THE RMX/86 OPERATING SYSTEM

While using a terminal that is under control of the Terminal Handler, an operator either reads an output message from the terminal's display or enters characters by striking keys on the terminal's keyboard. Normal input characters are destined for input messages that are sent to tasks. Special input characters direct the Terminal Handler to take special actions. The special characters are RUBOUT, Carriage Return, Line Feed, ESCape, control-C, control-D, control-O, control-Q, control-R, control-S, control-X, and control-Z. The output-only version of the Terminal Handler does not support any of the special

WAIT INTERRUPT

WAIT$INTERRUPT is used by an interrupt task to signal its readiness to service an interrupt.

```
CALL RQ$WAIT$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level which is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The WAIT$INTERRUPT system call is used by interrupt tasks immediately after initializing and immediately after servicing interrupts. Such a call places an interrupt task in the asleep state until reawakened by the interrupt handler for the same level. Each call (except the first) that an interrupt task makes to WAIT$INTERRUPT sends an end-of-interrupt signal to hardware.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	The calling task is not the interrupt task for the given level.
E$PARAM	The level parameter is invalid.

SUSPEND$TASK increases by one the suspension depth of a task.

```
CALL RQ$SUSPEND$TASK (task, except$ptr);
```

INPUT PARAMETER

task	A WORD which, • if not zero, contains a token for the task whose suspension depth is to be incremented. • if zero, indicates that the calling task is suspending itself.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTIONS

The SUSPEND$TASK system call increases by one the suspension depth of the specified task. If the task is already in either the suspended or asleep-suspended state, its state is not changed. If the task is in the ready or running state, it enters the suspended state. If the task is in the asleep state, it enters the asleep-suspended state.

SUSPEND$TASK cannot be used to suspend interrupt tasks.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	The task parameter is not a token for an existing object.
E$LIMIT	The suspension depth for the specified task is already at the maximum of 255.
E$TYPE	The task parameter is a token for an object that is not a task.

SIGNAL$INTERRUPT is used by an interrupt handler to activate an interrupt task.

```
CALL RQ$SIGNAL$INTERRUPT (level, except$ptr);
```

INPUT PARAMETER

level — A WORD containing an interrupt level which is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

An interrupt handler uses SIGNAL$INTERRUPT to start up its associated interrupt task. The interrupt task runs in its own environment with interrupts enabled, whereas the interrupt handler runs in the environment of the interrupted task with all interrupts disabled.

CONDITION CODES

E$OK	No exceptional conditions.
E$CONTEXT	There is not an interrupt task assigned to the specified level.
E$PARAM	The level parameter is invalid.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SET$INTERRUPT system call is used to inform the Nucleus that the specified interrupt handler is to service interrupts which come in at the specified level. In a call to SET$INTERRUPT, a task must indicate whether the interrupt handler will invoke an interrupt task and whether the interrupt handler has its own data segment. If there is to be an interrupt task, the calling task is that interrupt task. If there is no interrupt task, SET$INTERRUPT also enables the specified level, which must be disabled at the time of the call.

CONDITION CODES

ESOK	No exceptional conditions.
E$CONTEXT	Either • the specified level already has an interrupt handler assigned to it or • the job containing the calling task is partially deleted.
E$PARAM	Either • the level parameter is invalid or would cause the task to have a priority not allowed by its job. • the interrupt$task$flag parameter is greater than one.

SET$INTERRUPT assigns an interrupt handler to an interrupt level and, optionally, makes the calling task the interrupt task for the level.

```
CALL RQ$SET$INTERRUPT (level, interrupt$task$flag,
  interrupt$handler, interrupt$handler$ds, except$ptr);
```

INPUT PARAMETERS

level — A WORD containing an interrupt level that is encoded as follows (bit 15 is the high-order bit):

Bit	Value
15-7	0
6-4	the interrupt level (0-7)
3	1
2-0	0

interrupt$task$flag — A BYTE which,

- if one, indicates that the calling task is to be the interrupt task that will be invoked by the interrupt handler being set. The priority of the calling task is set by the Nucleus. The priority is derived from the level, according to the following table:

Level	Priority
0	18
1	34
2	50
3	66
4	82
5	98
6	114
7	130

Be certain that priorities set in this manner do not violate the max$priority attribute of the containing job.

SET EXCEPTION HANDLER

SET$EXCEPTION$HANDLER assigns an exception handler to the calling task.

```
CALL RQ$SET$EXCEPTION$HANDLER (exception$info$ptr, except$ptr);
```

INPUT PARAMETER

exception$info$ptr — A POINTER to a structure of the following form:

```
STRUCTURE(
   EXCEPTION$HANDLER$OFFSET   WORD,
   EXCEPTION$HANDLER$BASE     WORD,
   EXCEPTION$MODE             BYTE);
```

where

- exception$handler$offset contains the offset of the first instruction of the exception handler.
- exception$handler$base contains a token for the segment containing the first instruction of the exception handler.
- exception$mode contains an encoded indication of the calling task's intended exception mode. The value is interpreted as follows:

Value	When to Pass Control To Exception Handler
0	Never
1	On programmer errors only
2	On environmental conditions only
3	On all exceptional conditions

OUTPUT PARAMETER

except$ptr — A POINTER to a WORD to which the condition code for the call is to be returned.

SEND$MESSAGE sends an object token to a mailbox.

