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Using the iRMX 86™ Operating System

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OEM Microcomputer Systems Applications

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AFN-01540A

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Contents

INTRODUCTION

Companies seeking to develop microcomputer applications are faced with two significant problems. First, applications are growing more and more sophisticated. With competition always present, products are continually being enhanced with new features. This burdens the underlying computer system by increasing both the complexity of the software and the number of events and functions that must be handled by the system.

The second problem is a management problem. These newer and more sophisticated application systems must be developed quickly in order to hit shrinking market windows. Also, they must be developed with lower manpower costs to be feasible in an engineering community struck by insufficient technical personnel and skyrocketing software development costs.

These are the needs addressed by the iRMX 86™ Operating System. The two goals in the development of this product have been power/flexibility to meet the needs of increasingly complex application systems, and ease of understanding and use, to boost the productivity of available engineering resources. Users of Intel's line of iSBC 86™ Single Board Computers or custom-designed 8086-based boards can now obtain the same benefits from Intel supplied system software as they can from Intel supplied system hardware.

The reader of this application note is provided with information in four subject areas.

- The requirements of operating systems are discussed along with traditional solutions.
- The iRMX 86 Operating System is introduced and its features are discussed in relation to the requirements studied earlier.
- System design using the iRMX 86 Operating System is studied using example solutions.
- Code for two example systems is examined to learn the details of system implementation.

Some of the topics in this note may not be of interest to all readers. For example, an experienced real-time programmer may not need to read the entire overview of real-time systems. For those who want to brush up on a few topics, the overview is organized to allow the reader to focus attention on areas of specific interest.

Throughout this application note, various terms and concepts are introduced and discussed. If further information on any of these topics is desired, the references listed in the front of this note should be used.

OVERVIEW

This overview is provided to investigate both the problems encountered in the design of applications software and also the classical solutions to these problems.

Multitasking

A real-time system is defined to be a system that reacts to events occurring external to the computer and which monitors or controls these events as they occur (or in "real-time"). The converse of a real-time system is known as a batch system where the outcome of a program does not depend on when it is run (for example, a payroll program).

Two other characteristics typically encountered in a real-time system are asynchronous event occurrences and concurrent activity. The first characteristic is caused by events occurring randomly rather than at scheduled intervals. The second characteristic, concurrent activity, takes place when two or more events occur nearly at the same time, requiring simultaneous activity.

One method of dealing with the requirements of a real-time system would be to write a program that knows what events could potentially occur (for example, an interrupt occurrence, a real-time clock counting down to zero, a byte in memory being modified by another program). This program could then execute a large loop checking for the occurrence of these events.

There are several problems with this approach. While processing one event which has occurred, the program is not responsive to other events. Also, the programmer has no way of prioritizing the importance of the various events. From a maintenance standpoint, this program is complex and difficult to enhance or modify.

The traditional solution to these problems is a technique called multitasking. Essentially, this involves writing many small routines instead of one large one. Each of these routines (tasks) can process events independent of the other tasks in the system. In addition, a priority can be assigned each task so that the operating system can decide as to which task is the most important when more than one task requests control of the CPU.

The support for multitasking involves a scheduler which is part of the service provided by the operating system. The scheduler allows each task to execute its program as if it has sole control of the CPU, ensuring that all tasks desiring CPU time are serviced according to the priority associated with each task.

From the standpoint of system design, multitasking has many desirable qualities. Large and potentially complex application programs can be decomposed into smaller more manageable units. This makes feasible the use of programmer teams to implement the application. Perhaps even more importantly, the potentially overwhelming problems surrounding concurrent execution and interrupt handling become transparent to the application programmer. Also, multitasking makes the modification of existing tasks and the addition of new ones become a manageable objective since the interaction between tasks is minimized.

Interrupt Handling

A common event in a real-time system is the occurrence of an interrupt. Because this event is so common, an important feature of a real-time operating system is its interrupt processing capabilities.

From the standpoint of application software, interrupt handling can be cumbersome. The currently running task must be preempted, various hardware devices must be manipulated and perhaps a hardware interrupt controller must be dealt with.

A real-time operating system can abstract the occurrence of an interrupt into something more consistent with the way other events are handled. A task can simply inform the scheduler that it does not require any CPU time until an interrupt occurs. The relative priority of different interrupts can also be handled in the same manner as the priority of multiple tasks are handled. Thus, the application programmer need only deal with the actual processing related to interrupt occurrence.

Reliability

Reliability is a keyword in all real-time systems. In this type of system, reliability does not refer to mean time between failure. In fact, the software in a real-time application typically cannot be *allowed* to fail. The difficulty imposed on the software by the environment comes from the near infinite number of permutations that can occur. A system that appears to be fully debugged can fail in the field because of a combination of simultaneous events that never occurred before.

The only means to avoid failure in these instances is through the use of a consistent, well-thought-out model for handling events. Any special-cased solution is subject to failure when the special cases that were designed for are violated in the real world.

Error handling can also add reliability to an application system. When the application software is unable to anticipate the outcome of certain conditions, or the software has undiscovered bugs, it is vital for the operating system to gracefully handle the situation and allow for further processing to continue as best as possible.

I/O Handling

Many applications for 16-bit microcomputers require a variety of I/O devices. The support for I/O operations on these devices is typically provided by the operating system. Both sequential access and random access devices are typically encountered and, in addition, flexibility in handling I/O requests and acknowledgements is important.

The flexibility necessary typically involves the scheduling of a task's execution after an I/O request has been made. The greatest flexibility can be obtained by an *asynchronous* I/O system. In this system, a task makes an I/O request by calling the operating system. Once the processing of the request has begun, control is returned to the calling task.

In this manner, the task can continue executing its program while the I/O operation is progressing. When the results of the operation are desired, the task can call the operating system again to wait for the completion of the previous I/O request.

The second type of I/O support is less flexible but also easier to use. An operating system that supports *synchronous* I/O allows a task to make a single operating system call to make an I/O request. Once control is returned to the calling task, the I/O operation is complete and the results are immediately available. This type of I/O support sometimes takes advantage of a technique known as *autobuffering* to regain some of the performance advantage of the overlapped I/O found in the asynchronous system.

Debug Support

The inherent characteristics of the real-time environment sometimes make it difficult to debug new software. If the simultaneous occurrence of two events causes a bug in the software, detection may be difficult because the next time the system is run the error is not reproduced. Also, because of the fact that the software is broken down into many independent tasks, the interaction may be difficult to track using standard debugging techniques.

The solution to these problems is a piece of software called the system debugger. The debugger typically has three characteristics.

1) It is designed to interact with the operating system and therefore has intimate knowledge of code, data structures and system objects.
2) Since the debugger is just another task in the system, it does not affect the operation of the other tasks that are running.
3) Through the use of sophisticated breakpointing facilities, the debugger allows the designer to track the tasks in the system, investigate their interaction with other tasks and selectively stop one or more tasks without stopping the entire system.

Multiprogramming

In some application systems, there arises the requirement to run several "applications" on the computer at the same time. This may be due to the desire to squeeze more use out of the hardware or it may be due to some system design consideration. These separate "applications" (often termed jobs) share many system resources (especially the CPU) but at the same time they need to be protected as much as possible from other jobs. In essence, it should be possible to develop two jobs independently and then run them both on the same hardware without any interaction. If interaction is desired, the operating system should support some well-defined protocol for jobs to use to communicate.

Free Space Management

One of the most important resources in the computer system is the memory. In some applications, the amount of memory needed can be determined when the system is designed. In the more general case, the amount of memory needed by the system fluctuates. One solution to this management problem is to have available the amount needed in the worst possible case. A more flexible and economical solution is to dynamically allocate memory from a central pool upon demand and return it when possible. This service provides two tangible advantages. First, total memory needs are reduced. Second, this service allows for ease of use by the application programmer because there is no need to set aside blocks of memory and implement code to maintain information about current usage.

File Management

The ability to easily store and retrieve data stored on mass storage devices is a requirement in many application systems. Devices such as disks, tapes and bubble memories are used to store program code, data files and parameter tables. The operating system is called upon to store and retrieve the data and organize it such that application programs can easily find and manipulate the data when necessary.

Typically, this service is provided through the use of a file system. The mass storage device is partitioned into blocks and logical addresses are assigned to the blocks. Files are created to serve as directories where the names of other files can be cataloged and looked up.

In many systems, the directory structure can go many levels deep (see Figure 1). This provides several advantages. Directory searches can be done much faster if the general area where a file exists is known. Also, if several jobs are running at the same time, each can be given its own directory and therefore isolated from the others. Lastly, for human users, it is much easier to manage the information on the disk when some logical structure of files exists.

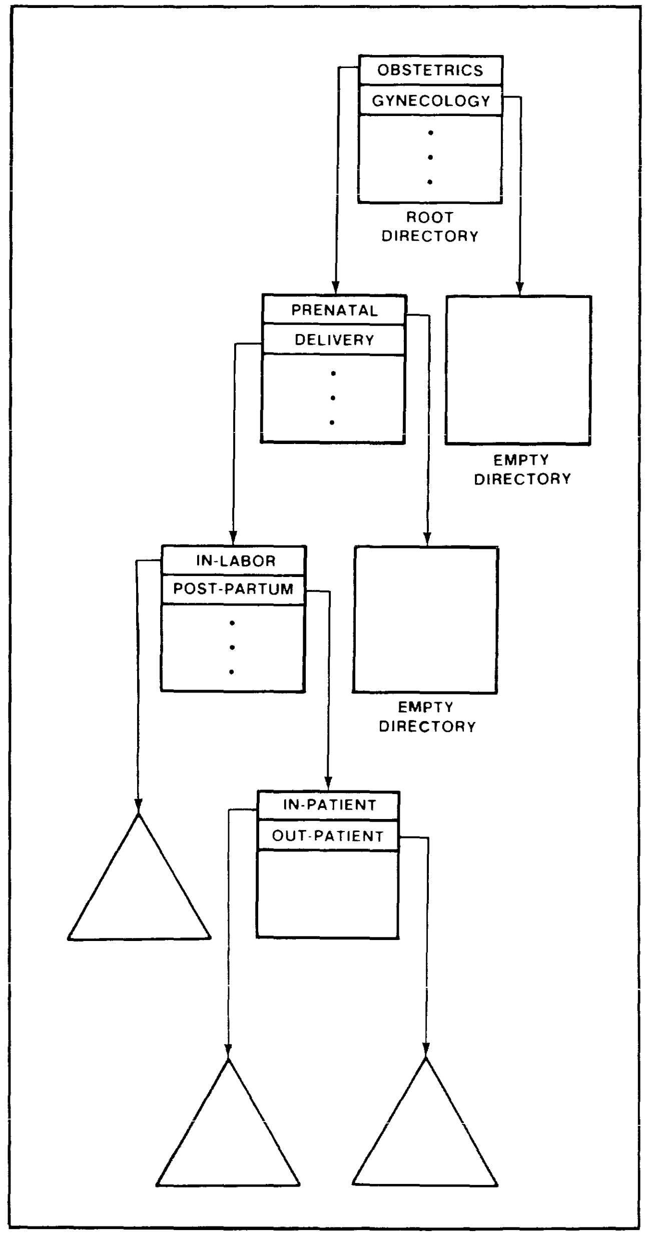

Figure 1. Hierarchical File System

Device Independence

One of the unfortunate characteristics of I/O devices is that they all tend to present different interfaces to the system software. When this is the case, the application programmer must become familiar with the unique characteristics of each device in order to communicate with it. One solution is to create an I/O driver which does the actual I/O. This driver can then be called by the application program whenever communication with the device is desired.

The problem with this solution is that the programmer must still know what type of device is being talked to since the I/O driver is specialized. If the system configuration changes, all of the software must be rewritten to call new device drivers. The best solution is to design a standard interface to device drivers and postpone until run-time the decision about which devices to use. With this type of system, an application program can be written assuming that at run-time the human or program that invokes it will provide a specification of which devices should be used.

High-Level Man-Machine Interface

In addition to the services provided for application programs by the operating system, a set of services typically is offered to the human user sitting at the system console. System utilities are needed for file copying, disk formatting, and directory maintenance. Programs need to be loaded off disk to run and the programs themselves must be able to retrieve parameters passed to them by the operator. All of these functions are usually provided by the man-machine interface software in the operating system.

Make Versus Buy

The previous sections dealt with operating system requirements. These requirements are encountered in the application development process. Whether the solution to meet the needs comes from the individual application designer or from a computer system vendor, the requirements do not change.

There usually exists a rather simple tradeoff between designing a custom operating system or buying a generalized system and tailoring it to the individual needs of the application. There are advantages to the custom solution. The system can often be made smaller since the requirements are known in great detail. Also, some small performance improvements can sometimes be made by taking advantage of the special cases to speed things up.

Buying an operating system from a computer system vendor offers five advantages.

1) Engineering resources are becoming scarce. The use of an opearting system from a vendor allows attention to be focused on the application software.
2) The time taken to bring the product to market can be shortened, thereby gaining a competitive edge and generating early revenue.
3) Long-term maintenance costs can be reduced because the vendor supports the operating system software.
4) Personnel in all branches of the company can become familiar with one software architecture and apply this knowledge to a range of products. This applies not only to the design engineers, but also to quality assurance, customer engineers and system analysts.
5) The computer system vendor has knowledge of future technological advances coming in the product lines. For this reason, the operating system can be constructed so that applications software can be transported to future hardware without the need for expensive redesign.

In summary, the trade-offs are clear. An operating system from a computer system vendor is not the answer for every application. But in most cases, the most economical and safest bet is to take advantage of the expertise of the vendor for the system software and use engineering resources to more quickly solve the application problem.

INTRODUCTION TO THE iRMX 86™ OPERATING SYSTEM

The iRMX 86 Operating System meets the needs of real-time applications while simultaneously providing the full set of services normally found in a general-purpose operating system.

The overall picture of the iRMX 86 Operating System is shown in Figure 2. The iRMX 86 Nucleus provides

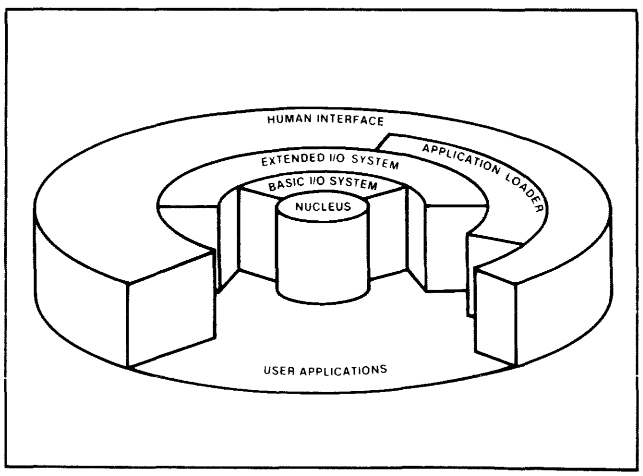

Figure 2. Layers of Support in the iRMX 86™ System

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support for multitasking, multiprogramming, intertask communication, interrupt handling and error checking. The Basic I/O System provides support for device independent and file format independent manipulation of data on I/O devices. The Extended I/O system provides synchronous I/O calls, automatic buffering, logical file name support and high-level job management. The application loader provides the ability to load code and data from mass storage devices into RAM memory. The Human Interface provides for a high-level man-machine interface as well as file utilities and parsing support for application programs.

The following sections deal in more detail with each of these iRMX 86 pieces. If more information is desired on the features discussed, please refer to the documents listed in the front of this application note.

Architecture

The iRMX 86 architecture is an object-oriented architecture. This means that the operating system is organized as a collection of building blocks that are manipulated by operators. The building blocks of the iRMX 86 system are called objects and are of several types. Some of the object types are tasks, jobs, mailboxes, semaphores and segments. These types are explained in subsequent sections of this application note.

This type of architecture has two major advantages. First, the system is easier to learn and use. The attributes of the various objects and the operations that can be performed on them are well defined and consistent. Once an object type is understood, all objects of that type are understood.

The second advantage to an object-oriented architecture is the ease with which the operating system can be tailored to the application. If there is no need for a given object in the application, all operators for that object are not included in the final configured system. On the other hand, if the application designer needs a more complex building block that is not in the basic system, he can define and use a new object type.

Table 1 lists all of the system calls in the iRMX 86 Nucleus. There are three groupings of system calls in this table.

1) The general system calls apply to all objects uniformly.
2) The first two system calls for each object are the create and delete calls. These calls simply create a new object and initialize its attributes or delete an existing object.
3) The remaining system calls are specific to the attributes of a particular object. With this organization in mind, the entire operation of the iRMX 86 nucleus can be glimpsed in a single table.

Tasks

Tasks are the active objects in the iRMX 86 architecture. Tasks execute program code and therefore are the only objects that can manipulate other objects. The attributes of a task include its program counter, stack, priority and dispatcher state.