```
CALL RQ$SEND$MESSAGE (mailbox, object, response, except$ptr);
```

INPUT PARAMETERS

mailbox	A WORD containing a token for the mailbox to which an object token is to be sent.
object	A WORD containing an object token which is to be sent.
response	A WORD which, • if not zero, contains a token for the desired response mailbox or semaphore. • if zero, indicates that no response is requested.

OUTPUT PARAMETER

except$ptr	A POINTER to a WORD to which the condition code for the call is to be returned.

DESCRIPTION

The SEND$MESSAGE system call sends the specified object token to the specified mailbox. If there are tasks in the task queue at that mailbox, the task at the head of the queue is awakened and is given the token. Otherwise, the object token is placed at the tail of the object queue of the mailbox. The sending task has the option of specifying a mailbox or semaphore at which it will wait for a response from the task that receives the object. The nature of the response must be agreed upon by the writers of the two tasks.

CONDITION CODES

E$OK	No exceptional conditions.
E$EXIST	One or more of the input parameters is not a token for an existing object.
E$TYPE	Either • the mailbox parameter is a token for an object that is not a mailbox or • the response parameter is a token for an object that is neither a mailbox nor a semaphore.

tttt	A token for the breakpoint task.
s	The breakpoint state of the breakpoint task. Possible values are X (for execute), E (for exchange), Z (for exception), S (for step), and blank (for null).

If there is no breakpoint task, the display is

```
BT=0
```

Removing a Task from the Breakpoint List --- The G Command

Syntax

The syntax for the G command is given in Figure 12-9.

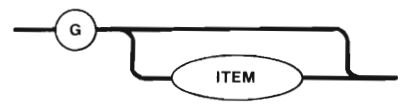


Figure 12-9. Syntax Diagram for Removing a Task from the Breakpoint List

Explanation of Syntax

ITEM	A token for a task on the breakpoint list. If the given token is not for a task on the breakpoint list, an error message will be displayed.

Effects

The G command resumes a task and removes it from the breakpoint list. When resumed, the task continues from where it last incurred a breakpoint. If ITEM is present, the task for which it is a token is resumed. Otherwise, the breakpoint task is resumed. Until re-established by the BT command, the Debugger's breakpoint task is undefined. If the G command is used without ITEM when there is no breakpoint task, an error message is displayed.

Establishing the Breakpoint Task --- The BT Command

Syntax

The syntax for this command is given in Figure 12-10.

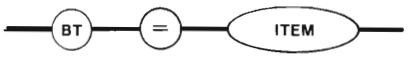


Figure 12-10. Syntax Diagram for Establishing the Breakpoint Task

Explanation of Syntax

ITEM	A token for an existing task.

Effects

The task designated by ITEM becomes the breakpoint task. If it is not already on the breakpoint list, it is suspended and placed on the breakpoint list.

Inquiring as to the Breakpoint Task --- The BT Command

Syntax

The syntax for this command is given in Figure 12-10.

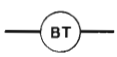


Figure 12-11. Syntax Diagram for Inquiring as to the Breakpoint Task

This command causes the following to be displayed at the terminal:

BT=jjjjJ/ttttT(s)

where

jjjj	A token for the job containing the breakpoint task.
tttt	A token for the breakpoint task.
s	The breakpoint state of the breakpoint task. Possible values are X (for execute), E (for exchange), Z (for exception), S (for step), and blank (for null).

If there is no breakpoint task, the display is

BT=0

Viewing the Breakpoint Task's Registers --- The R Command

Syntax

The syntax for this command is given in Figure 12-12.

Explanation of Syntax

R	The command key letter. By itself, it represents a request for the display of all the breakpoint task's 8086 register values.
Ryz	Represents a request for the display of only the breakpoint task's yz register value.

Effects

If the command is simply "R", then all of the breakpoint task's registers are displayed, in the following format:

```
RAX=xxxx    RSI=xxxx    RCS=xxxx    RIP=xxxx
RBX=xxxx    RDI=xxxx    RDS=xxxx    RFL=xxxx
RCX=xxxx    RBP=xxxx    RSS=xxxx
RDX=xxxx    RSP=xxxx    RES=xxxx
```

If the command has the form Ryz, then the contents of the breakpoint task's register are displayed, either as

Ryz=xxxx

or as

Ryz=xx,

depending on whether yz is a byte-size register (like AH) or a word-size register (like AX).

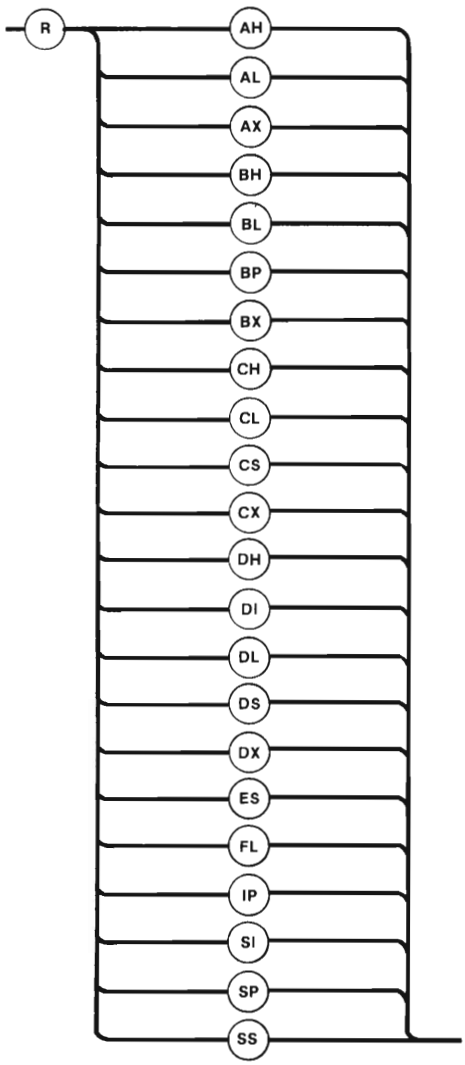


Figure 12-12. Syntax Diagram for Viewing the Breakpoint Task's Registers

Altering the Breakpoint Task's Registers --- The R Command

Syntax

The syntax for this command is given in Figure 12-13.

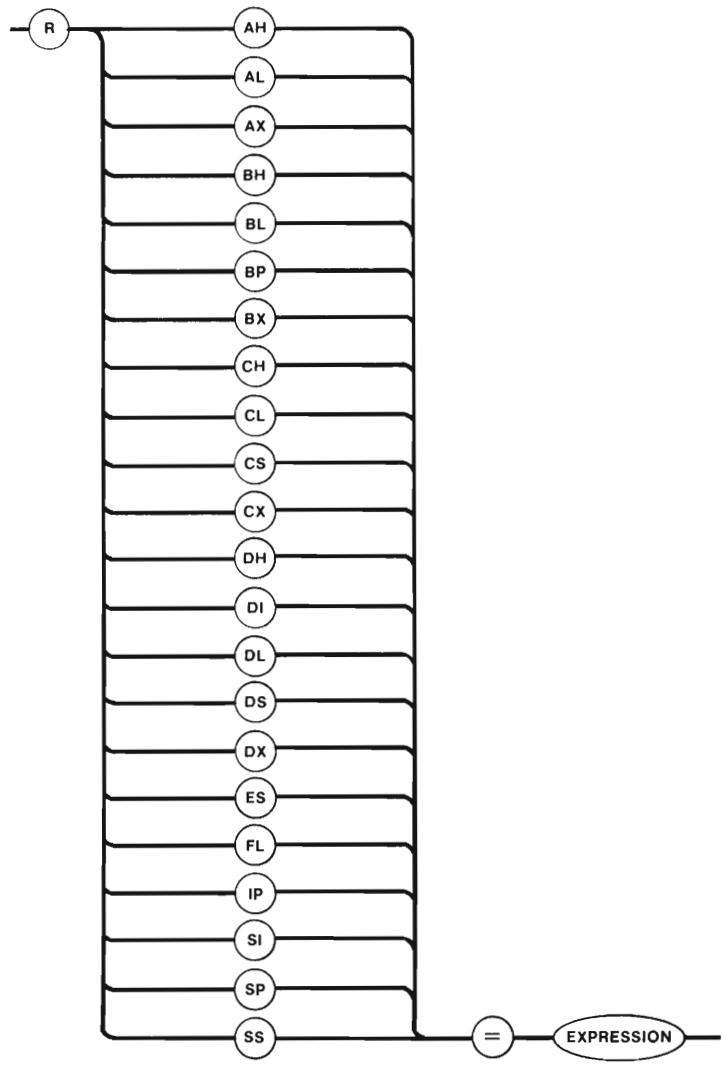


Figure 12-13. Syntax Diagram for Altering the Breakpoint Task's Registers

Explanation of Syntax

Ryz	Signals a request that the contents of the breakpoint task's yz register are to be changed.

Effects

This command requests that the breakpoint task's register, as specified in the command request, be updated with the value of the EXPRESSION.

OBSERVATION AND MANIPULATION COMMANDS

The commands in this section enable you to inspect or modify the contents of absolute memory locations, to view the RMX/86 system lists, and to inspect tasks, jobs, exchanges, and segments.

In the descriptions of the commands for inspecting and modifying memory locations, frequent mention is made of the current display mode, the current segment base, the current offset, the current address, and the display of memory locations. This terminology is defined as follows:

- The current display mode determines the manner in which memory values are interpreted for display purposes. The possible modes are designated by the letters B, W, P, and A, and they stand, respectively, for byte, word, pointer, and ASCII. The effects of these modes are best explained in the context of an example. Suppose that memory locations 042B through 042E contain, respectively, the values 25, F3, 67, and 4C. If you ask for the display of the memory at location 042B, then the effects, which depend on the current display mode, are as follows:

Current Display Mode	Display
B	25
W	F325
P	4C67:F325
A	%

  Observe that words and pointers are displayed from high-order (high address) to low-order (low address).

  If a location contains a value which does not represent a printable ASCII character, and the current display mode is A, then the Debugger prints a period. The initial current display mode is B.

- The value of the current segment base is always the value of the most recently used segment base. The initial value of the current segment base is 0.

- The current offset is a value the Debugger maintains and uses when reference is made to a memory location without explicitly citing an offset value. Except when the current offset has been modified by certain options of the M command, the current offset is always the value of the most recently used offset. The initial value of the current offset is 0.

- The current address is the 8086 memory address computed from the combination of the current segment base and the current offset.