Tasks compete with each other for CPU time and the iRMX 86 scheduler determines which task to run based upon priorities. The dispatcher states for an iRMX 86 task are shown in Figure 3. At any given point in time, the highest priority task that is ready to run has control of the CPU. Control is transferred to another task only when

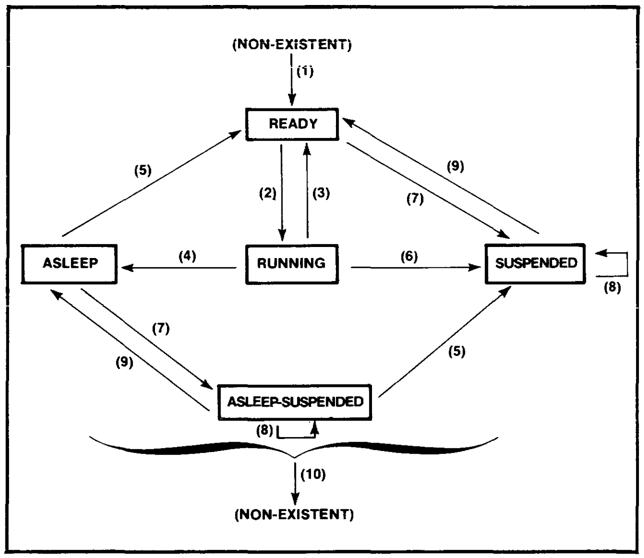


Figure 3. Task State Transition Diagram

1) the running task makes a request that cannot immediately be filled and is, therefore, moved to the asleep state,
2) an interrupt occurs causing a higher-priority task to become ready to run or
3) the running task causes a higher-priority asleep task to become ready by releasing some resource.

The suspended and asleep-suspended states are entered whenever the suspend system call is invoked for a particular task.

Job and Free Space Management

Support for multiprogramming is provided by the job object. A job provides the environment for tasks to execute their programs. All other objects needed for a particular application are contained within the job.

Table 1. Nucleus Object Management System Calls

System Calls for All Objects	O.S. Objects	Attributes	Object-Specific System Calls
CATALOG$OBJECT UNCATALOG$OBJECT LOOKUP$OBJECT ENABLE$DELETION DISABLE$DELETION FORCE$DELETE GET$TYPE	JOBS	Tasks Memory pool Object directory Exception handler	CREATE$JOB DELETE$JOB SET$POOL$MIN GET$POOL$ATTRIB OFFSPRING
	TASKS	Priority Stack Code State Exception handler	CREATE$TASK DELETE$TASK SUSPEND$TASK RESUME$TASK GET$EXCEPTION$HANDLER SET$EXCEPTION$HANDLER SLEEP GET$TASK$TOKENS GET$PRIORITY SET$PRIORITY
	SEGMENTS	Buffer with length	CREATE$SEGMENT DELETE$SEGMENT GET$SIZE
	MAILBOXES	List of objects List of tasks waiting for objects	CREATE$MAILBOX DELETE$MAILBOX SEND$MESSAGE RECEIVE$MESSAGE
	SEMAPHORES	Semaphore unit value List of tasks waiting for units	CREATE$SEMAPHORE DELETE$SEMAPHORE RECEIVE$UNITS SEND$UNITS
	REGIONS	List of tasks waiting for critical section	CREATE$REGION DELETE$REGION RECEIVE$CONTROL ACCEPT$CONTROL SEND$CONTROL
	USER OBJECTS	License rights to a given extension type	CREATE$EXTENSION DELETE$EXTENSION
		New object template	CREATE$COMPOSITE DELETE$COMPOSITE INSPECT$COMPOSITE ALTER$COMPOSITE

A specific attribute of the job is a free memory pool from which blocks can be allocated only by tasks within the job. Also, the job contains an object directory which can be used by tasks to catalog objects under ASCII names so that other tasks, knowing the ASCII name, can look up the object and thereby gain addressability to it.

More than one job can co-exist in the computer system. Tasks within jobs can also create children jobs forming a hierarchical tree of jobs (see Figure 4). Each job in the system has its unique set of contained objects, its own memory pool and its own object directory.

Segments

A fundamental resource that tasks need is memory. Memory is allocated to tasks in the form of the segment object. The segment is a block of contiguous memory. The attributes of a segment are its base address and size. 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.

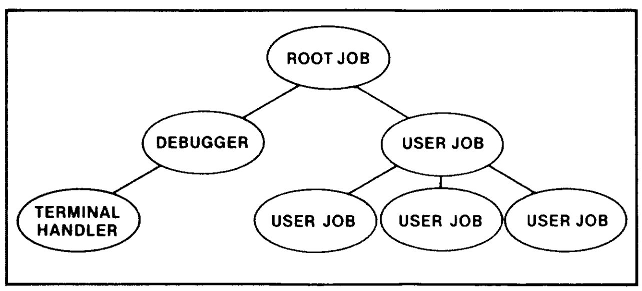


Figure 4. iRMX 86™ Job Tree Example

If there is not enough memory available, the Nucleus will try to get the needed memory from ancestors of the job.

Communication and Synchronization

In many cases it is necessary for two tasks to communicate in order to exchange data and commands. This is supported through the use of an object known as a mailbox. As its name implies, a mailbox is a holding place for objects. One task can send an object to a mailbox, causing the object to be queued there. Another task can later receive an object from the mailbox and thereby gain access to it (see Figure 5). If a task tries to receive an object from a mailbox and there are no objects there, the task can optionally be made to sleep for a specified time for an object to appear.

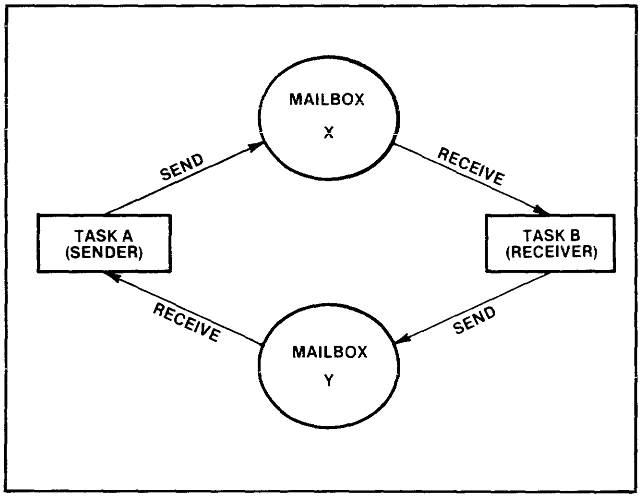


Figure 5. Intertask Communication via Mailboxes

Note that any object can be sent to a mailbox to be received by another task. Typically, the object sent is a segment which is a block of memory and can contain any commands or data. The term message is often used to describe the object during the time it is being sent through a mailbox.

In those cases where there is a requirement for synchronization between tasks but no data need be sent, a simpler more efficient mechanism exists. The semaphore object provides for the allocation of abstract entities called units. The primary attribute of the semaphore is an integer number. Tasks may send units to a semaphore thereby increasing the integer number or they can request units, thereby decreasing the number. If a task makes a request for more units than are available, it can optionally be made to sleep for a specified amount of time. This mechanism can be used for synchronization, resource allocation and mutual exclusion.

Interrupt Management

When an interrupt is sensed by the 8086 hardware, a user interrupt handler is executed. The interrupt handler can either perform all interrupt processing itself without making any iRMX 86 system calls, or it can signal an interrupt task allowing more general interrupt processing including calls to the operating system.

The operating system maps hardware interrupt priorities into the software priority scheme allowing the designer to specify what software functions are important enough to have some interrupt levels masked off during their execution. Although this mapping should always be kept in mind during design, the mechanics of dealing with interrupt control are handled by the operating system.

Error Management

One of the central themes in the design of the iRMX 86 operating system has been reliability. The results of these efforts are evident in two particular features of the architecture. Beyond the ease of understanding brought about by the symmetry of the system, the reliability of applications using the iRMX 86 software is increased.

The general case (as opposed to checking only for specific combinations of errors) has been designed for. Because of this, an unexpected combination of events or the simultaneous occurrence of interrupts will never catch the system by surprise.

In the event that errors do occur, the operating system is set to detect them. Virtually all parameters in calls to the operating system are checked for validity. Any inconsistency causes a jump to an error routine to handle the problem. Two types of errors can potentially occur and there are two ways of handling errors.

The first error type is the programmer error condition which comes about due to some mistake in the coding of a system call. The second type is an environmental condition which arises due to factors out of the control of the engineer (e.g. insufficient memory). Each of these error types can be handled in-line by checking a status code upon return from the call or can cause an error handling subroutine to be called by the system. The system designer can choose the desired method for the system, for a specific job, and even for individual tasks within a job.

Asynchronous I/O

Asynchronous I/O system calls are provided to support device independent I/O to any device in the system. The type of I/O and the type of device are interrelated as shown in Figure 6. Every device driver in the I/O system is required to support a standard interface. In this manner, all devices look the same to higher level software. In the same manner, the individual file drivers, which provide the different types of file systems, all have a standard interface and call upon the various device drivers to perform I/O. These interface standards

1) provide for the device independence in the higher layers of the I/O system
2) make it easier for Intel to add future device drivers as new devices become available and
3) make it possible for iRMX 86 users to add their own drivers for custom I/O devices.

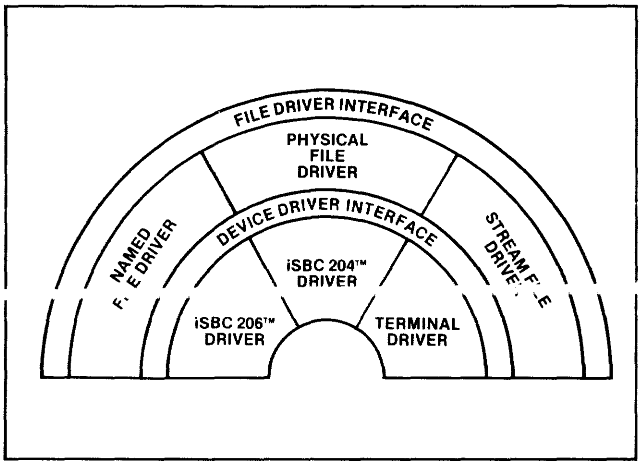


Figure 6. I/O System Structure

The iRMX 86 I/O system provides both asynchronous and synchronous system calls. The asynchronous I/O calls are faster, provide more flexibility in the selection of options and allow the program making the call to perform other functions while waiting for the I/O operation to complete.

The method by which the I/O system responds to the requestor is through the use of a mailbox. When any call is made to the asynchronous I/O system, one of the parameters indicates a mailbox where the caller expects to receive a segment containing the results of the operation (see Figure 7).

Synchronous I/O

The alternative to using the asynchronous I/O system is to use synchronous I/O system calls. As shown in Figure 8, the number of options available are fewer and the caller cannot continue execution until the entire I/O operation is completed but from an ease-of-use standpoint, the situation is much simplified.

```
Response$mailbox$token = RQ$create$
  mailbox (0, @status);
CALL RQ$A$read(connection$token, buf$ptr,
  count, response$mailbox$token, @status);
IORS$token = RQ$receive$message
  (response$mailbox$token,OFFFFH,
  @resp$t, @status);
{check status}
Call RQ$delete$segment(IORS$token,
  @status);
```

Figure 7. Asynchronous I/O Call

```
Call RQ$S$read(connection$token,buf$ptr,
  count, @status);
{check status}
```

Figure 8. Synchronous I/O Call

Two other features provided by the Extended I/O System are logical name support and autobuffering. Logical names allow the application designer to postpone the decision concerning which files to use until run-time. Essentially, all programs can be written and compiled using logical file names and then these logical names can be mapped into real file names at run-time.

The use of autobuffering regains much of performance advantage offered by overlapped I/O. When a user task opens a file for input, one or more buffers are automatically created and filled with data from the file. Thus, when the user task makes an I/O request, the data may already be available in memory. A similar case exists for write requests in that the I/O system will buffer data to be written to a device, allowing the user task to continue on.

Loaders

The iRMX 86 application loader and bootstrap loader perform a variety of services for the user software. The following is a brief summary of the available features.

1) Systems can be boot loaded from mass storage devices at system reset. This saves not only ROM or EPROM memory, but also reduces field maintenance costs by allowing easy field updates.
2) Users can design their own SYSGEN procedure allowing tailoring of an application system to the individual installation.
3) Infrequently used programs can be brought in from mass storage when needed instead of using system memory unnecessarily.

File Management

There are three types of files supported by the iRMX 86 I/O system, named files, physical files and stream files. Named files are supported on devices possessing mass storage capability. Files in this system have ASCII pathnames and are cataloged in directories. Each device in the system contains a directory tree as shown previously in Figure 1. Access protection is provided through the use of access lists for each file. Each user or group of users in the system can be given different types of access to the file or can be denied access to it.

For devices that cannot support a named file structure (e.g. printers and terminals) the physical file driver is used. Devices in this category are treated strictly as data going into and/or out of the device. If it is desirable to treat a mass storage device strictly as a large mass of data, it can also be addressed through the physical file driver.

The third type of file is the stream file. This file type has no correlation with any physical device but rather uses system memory for temporary storage of data. An example of the usage of a stream file is a job that gets its input stream of data from a file. Depending on which time the job is run, this file might be a named file on disk, a terminal, or a stream file being written to by another job (see Figure 9).

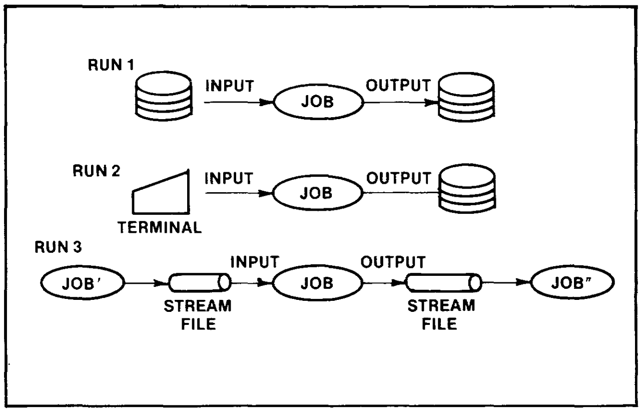


Figure 9. Stream File Example

Human Interface Subsystem

The highest level of support provided by the iRMX 86 Operating System is the Human Interface Subsystem. This piece of software provides two basic services. Programs can be invoked by typing the program name at the system console. The Human Interface will load the given program into memory, set it up as a job and start it running. The invoked program can then call upon the Human Interface routines to determine what parameters were passed to it as part of the operator input.

The Human Interface also contains a set of system utility routines which are used to copy files and disks, format disks, dynamically alter the system configuration and others.

Debugging Subsystem

The iRMX 86 Debugging Subsystem allows the designer to interact with the prototype system and isolate and correct program errors. Since the debugger is an object-oriented debugger and is aware of the internal structure of the operating system, it can provide detailed information concerning objects and can monitor mailboxes and semaphores providing a breakpoint facility as well as error detection.

Specifically, the iRMX 86 Debugging Subsystem provides six sets of functions:

1) Wake-up upon operator invocation. The operator types a control-D key to cause the debugger to wake up.
2) View system lists. The debugger can view lists of objects either globally or specifically for a given job. Also, lists of objects and tasks queued at mailboxes and semaphores can be seen.
3) Inspect objects. A detailed report on any object can be requested showing the current state of all relevant attributes.
4) Inspect and modify memory.
5) Breakpoint control. Any number of breakpoints can be set causing a single task to break on either execution of particular instructions or sends and receives of messages or units.
6) Error handling. The debugger can be set up to be the system default error handler thus catching system exceptions.

Configuration and Initialization

Once the application is designed and coded, the engineer needs a mechanism to inform the operating system of the software and hardware configuration. Essentially, this involves building tables of information using tools provided with the iRMX 86 product.

As shown earlier in Figure 4, the jobs in an iRMX 86 system form a hierarchical tree. The root in every job tree is known as the root job and is supplied as part of the iRMX 86 system. There are three important features of this job.

1) The root job has an object directory for cataloging and looking up objects. The special feature of this directory is that is is accessible by all tasks in the system since everyone can address the root job. For this reason the root object directory is useful for setting up inter-job communication paths.

2) The root job initially contains all free space in the system. Part of the system initialization code performs a memory scan to automatically determine the amount of free RAM in the system. This memory is put into the free space pool of the root job and parceled out as user jobs are created.
3) The root job contains only one task, the root task. This task scans the configuration tables generated by the user and creates the user-specified jobs.

Examples of configuration, initialization and the LINK 86 and LOC 86 operations needed to generate a system will be presented in the Code Examples section.

DESIGN METHODOLOGY

This section describes the design process involved in using the iRMX 86 system to solve application problems and presents two example solutions.

System design with the iRMX 86 Operating System should be viewed as a process starting with the highest level definition of system requirements and successively adding more detail until the end product is program code. This description sounds very much like the description of top-down design and, of course, it should. This methodology offers not only quicker designs, fewer design flaws and easier implementation, but also easier maintenance and enhancement.

In general, every iRMX 86 design progresses through the following steps:

1) Define system requirements.
2) Breakdown into highest level sub-functions (jobs).
3) Define job functions.
4) Determine inter-job command and data flow.
5) Break down each job into sub-functions.
6) Based upon requirements, assign tasks to perform job functions.
7) Determine inter-task command and data flow.
8) Write program code for each task.

Step 8 becomes the design process associated with the application programs themselves. The code for each task is essentially a sequential program that performs one of the functions of the computer system. Standard techniques for top-down design can therefore be used here to specify each module and its inputs and outputs as well as global and local data structures etc. The end product of this procedure is a modularized application system that should be easy to debug.