- When memory locations are displayed, the format is as follows:

  xxxx:yyyy=value

  where xxxx and yyyy are the current segment base and current offset, respectively, and value is a byte, word, pointer, or ASCII character, depending on the current display mode. In case several contiguous memory locations are being requested in a single request, each line of display is as follows:

  xxxx:yyyy=value value value ... value

  where xxxx, yyyy, and value are as previously described, and xxxx:yyyy represent the address of the first value on that line.

  The first such line begins with the first address in the request and continues to the end of that (16 byte) paragraph. If additional lines are required to satisfy the request, each of them begins at an offset which is a multiple of 16 (10 hexadecimal).

Examining or Modifying Memory --- The M Command

Syntax

The syntax for the M command is given in Figure 12-14.

Explanation of the M Command Options

The options in the M command fall into three categories:

- If an option begins with "!", then it is a request to redefine the current display mode.

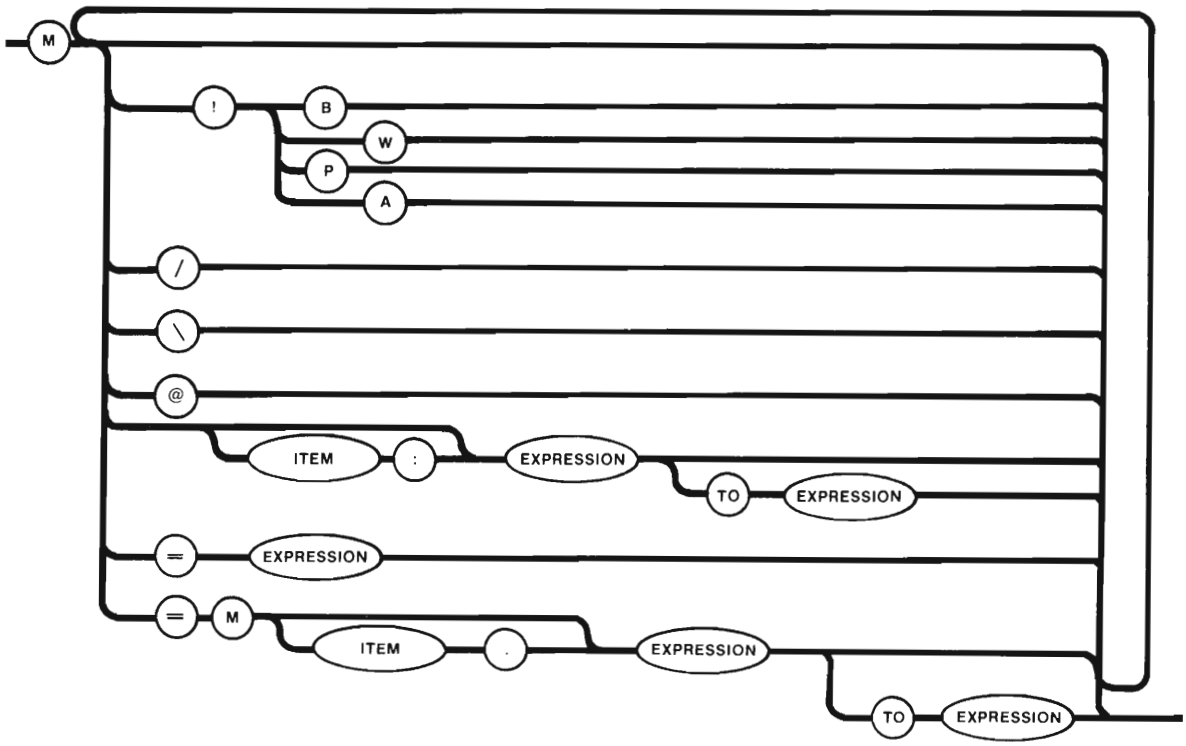


Figure 12-14. Syntax Diagram for Examining or Modifying Memory

- If an option begins with "=", it is a request to alter memory.
- The remaining options are requests for display of memory.

In what follows, the options of the M command are described with examples. As much as possible, effects are described separately for each option. When combinations of options produce special effects, these effects are described.

As the syntax diagram reveals, it is permissible to make multiple requests in the same command line. The Debugger treats multiple requests as if they had been submitted one at a time. For example, M/// is treated as three M/ requests. In the following descriptions, it is assumed that each command line consists of only one request.

You must separate the elements in a command with a space. An exception is that ITEM, colon, and EXPRESSION may be contiguous, like 4C67:F325.

NOTE

When using the M command, be aware of the following hazards:

- It is possible for you to modify memory within RMX/86 components, such as the Nucleus and Debugger. Doing so can jeopardize the integrity of your application system, and should therefore be avoided.

- It is possible to request that non-RAM memory locations be modified. If you attempt to modify a location that is in ROM, an "attempt to modify non-RAM location" message appears on the display. If you attempt to read or write to a non-existent location, nothing happens to memory and the displays indicate that the specified locations contain zeros.

- A memory request might cross segment boundaries. In processing such a request, the Debugger ignores such boundaries, so don't assume that a boundary will terminate a request.

Each description is followed by an example in which the request and resulting display are shown exactly as they would appear at the terminal. Assume, for each example request, that the following circumstances exist when the request is made:

- The following memory locations contain the indicated values:

```
base:0300      21      47      E2      C8      31

    offset:  2643    2644    2645    2646    2647


base:0400      01      02      03  ....  0F      10  ...  16

    offset:  0000    0001    0002      000E    000F      0A09
```

- The current address is 0400:0008, that is, the current segment base is 0400 and the current offset is 0008.

- The current display mode is byte.

Options for Setting the Current Display Mode

M!B --- This option sets the current display mode to byte.

M!W --- This option sets the current display mode to word.

M!P --- This option sets the current display mode to pointer.

M!A --- This option sets the current display mode to ASCII.

None of these requests results in an immediate display.

Options for Displaying Memory

The options in this section all enable you to ascertain the contents of memory without disturbing those contents. Be aware, however, that all of these options change the current offset, and some of them change the current segment base. None changes the current display mode.

M/ --- This option increments the current offset according to the current display mode: by one for byte or ASCII, by two for word, or by four for pointer. Then it displays the contents of the new current address.

Example:
```
M/
0400:0009 0A
```

M\ --- This option is just like M/, except that the current offset is decremented.

Example:
```
M\
0400:0007 08
```

M --- When used by itself, M is an abbreviated way of specifying M/ or M\ , whichever was used most recently. If neither has been used in the current Debugging session, M is interpreted as an M/ request.

Example:
```
M
0400:0007 08
M
0400:0006 07
```

M@ --- This option sets the current offset equal to the value at the current address. Then the value at the adjusted current address is displayed.

Example:
```
M@
0400:0A09 16
```

M EXPRESSION --- This option sets the current offset equal to the value of the EXPRESSION and displays the value at the new current address.

```
Example:  M 3
          0400:0003 04
```

M ITEM:EXPRESSION --- This option is just like M EXPRESSION, except that ITEM is used as the base in the address calculation, and after the operation ITEM is the new current segment base.

```
Example:  M 300:2644
          0300:2644 47
```

M EXPRESSION TO EXPRESSION --- This option displays the values in a series of consecutive locations. The expressions determine the beginning and ending offsets, respectively. The current segment base is used as a base. After the display is output, the current offset is set to the value of the second expression. If the specified range of locations is incompatible with the current display mode --- for example, an odd number of locations is not compatible with the word or pointer modes --- then all words or pointers that lie partially or totally inside the range are displayed.

```
Examples: (1) M 4 TO 6
              0400:0004 05 06 07
          (2) M!W
              M 4 TO 6
              0400:0004 0605 0807
```

Options for Altering Memory

The options in this section enable you to change the contents of designated RAM locations.

CAUTION

> Because the Debugger is generally used during system development, while your tasks, the Nucleus, the Debugger, and possibly other RMX/86 components are in RAM, you should use these M command options with extreme care.

Unlike the displaying options of the previous section, the modifying options do not affect either the current segment base or the current offset.

When executing the options of this section, the Debugger displays the contents of the designated locations, then updates the contents, and finally displays the new contents. Thus, if you inadvertently destroy some important data, the information you need to restore it is available.

The options of this section copy data in the byte mode. The current display mode is not affected by these copying options.

Some M command lines have the form M⟨destination⟩=M⟨source⟩, where both ⟨source⟩ and ⟨destination⟩ have the following syntax:

In the descriptions that follow, occasional references are made to options of this form because, when used, they can affect the results of the next invocation of an option for altering memory.

For convenience, we use the phrase "the previous option has a destination field" as an abbreviation for

"The following conditions are both true:

- The previous option used was of the M⟨destination⟩=M⟨source⟩ variety.
- ⟨destination⟩ specifies a range of at least two addresses."

M=EXPRESSION --- This option can be used only if the current display mode is byte or word. M=EXPRESSION copies the value represented by EXPRESSION into the byte or word at the current address. However, if the previous option had a destination field, this option instead copies the value of EXPRESSION into each byte or word in ⟨destination⟩.

Examples:

(1) When the previous option did not have a destination field:

```
M = 4C
0400:0008 09
0400:0008 4C
```

(2) When the previous option had a destination field:

```
M 1 TO 4 = M 5 TO 8
```

```
0400:0001 02 03 04 05
0400:0001 06 07 08 09
M = 4C
0400:0001 06 07 08 09
0400:0001 4C 4C 4C 4C
```

M=M EXPRESSION --- This option uses the current segment base and the offset indicated by the value of EXPRESSION to compute an address. It copies the value at that computed address into the location specified by the current address. However, if the previous option had a destination field, the value at the computed address is instead copied to the locations in the destination field.

Examples:

(1) When the previous option did not have a destination field:

```
M = M 4
0400:0008 09
0400:0008 05
```

(2) When the previous option had a destination field:

```
M 1 TO 3 = M 5 TO 7
0400:0001 02 03 04
0400:0001 06 07 08
M = M 4
0400:0001 06 07 08
0400:0001 05 05 05
```

M=M ITEM:EXPRESSION --- This option uses ITEM and EXPRESSION as base and offset, respectively, to compute an address. M=M ITEM:EXPRESSION copies the value at that computed address into the location specified by the current address. However, if the previous option had a destination field, the value at the computed address is instead copied to the locations in the destination field.

Examples:

(1) When the previous option did not have a destination field:

```
M = M 300:2643
0400:0008 09
0400:0008 21
```

(2) When the previous option had a destination field:

```
M 1 TO 4 = M 5 TO 8
0400:0001 02 03 04 05
0400:0001 06 07 08 09
M = M 300:2643
0400:0001 06 07 08 09
0400:0001 21 21 21 21
```

M=M EXPRESSION TO EXPRESSION --- This option uses the current segment base and, in order, the offsets indicated by the EXPRESSIONs, to compute a beginning address and an ending address. M=M EXPRESSION TO EXPRESSION copies the sequence of values bounded by the computed addresses to the sequence of locations that begin at the current address. However, if the previous option had a destination field, the sequence of values bounded by the computed addresses is copied to the destination field, with the source values being truncated or repeated as required.

Examples:

(1) When the previous option did not have a destination field:

```
M = M A TO C
0400:0008 09 0A 0B
0400:0008 0B 0C 0D
```

(2) When the previous option had a destination field:

```
M 1 TO 4 = M 5 TO 8
0400:0001 02 03 04 05
0400:0001 06 07 08 09
M = M A TO C
0400:0001 06 07 08 09
0400:0001 0B 0C 0D 0B    (first value
                          repeated)
```

M=M ITEM:EXPRESSION TO EXPRESSION --- This option uses ITEM as a base and the EXPRESSIONs as offsets to compute a beginning and an ending address. The sequence of values bounded by the computed addresses is copied to the sequence of locations beginning at the current address. However, if the previous option had a destination field, the sequence of values bounded by the computed addresses is copied to the destination field, with the source values being truncated or repeated as required.

Examples:

(1) When the previous option did not have a destination field:

```
M = M 300:2643 TO 2647
0400:0008 09 0A 0B 0C 0D
0400:0008 21 47 E2 C8 31
```

(2) When the previous option has a destination field:

```
M 1 TO 4 = M 5 to 8
0400:0001 02 03 04 05
0400:0001 06 07 08 09
M = M 300:2643 TO 2647
0400:0001 06 07 08 09
0400:0001 21 47 E2 C8    (last value
                          truncated)
```

Examining System Objects --- The I Command

Syntax

The syntax for the I command is given in Figure 12-15.

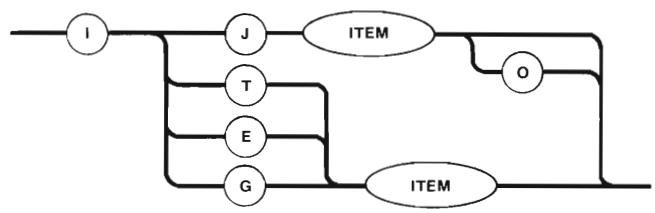


Figure 12-15. Syntax Diagram for Examining System Objects

Explanation of I Command Options

J --- This option lists the principal attributes of the job whose token is represented by ITEM. IF the O option is included, the object directory for the job is listed as well. In case there is a large number of entries in the object directory, the display might roll off the screen. To deal with this, use control-O, which works as described in Chapter 11. The form of the display is as follows:

```
                    -----RMX/86 JOB REPORT-----
JOB TOKEN                 XXXX    PARENT JOB              XXXX
POOL MAXIMUM              XXXX    POOL MINIMUM            XXXX
CURRENT ALLOCATED         XXXX    CURRENT UNALLOCATED     XXXX
CURRENT # OBJECTS         XXXX    CURRENT # TASKS         XXXX
MAXIMUM # OBJECTS         XXXX    MAXIMUM # TASKS         XXXX
CURRENT # CHILDREN JOBS   XXXX    DELETION PENDING         AAA
EXCEPTION MODE            XXXX    EXCEPTION HANDLER       XXXX:XXXX
MAXIMUM PRIORITY          XXXX

NAMES(S) AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
         AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA

                    -----OBJECT DIRECTORY-----
MAXIMUM SIZE         XXXX      VALID ENTRIES           XXXX
NAME      TOKEN        NAME      TOKEN         NAME          TOKEN
AAAAAAAAAAAA  XXXX     AAAAAAAAAAAA  XXXX    AAAAAAAAAAAA     XXXX
```

The X's represent hexadecimal digits. The A's represent alphanumeric characters. Most of the field names are self-evident to someone who is familiar with the Nucleus portion of this manual. The less obvious names are explained as follows:

- CURRENT ALLOCATED and CURRENT UNALLOCATED refer, respectively, to the allocated and unallocated portions of the job's memory pool. The quantities given are numbers of paragraphs.

- DELETION PENDING tells whether a task has attempted to delete the job but was unsuccessful because the job has obtained protection from the DISABLE DELETION primitive (which is described in the RMX/86 Systems Programmer's Reference Manual). The possible values of DELETION PENDING are YES and NO.

- NAME(S) are the names under which the job is cataloged in the root object directory or the object directory of the job's parent.

T --- This option lists the principal attributes of the task whose token is represented by ITEM. The form of the display is as follows:

```
                -----RMX/86 TASK REPORT-----
TASK TOKEN           XXXX      CONTAINING JOB          XXXX
STACK SEGMENT BASE   XXXX      STACK SEGMENT OFFSET    XXXX
STACK SEGMENT SIZE   XXXX      STACK SEGMENT LEFT      XXXX
CODE SEGMENT BASE    XXXX      DATA SEGMENT BASE       XXXX
INSTRUCTION POINTER  XXXX      TASK STATE              AAAAAAAA
STATIC PRIORITY      XXXX      DYNAMIC PRIORITY        XXXX
SUSPENSION DEPTH     XXXX      SLEEP UNITS REQUESTED   XXXX
EXCEPTION MODE       XXXX      EXCEPTION HANDLER       XXXX:XXXX

NAME(S) AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
        AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
```

The X's represent hexadecimal digits. The A's represent alphanumeric characters. Most of the field names are self-evident to someone who is familiar with the Nucleus portions of this manual. The less obvious names are explained as follows:

- STATIC PRIORITY is the priority of the task as described in the chapter on task management.
- DYNAMIC PRIORITY is a temporary priority that is sometimes assigned to the task by the Nucleus. This is done to improve system performance.
- NAME(S) are the names under which the task is cataloged in the root object directory or the object directory of the job that contains the task.

E --- This option lists the principal attributes of the exchange whose token is represented by ITEM. The form of the display is one of the following, depending on the type of the exchange.