APPLICATION EXAMPLE 1

The first example presented here is based on the distributed local network diagrammed in Figure 10. Each

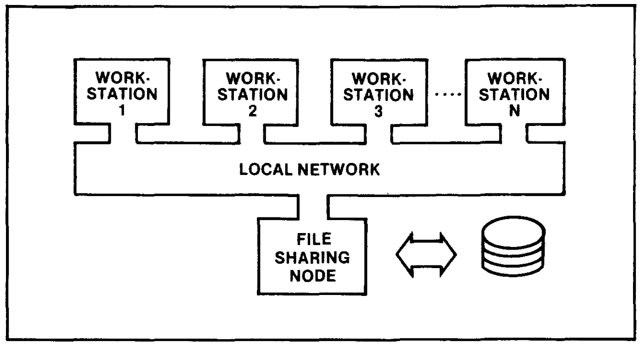


Figure 10. Block Diagram of Example System 1

workstation shown is an intelligent terminal having local data and program storage. The stations all use the File Sharing Node (FSN) for storage and retrieval of records in much the same way as the secretaries in an office would make use of a filing cabinet. The FSN maintains the files on a fixed disk device and responds to requests from the workstations for access to the data. The design to follow concentrates on the File Sharing Node.

System Requirements

Each intelligent terminal in the network has command processing software. When a file reference is made that cannot be satisfied by the local file system, a request is made to the File Sharing Node. This request consists of a log-on request followed by a string of I/O requests and ultimately a log-off request.

The number of intelligent terminals (workstations) hooked up to the FSN varies from installation to installation. Therefore, the FSN must be capable of handling many simultaneous requests and no assumptions can be made about the maximum number of workstations or requests that may need to be handled.

Each node in the network has a unique address. A packet is sent onto the network by one node and the address field is examined by all other nodes. If this field does not match the node's address the packet is ignored. If a match is found the packet is retrieved from the network.

Hardware Requirements

The three main hardware building blocks needed by this application are shown in Figure 11. The iSBC 86/12A Single Board Computer will communicate with the iSBC 544 Intelligent Communications Controller to establish and maintain communications with the network. The Intel 8085A on the iSBC 544 board will perform all of the address recognition, acknowledgements, packet retrieval and packet transmittal. The iSBC 206 Hard Disk Controller will be used to create, maintain and access the data files which are at the heart of this application.

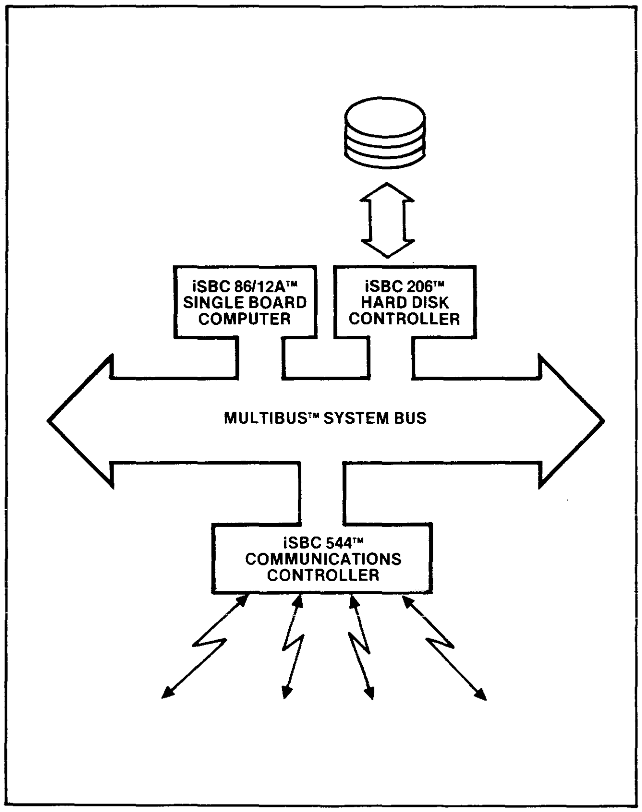


Figure 11. Hardware Block Diagram

System Design

The first step in the system design process is the breakdown of the system functions into one or several jobs. The reasons for doing this are system modularity and protection. With this type of design, each job can be designed separately, perhaps even by a different engineer or engineering team. The input and output requirements will be specified very tightly and the job will take on the appearance of a black box to other jobs in the system. If the job is enhanced or modified at a later date, the rest of the system can be left undisturbed providing that the input and output response remains the same.

The job object in the iRMX 86 operating system also affords a degree of software protection for the tasks and other objects contained within the job. Each job has a separate memory pool, a separate object directory and a separate identification to the I/O system.

The two primary groupings of functions in this application are those related to the network communications and those related to processing the file transaction request. A list of a possible split-up of system functions is shown in Figure 12.

COMMUNICATIONS JOB	FILE TRANSACTION JOB
• iSBC 544™ INPUT INTERRUPT SERVICE	• RETRIEVE INPUT REQUEST PACKETS FOR SERVICING
• iSBC 544™ OUTPUT INTERRUPT SERVICE	• DETERMINE WORKSTATION STATUS
• SERVICE OUTPUT REQUEST MAILBOX	• SERVICE TRANSACTION REQUESTS
• QUEUE PACKETS OF INPUT DATA AT INPUT MAILBOX	• PERFORM LOG-ON AND LOG-OFF FUNCTIONS
• ACKNOWLEDGEMENT GENERATION	• BUILD AND SEND RESPONSE MESSAGES

Figure 12. Function Split-up

The communication between the file transaction job and the communication job must fulfill two basic needs. The communication job will receive interrupts when packets addressed to the FSN are received. In order to remain attentive to new requests coming in, the communications job should have the capability to "spool" the requests off to the file transaction job. This buffering can be provided by using the mailbox object. Segments can be created to contain the packet request data and can then be sent to a mailbox where the file transaction job can receive and process them.

When the file transaction job must send a packet to a workstation, the requirement is seen for another queue of requests. Since the communications board can only put one packet at a time on the network, a mailbox should be provided to allow tasks in the file transaction job to send output request segments into the queue and then continue on (see Figure 13).

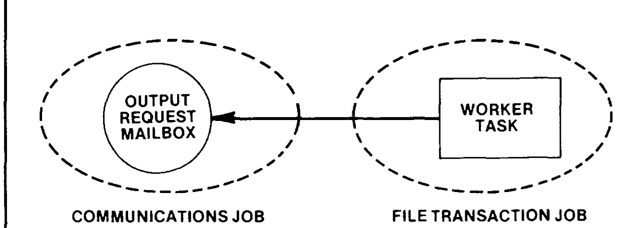


Figure 13. Output Mailbox Queue

Since tasks in both the file transaction job and the communications job must have access to these input and output mailboxes, some means must be set up to "broadcast" the identifier for these objects.

In the iRMX 86 system, each object has associated with it a 16-bit number called a token. Whenever an object is referenced in an operating system call, the token for the object is used. For example, assume that a segment must be sent to a mailbox. The segment and mailbox each have a token and these tokens are passed to the operating system as parameters in the *send$message* system call.

There are three major ways to get the token for an object. The first way is to create an object. Whenever the operating system is called to create a new object, the value returned from the procedure call is the token for the new object. The second way to receive a token is through the receive message system call where an object is received from the queue at a mailbox where it was sent by another task.

The third major mechanism for the receipt of a token is provided by the object directory concept. As mentioned previously, each job in the system has an object directory.

If a task in a job has the token for an object and wishes to let other tasks in other jobs have access to the object, the task can "catalog" the object in the object directory. The *catalog$object* system call takes the token for an object and an ASCII name as parameters and creates an entry in the object directory. If another task knows the ASCII name for an object, it can obtain the token by performing a *lookup$object* call.

The object directory mechanism will be used in this example to allow the communications job to "broadcast" the tokens for the input and output mailboxes. The jobs for this application are shown in Figure 14.

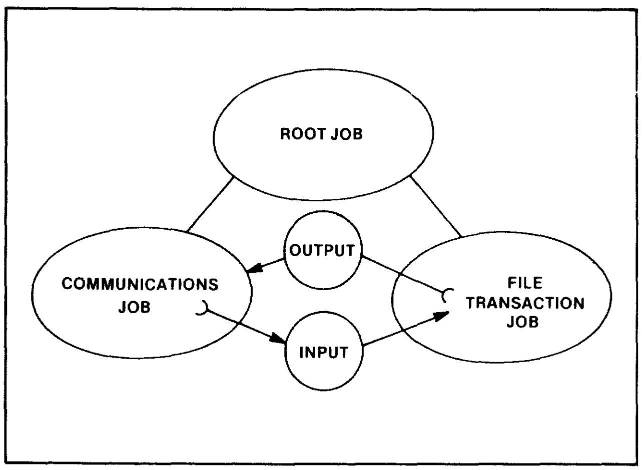


Figure 14. Job Structure

The next step of the design methodology calls for each job to be further divided into sub-functions. In this application note, only the file transaction job is studied.