```
               -----RMX/86 MAILBOX REPORT-----
MAILBOX TOKEN        XXXX          CONTAINING JOB        XXXX
# TASKS WAITING      XXXX          # OBJECTS WAITING     XXXX
FIRST WAITING XXXXJ/XXXX*          QUEUE DISCIPLINE      AAAAAA

NAME(S) AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
        AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA


               -----RMX/86 SEMAPHORE REPORT-----
SEMAPHORE TOKEN      XXXX          CONTAINING JOB      XXXX
# TASKS WAITING      XXXX          QUEUE DISCIPLINE    AAAAAAA
FIRST WAITING  XXXXJ/XXXXT
CURRENT VALUE        XXXX          MAXIMUM VALUE       XXXX

NAME(S) AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
        AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
```

The X's represent hexadecimal digits. The A's represent alphanumeric characters. The * represents either J (for job), T (for task), M (for mailbox), S (for semaphore), R (for region), C (for composite), or G (for segment). Most of the field names are self-evident to someone who is familiar with the Nucleus portion of this manual. The less obvious names are explained as follows:

- FIRST WAITING is the token for either the first task in the task queue or the first object in the object queue. Because, at all times, one of these queues is empty, FIRST WAITING is not ambiguous.
- QUEUE DISCIPLINE is the queueing scheme that is employed in the exchange's task queue. Its value is FIFO or PRIORITY.
- NAME(S) are the names under which the exchange is cataloged in the root object directory or the object directory of the job that contains the exchange.

G --- This option lists the principal attributes of the segment whose token is represented by ITEM. The form of the display is as follows:

```
                    -----RMX/86 SEGMENT REPORT-----
SEGMENT TOKEN       XXXX              CONTAINING JOB        XXXX
SEGMENT BASE        XXXX              SEGMENT LENGTH        XXXX

NAME(S)  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
         AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA  AAAAAAAAAAAA
```

The X's represent hexadecimal digits. The A's represent alphanumeric characters. The names of the first four fields in the display are self-evident to someone who is familiar with the Nucleus portion of this manual. NAME(S) are the names under which the segment is cataloged in the root object directory or the object directory of the job that contains the segment.

Viewing RMX/86 System Lists --- The V Command

Syntax

The syntax for the V command is given in Figure 12-16.

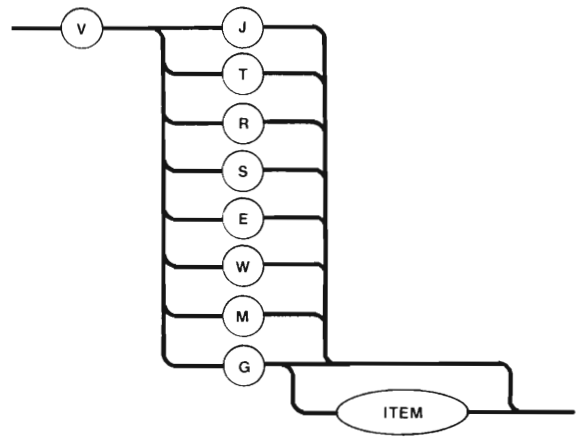


Figure 12-16. Syntax Diagram for Viewing RMX/86 System Lists

Explanation of V Command Options

J --- This option lists all jobs as

JL=ppppJ/jjjjJ ppppJ/jjjjJ ... ppppJ/jjjjJ

where

jjjj	A job token.
pppp	A token of its parent job. If the optional ITEM is included in the command and it contains a job token, then the tokens of all of that job's children are listed.

T --- This option lists all tasks as

TL=jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT

where

tttt	A task token.
jjjj	A token for the job that contains the task. If the optional ITEM is included in the command and it contains a job token, then the tokens of all the tasks in that job are listed. An asterisk following a task token indicates that the task has overflowed its stack.

R --- This option lists all ready tasks as

RL=jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT

where

tttt	A token of a ready task.
jjjj	A token for the job containing the task. If the optional ITEM is included in the command and it contains a job token, then the tokens of all the ready tasks in that job are listed. An asterisk following a task token indicates that the task has overflowed its stack.

S --- This option lists all suspended tasks as

SL=jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT

where

tttt	A token of a suspended task.
jjjj	A token for the job containing the task. If the optional ITEM is included in the command and it contains a job token, then the tokens of all the suspended tasks in that job are listed. An asterisk following a task token indicates that the task has overflowed its stack.

E --- This option lists all exchanges as

EL=jjjjJ/xxxxt jjjjJ/xxxxt ... jjjjJ/xxxxt

where

xxxx	A token for an exchange.
t	The type of the exchange (M for mailbox or S for semaphore).
jjjj	A token for the job containing the exchange. If the optional ITEM is included in the command and it contains a job token, then the tokens of all the exchanges in that job are listed.

W --- This option lists the task queues at exchanges as

```
WL jjjjJ/xxxxt = jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT
WL jjjjJ/xxxxt = jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT
   .
   .
   .
WL jjjjJ/xxxxt = jjjjJ/ttttT jjjjJ/ttttT ... jjjjJ/ttttT
```

where

xxxx	A token for an exchange
t	The type of the exchange (M for mailbox, S for semaphore).
tttt	A token for a task which is queued at that exchange.
jjjj	A token for the job containing the task. If the optional ITEM is included in the command and it contains the token for an exchange, then the tokens for the tasks in that exchange's task queue are listed. An asterisk indicates that the task has overflowed its stack.

M --- This option lists the object queues at mailboxes as

```
ML jjjjJ/mmmmM = jjjjJ/oooot jjjjJ/oooot ... jjjjJ/oooot
ML jjjjJ/mmmmM = jjjjJ/oooot jjjjJ/oooot ... jjjjJ/oooot
   .
   .
   .
ML jjjjJ/mmmmM = jjjjJ/oooot jjjjJ/oooot ... jjjjJ/oooot
```

where

mmmm	A token for a mailbox.
oooo	A token for an object in that exchange's object queue.
t	The type of the object (J for job, T for task, M for mailbox, S for semaphore, and G for segment).
jjjj	A token for the job containing the exchange or object. If the optional ITEM is included in the command and it contains the token for a mailbox, then the tokens for the objects in that mailbox's object queue are listed.

G --- This option lists the segments as

GL=jjjjJ/ggggG jjjjJ/ggggG ... jjjjJ/ggggG

where

gggg	A token for a segment.
jjjj	A token for the job containing the segment. If the optional ITEM is included in the command and it contains the token for a job, then the tokens for the segments in that job are listed.

Exiting the Debugger --- The Q Command

Syntax

The syntax for the Q command is given in Figure 12-17.

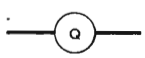


Figure 12-17. Syntax Diagram for Exiting the Debugger

Effects

This command deactivates the Debugger. When a debugging session is terminated, the tables and lists the Debugger maintains are not destroyed. Q also causes the message "EXIT RMX/86 DEBUGGER" to be displayed.

USING SYMBOLIC NAMES WHILE DEBUGGING

For your convenience during debugging, the Debugger supports the use of alphanumeric variable names that stand for numerical quantities. The names and their associated values can be accessed by the Debugger from any of the following sources:

- A Debugger-maintained symbol table. The table contains name/value pairs that have been cataloged by the Debugger as numeric variables. Commands for defining, changing, listing, and deleting numeric variables are described later in this section.
- The object directory of the current job. The current job is defined to be the job that contains the breakpoint task. If there is no breakpoint task, the current job is the root job.
- The object directory of the root job.

When you use a symbolic name that is not the name of a breakpoint variable, the Debugger searches these sources in the order just listed.

Suppose that you want to refer to a particular task by means of the name .TASK001. If the task is cataloged in the object directory of either the root job or the current job, then the Debugger will go to the appropriate directory and fetch a token for the task whenever the name .TASK001 is used in a Debugger command. If the task is not so cataloged, you can use VJ (view job), IJ (inspect job), VT (view task), and IT (inspect task) commands to deduce a token for the task. Then you can define .TASK001 to be a numeric variable whose value is that token.

Defining a Numeric Variable --- The D Command

Syntax

The syntax for the D command is given in Figure 12-18.

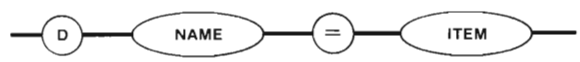


Figure 12-18. Syntax Diagram for Defining a Numeric Variable

Effects

This command puts the NAME and the value of ITEM in the Debugger's symbol table.

Changing a Numeric Variable

Syntax

The syntax for this command is given in Figure 12-19.

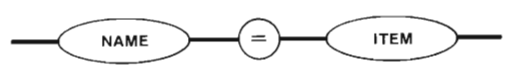


Figure 12-19. Syntax Diagram for Changing a Numeric Variable

Effects

This command removes from the Debugger symbol table the value originally associated with NAME, and replaces it with the value of ITEM.

Deleting a Numeric Variable --- The Z Command

Syntax

The syntax for the Z command is given in Figure 12-20.

Figure 12-20. Syntax Diagram for Deleting a Numeric Variable

Effects

This command removes the NAME and associated value from the Debugger's symbol table.

Viewing Numeric Variables --- The L Command

Syntax

The syntax for the L command is given in Figure 12-21.

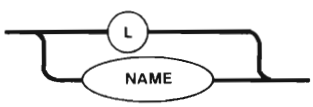


Figure 12-21. Syntax Diagram for Viewing Numeric Variables

Effects

The L command causes all numeric variable names and their associated values to be listed. If only NAME is specified, only one pair is listed. In either case, one pair is listed per line in the format

NAME=xxxx

where xxxx is the associated value.

APPENDIX A. RMX/86 DATA TYPES

The following are the data types that are recognized by the RMX/86 Operating System:

BYTE - An unsigned, one byte, binary number.

WORD - An unsigned, two byte, binary number.

INTEGER- A signed, two byte, binary number that is stored in two's complement form.

OFFSET - A word whose value represents the distance from the base of a segment.

TOKEN - A word whose value identifies an object.

POINTER- Two words containing the base of a segment and an offset, in the reverse order.

STRING - A sequence of consecutive bytes. The first byte contains the number (not to exceed 12) of bytes that follow it in the string.

APPENDIX B. RMX/86 TYPE CODES

Each RMX/86 object type is known within RMX/86 systems by means of a numeric code. For each code, there is a mnemonic name that can be substituted for the code. The following lists the types with their codes and associated mnemonics.

OBJECT TYPE	INTERNAL MNEMONIC	NUMERIC CODE
Job	T$JOB	1
Task	T$TASK	2
Mailbox	T$MAILBOX	3
Semaphore	T$SEMAPHORE	4
Segment	T$SEGMENT	6

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