In time sequence, the file transaction job will:

1) Retrieve input requests from the mailbox set up by the communication job.
2) Determine state of specified workstation (for example, is it logged on?).
3) Perform I/O operation or log-on or log-off.
4) Build and send response to the workstation.

Recall from the discussion of system requirements that the number of nearly simultaneous requests that may be received by the FSN is not known. For this reason, some mechanism must be provided to allow parallel processing of many requests. This should prove feasible since the performance of step 3 will involve many delays while waiting for the operating system to perform I/O operations.

One straightforward way to provide for parallel processing is to create a task for each workstation that logs on. In this manner, each I/O request will be handled by a unique task. Through the use of the iRMX 86 scheduler, maximum CPU utilization will be gained by allowing each task to individually compete for CPU time. These "worker" tasks fulfill function 3 and 4 for the file transaction job.

Function 1 and 2 can be fulfilled by a single task. This task will wait at the input mailbox set up by the communications job. When a packet is received that requests a log-on operation, the "listener" task will create a new "worker" task to handle the request. Figure 15 shows a picture of the design.

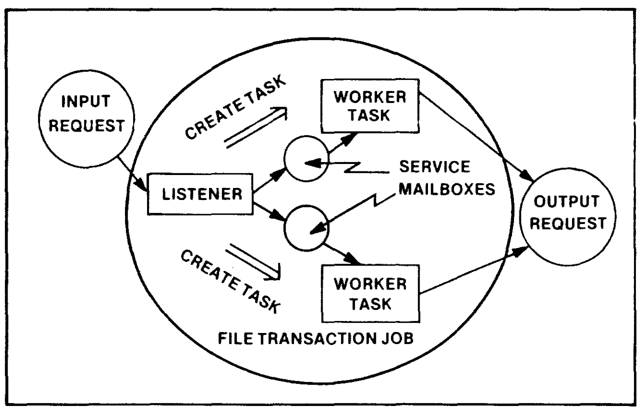


Figure 15. Diagram of Design of File Transaction Job

The string of transaction requests that follow will simply be demultiplexed by the listener task. The workstation ID will be searched for and, if found, the packet will be sent to the appropriate worker task. If a request comes in from a station that is not logged on, an error response is sent directly to the communications output mailbox for transmittal to the station that made the request.

If the request packet indicates that a station desires to log-off, the listener task will delete all local reference to the station and pass the packet along. The listener task cannot simply delete the worker since the worker may be in the process of servicing a previous I/O request. In general, it is never a good idea to arbitrarily delete another task. A better protocol is to pass along the message signaling the worker task to delete itself when convenient.

An investigation of the intertask communications needs highlights the requirement for passing data between tasks. The interjob communications protocol discussed earlier specified that the listener task will receive input request segments from the communications job via a mailbox.

Within these segments are fields containing the workstation ID and the command. Based upon these fields one of two things happens. If the command indicates that the station wishes to log on, a new worker task must be created to process the I/O requests that will follow.

The code executed by all worker tasks will be identical since they all perform identical functions. However, some unique pieces of information must be passed to a new worker task. This can be accomplished by having the worker task first wait at a "log on" mailbox. Here it will receive a segment from the listener task which contains the necessary information (see Figure 16).

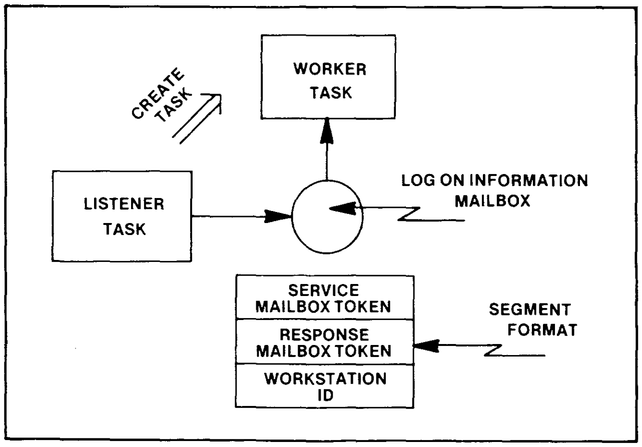


Figure 16. Communications Between Listener Task and a Newly Created Worker Task

After this initialization is complete, the workstation requests that are received by the listener task can be sent to the service mailbox associated with the workstation. The token for the service mailbox is one of the pieces of information contained in the log on segment.

The last communication path needed is predefined by the interjob communication protocol. When either the listener task or one of the worker tasks needs to transmit a packet to a workstation, a segment is sent to the output request mailbox of the communication job.

The final step in the design methodology is to write program code for the tasks in the system. This step is performed in the Code Examples section.

APPLICATION EXAMPLE 2

This example will deal with the design of a custom device driver for the iRMX 86 operating system. As shown in Figure 6, a device driver accepts high-level commands from the file drivers (such as read, write, seek, etc.) and transforms these commands into I/O port read and write commands in order to communicate with the device itself. By studying the construction of a driver for the iSBC 534 Serial Communication Expansion Board, a better understanding of the iRMX 86 I/O system will be gained along with an example of the use of nucleus facilities to construct a higher-level software function.

Overview of Device Driver Construction

Each I/O device consists of a controller and one or more units. A device as a whole is identified by a device number. Units are identified by unit number and device-unit number. The unit number identifies the unit within the device and the device-unit number identifies the unit among all the units on all of the devices.

A device driver must be provided for every device in the hardware configuration. That device driver must handle the I/O requests for all of the units on the device. Different devices can use different device drivers; or if they are the same kind of device, they can use the same device driver code.

At its highest level, a device driver consists of four procedures which are called directly by the I/O System. These procedures can be identified according to purpose, as follows:

Initialize I/O
Finish I/O
Queue I/O
Cancel I/O

When a user makes an I/O System call to manipulate a device, the I/O System ultimately calls one or more of these procedures, which operate in conjunction with an interrupt handler to coordinate the actual I/O transfers. This section provides a general description of each of these procedures, and the interrupt handler.

INITIALIZE I/O

This procedure creates all of the iRMX 86 objects needed by the remainder of the routines in the device driver. It typically creates an interrupt task and a segment to store data local to the device. It also performs device initialization, if any such is necessary. The I/O System calls this routine just prior to the first attach of a unit on the device (the first RQAPHYSICAL $ATTACH$DEVICE system call). The time sequence of calls to these procedures will be described a little later.

FINISH I/O

The I/O System calls this procedure after all units of the device have been detached (the last RQA PHYSICAL$DETACH$DEVICE system call). The *finish$IO* procedure performs any necessary final processing on the device and deletes all of the objects used by the device handler, including the interrupt task and the device-local data segment.

QUEUE I/O

This procedure places I/O requests on a queue, so that they can start when the appropriate unit becomes available. If the device is not busy, the *queue$IO* procedure starts the request.

CANCEL I/O

This procedure cancels a previously queued I/O request. Unless the device is such that a request can take an indefinite amount of time to process (such as keyboard input from a terminal), this procedure can perform a null operation.

INTERRUPT HANDLERS AND INTERRUPT TASKS

After a device finishes processing an I/O request, it sends an interrupt to the iRMX 86 system. As a consequence, the interrupt handler for the device is called. This handler either processes the interrupt itself or signals an interrupt task to process the interrupt. Since an interrupt handler is limited in the types of system calls that it can make, an interrupt task usually services the interrupt. The interrupt task feeds the results of the interrupt back to the application software (data from a read operation, status from other types of operations). It then gets the next I/O request from the queue and starts the device processing this request. This cycle continues until the device is detached. The interrupt task is normally created by the initialize I/O procedure.

The I/O System calls each one of the four device driver procedures in response to specific conditions. Three of the procedures are called under the following conditions.

1) In order to start I/O processing, the user must make an I/O request. This can be done by making a variety of system calls. However, the first I/O request to each device-unit must be the RQAPHYSICAL$ ATTACH$DEVICE system call.
2) The I/O System checks to see if the I/O request results from the first RQAPHYSICAL$ATTACH $DEVICE system call for the device (the first unit attached in a device). If it is, the I/O System realizes that the device has not been initialized and calls the initialize I/O procedure first, before queueing the request.
3) Whether or not the I/O System called the initialize I/O procedure, it calls the queue I/O procedure to queue the request for execution.
4) The I/O System checks to see if the request just queued resulted from the last RQAPHYSICAL$ DETACH$DEVICE system call for the device (detaching the last unit of a device). If so, the I/O System calls the finish I/O procedure to do any final processing on the device and clean up objects used by the device driver routines.

The I/O System calls the fourth device driver procedure, the cancel I/O procedure, under the following conditions:

- If the user makes an RQAPHYSICAL$ DETACH$DEVICE system call specifying the hard detach option, in order to forcibly detach the connection objects associated with a device-unit.
- If a job containing the task which made the request is deleted.

Each procedure will now be discussed in more detail. The initialize $IO procedure takes three parameters:

init$io: Procedure (duib$p, ret$data$t$p, status $p)

The *duib$p* parameter contains a pointer to a device unit information block (DUIB) which is the configuration table for the device in question. The structure of this table is shown in Figure 17. Note that this table contains pointers to device and unit information tables which can contain hardware specific information (such as I/O base addresses, interrupt levels etc.).

The second parameter is a pointer to a word which can be assigned the value of a token for an iRMX 86 object. Quite often this object would be a segment which could be created by the *init$io* procedure and filled with information needed by the other procedures in the driver. The token for this segment will be provided to the other procedures when they are called.

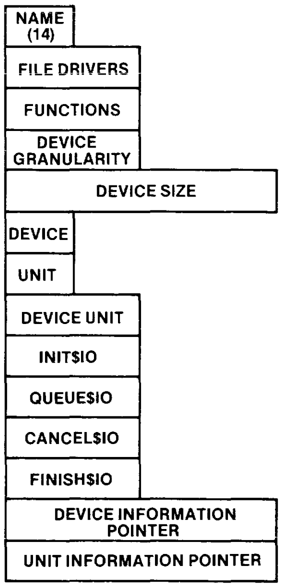


Figure 17. DUIB Format

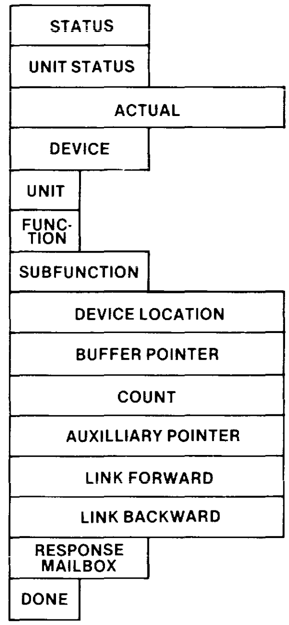


Figure 18. I/O Request Segment Format

The final argument in the call is a pointer to a status word. This word should be assigned by the *init$io* procedure before a RETURN is executed. If a non-zero value is returned indicating an error condition, the I/O System assumes that *init$io* has deleted any objects created before the error was encountered.

The *finish$io* procedure is called by the I/O System just after the last *detach$device* call is made on the device. This procedure is expected to delete any objects created by the *init$io* procedure and shut down the connected device.

finish$io: Procedure (duib$p, ret$data$t);

Once again, the first parameter to the call is a pointer to a DUIB. The second parameter is the token returned by the *init$io* procedure.

The *queue$io* procedure is called to initiate an I/O request.

queue$io: Procedure (IORS$t,duibp, retdata$t)

The specifics of the request are indicated in an I/O request segment (IORS) which is provided by the first parameter. The format of this segment is shown in Figure 18. The most important fields here are the count, function, status and buffer pointer fields which tell the *queue$io* procedure what needs to be done. The second and third parameters are once again the pointer to the DUIB and the token for the object created by the *init$io* procedure.

The final device driver procedure is *cancel$io*. This procedure is called by the I/O System to cancel a previous I/O request. If the device is of such a nature that a request will complete in a bounded amount of time, this procedure can be a null procedure. The parameters to the call are identical to those for the *queue$io* call.

In addition to the elementary support discussed here, the I/O System provides extra support to the designer of a device driver if some simplifying assumptions about the device can be made. Also, if the device supports random access (such as disks, magnetic bubbles, etc.), support routines can be used to simplify the process of blocking and deblocking I/O requests. More detail on the process of writing I/O drivers can be found in the manual titled "A Guide to Writing Device Drivers for the iRMX 86 I/O System."

Design of an iSBC 534™ Device Driver

The following section will discuss an example device driver for the iRMX 86 Operating System. The driver will be for the iSBC 534 board which contains four 8251 USART devices; therefore, there is one device and four units on the device.

The *init$io* procedure for this driver initializes the hardware, creates an interrupt task, creates other necessary objects and creates a segment to contain the relevant information.

The structure of the *queue$io* procedure is more complex. When calls are made to this procedure to perform data reading and writing, the actual operation could be somewhat lengthy (especially an input operation). Since the *queue$io* procedure is called by the I/O system, it is not efficient to perform the entire operation before control is returned to the I/O system.

A more efficient mechanism is to have an independent task take the request and fulfill it while the *queue$io* procedure returns to the I/O system allowing other operations to be started in parallel. This leads to the structure diagrammed in Figure 19. When a read or a write request is received, the I/O request segment is sent to the request mailbox where it is received by an I/O handler task. When the request is complete, the I/O task sends the segment to the response mailbox indicated in the segment.

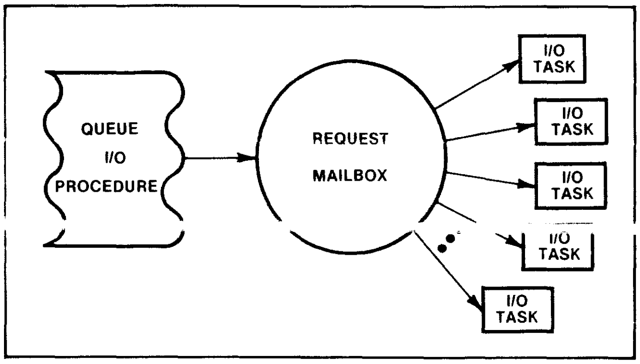


Figure 19. Queue$io Procedure Interface to I/O Tasks

The remaining design of the device driver is concerned with interrupt handling. The iSBC 534 board contains four 8251 USART devices. Each device supplies two interrupts; one indicating that the receiver has a data character available and the other indicating that the transmitter is ready to accept a character. Each of these interrupts (8 in all) are connected to one of the 8259 Interrupt Controllers on the board. The software on the iSBC 86/12A board must read a register in the 8259 controller to determine which of the eight sources caused the current interrupt. This information must then be fed to the I/O task which may be waiting for the event.

One way to meet this requirement uses an interrupt task for the iSBC 534 board. The task receives the interrupt, determines which device caused it, and sends a unit to a semaphore to indicate the occurrence of the event. Thus, when an I/O task wishes to be informed of a receiver or transmitter interrupt, it simply tries to receive a unit from the appropriate semaphore. If a unit is available, the receiver has a character or the transmitter is ready. If the unit is not available, the USART is not ready and the task will be put in the asleep state until the interrupt occurs and the unit is sent.

CODE EXAMPLES

This chaper will present and analyze some sample code for the iRMX 86 applications presented in Chapter 4. The code listings are contained in Appendix A and the individual modules are numbered sequentially. When a specific line or sequence of lines of code must be pointed out in the text, a two part number is used where the first part is the module number and the second is the compiler-assigned line number. For example, 3.27 would be used to point out line 27 in module 3.

A standard set of suffixes to labels will be followed in the code to follow. A PL/M-86 WORD variable that will contain the token for an iRMX 86 object will have the suffix "*$t*." A POINTER variable will be followed by "*$p*" and a structure used to overlay a POINTER allowing access to the base and offset will be followed by "*po*."

Listener Task

The first module to be studied contains the code for the listener task. The various include statements bring in literal declarations and external procedure declarations. The file NUCPRM.EXT is on the iRMX 86 diskette and contains the external declarations for all iRMX 86 nucleus system calls.

Line 1.323 contains all of the declarations for the module. The literal *req$segment$struc* is used to access the fields of a segment returned from the communications job. The format of a request packet from a workstation is shown in Figure 20. The literal *node* is used to access the information in a segment used as a workstation descriptor in a list maintained by the listener task. The format of a *node* in this list is shown in Figure 21. The structure at the end of the declaration statement is used to individually access the two halves of a 32-bit PL/M-86 POINTER.

Note in line 1.330 that the task is coded as a public procedure having no parameters. A main procedure should never be used for a task's code since the preamble for a main procedure sets the stack pointer.

The mailbox to be used for sending a newly created worker task an information segment is called the *logoninfo$mbox*. This mailbox is created in line 1.331. Lines 1.332-1.334 perform the operation of finding the tokens for the communication job's input and output request mailboxes in the object directory of

FUNCTION
COUNT
ACTUAL
EXCEPTION CODE
WORKSTATION ID
COMMAND
SHARE
MODE
STATUS
FILE NAME (64)
BUFFER (128)

Figure 20. Request Packet Format

LINK FORWARD
LINK BACKWARD
WORKSTATION ID
SERVICE MAILBOX
WORKER TASK TOKEN
RESPONSE MAILBOX

Figure 21. Workstation Descriptor Format

the root job. The token for the root job is obtained by the system call in 1.332.

Whenever a workstation logs on, various actions are taken by the listener task. One of these actions involves adding a descriptor for the workstation to a list so that the state of the workstation can be maintained by the listener task. The list structure is shown in Figure 22. Statements 1.336-1.340 create the root of this list and initialize the list to an empty state.

Line 1.340 marks the beginning of an infinite loop. Most often a task executes a procedure which performs some initialization and then enters an endless loop performing the necessary processing. The literal "*forever*" translates into "*while 1.*"

A packet is received from the input mailbox by the call in line 1.341. The command field of the message is checked in line 1.343. If the command indicates that a log on request is being made, lines 1.345-1.356 are executed. A log on information segment is created in line 1.345. A mailbox is created to handle further request packets and another is created to be used by the worker task as a response mailbox. The worker

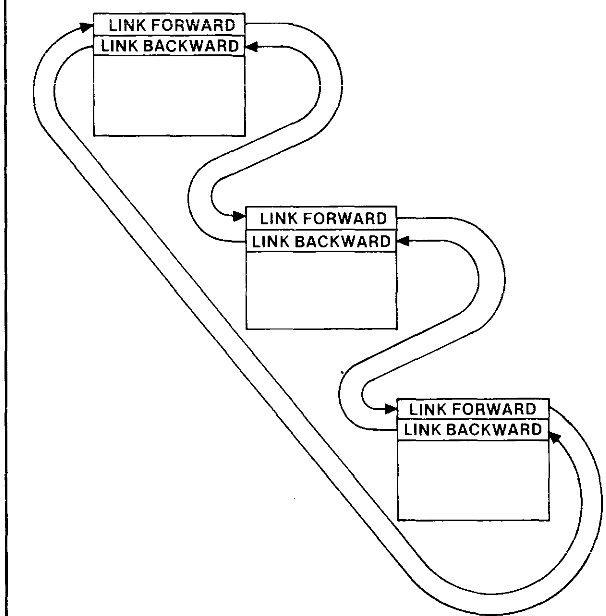


Figure 22. Workstation Descriptor List Structure

task that will handle I/O requests from this workstation is created in line 1.351. Note the use of the structure *datasegp$o*, which is declared at the same address as the POINTER *datasegp*. The POINTER is initialized to equal the beginning of the data segment of the worker task module (1.323) and then the base portion is used as a parameter in the create task call.

Once the worker task is created, it will wait at the *logoninfo$mbox* for a segment giving it its initialization information. The segment is sent in line 1.352 and received back as an acknowledgement in line 1.353. At this point, the segment is inserted on the list of active workstation descriptors by the call in line 1.354. Finally the request packet itself is sent to the worker task via the service mailbox for the new worker.

If a log off request is received, lines 1.358 to 1.366 are executed. First, the active workstation list is searched for the ID of the requesting station. If the station is not found to be logged on, the status field is set and the request segment is sent to the workstation through the communications job. If the station is logged on, the descriptor is deleted from the list, the packet is sent along to the worker task, and the descriptor is deleted.

If the command is anything but log on or log off, lines 1.368-1.376 are executed. Once again the station ID is checked to see if it is logged on. If not, an error message is returned. If the station is logged on, the request packet is sent along to the worker task.

WORKER TASK

The code for the worker task is shown in module 2. Upon creation of a new worker task, a segment is received at the *logoninfo$mbox* (2.242). The data in this segment is copied into local variables and the segment is returned (2.247).

The initialization task for this job has already created a user object for this job and has also set up a prefix which points to the root directory for the disk device. These tokens have been cataloged in the root object directory. The worker task obtains these tokens through the sequence of calls 2.248-2.250.

The worker task now enters an infinite loop servicing the workstation it is assigned to. The specific action to be taken by the worker is determined by inspecting the *cmd* field of the request message.

If the command is a log on, the code from 2.256-2.263 is executed. The file name specified in the request segment is attached and opened and thereby made ready for subsequent I/O requests. After this, an acknowledgement is sent back to the workstation via the *output$request$mailbox* (2.263).

If a log off command is received, the file is closed and detached, the service and response mailboxes are deleted, a response is sent to the workstation and the worker task is deleted.

If the command is either a read or write command, the operation is performed by calling the I/O system. When the response is received, an acknowledgement is sent to the workstation. Note that the task would normally perform more processing. In this example its duties have been kept simple.

POINTERIZE PROCEDURE

The ASM-86 code for the *pointerize* support routine is shown in Module 3. The token for a segment is the base portion of a 32-bit POINTER to the memory. In order to access the data in a segment, this 16-bit token must be loaded into the base part of a POINTER while the offset portion of the POINTER is set to zero. The base and offset values are returned in the ES and BX regusters as specified by the PL/M-86 calling conventions. This is the operation performed by the *pointerize* routine.

LIST MANIPULATION ROUTINES

Lines 4.1-4.47 provide three subroutines used by the tasks in this system to manipulate the list of workstation descriptors. *Insertonlist* (4.15-4.26) inserts the indicated node at the head of the list whose root is given as the first parameter. *Delete$from$list* (4.27-4.35) unlinks the indicated node from the list it belongs to. *Search$list* (4.36-4.46) searches a list for the workstation ID given. If the ID is not found, a zero is returned. If the ID is found, the token for that node is returned.

At this point an overview of the configuration process is needed. A more detailed coverage of the process of configuring an iRMX 86 system is provided in the manual entitled "iRMX 86 Configuration Guide for ISIS-II Users."

For each iRMX 86 application, the following steps must be performed.

1) Program code for each task in the system must be written and compiled or assembled.
2) A memory map for the software must be drawn up.
3) The system software must be linked and located.
4) The application jobs must be linked and located.
5) Tables of configuration data must be drawn up.
6) The tabular data from step 5 must be formatted into a memory data block through the use of a set of ASM-86 macros provided with the iRMX 86 product.
7) The root job must be linked and located.

The code executed by the root task is part of the iRMX 86 system code. This task is initially the only task in the system. The root task will access the data block constructed by the ASM-86 macros and will create the user jobs specified by the macros. The data for the configuration process for example 1 is shown in Appendix B.

The first page diagrams the memory map for the example. The iterative link and locate process to put these pieces together begins on the second page. The LINK86 and LOC86 commands shown place the iRMX/86 nucleus into memory. The LOCATE map indicates that the last memory location used by the nucleus was 077DFH. Therefore, the next contiguous piece, the I/O system, is located at 077EOH.

This process is repeated for the remainder of the jobs in the system.

When the link and locate process is complete, the information for the ASM-86 macros must be brought together. Worksheets are provided in the iRMX 86 configuration guide to simplify this process.

The filled-out worksheets for the macros are shown in the appendix. A configuration file is constructed using the editor and the worksheet information is entered into this file. When the file is complete, the configuration table is created by assembling the file CTABLE. A86. This file accesses the configuration file built earlier.

The configuration tables are then linked and located together with the code for the root task and the system generation process is complete.

EXAMPLE 2

INIT$IO AND FINISH$IO

The *startandfinish* module (5.1-5.371) contains the code for the *init534io* and *finish534io* procedures. The *init534io* procedure creates a segment, shown in Figure 23, which is used to hold the various pieces of information needed by the other driver procedures (5.323). The discussion of this procedure in Chapter 4 pointed out that any errors encountered in the initialization are indicated by the non-zero status and that the assumption is made that any partial creations must be cleaned up by the *init$io* procedure. This assumption is carried out by the check at line 5.324 (and the others at 5.331, 5,335, 5.339 and 5.342).

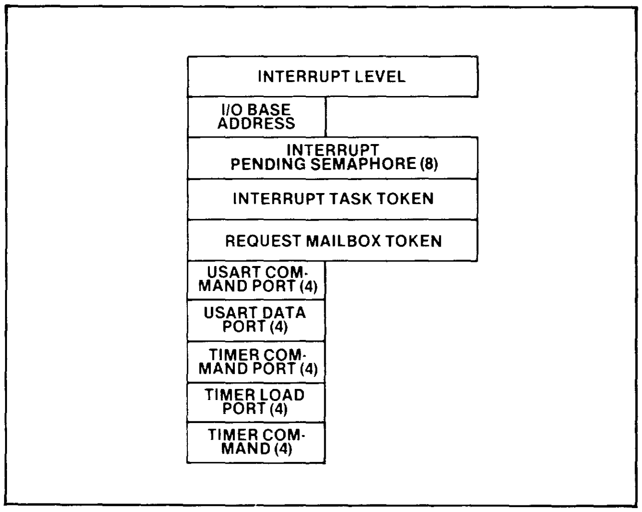


Figure 23. init534io Segment Format

The device information contained in the device unit information block for this device is retrieved in line 5.328-5.329. A mailbox to be used for sending I/O request segments to the I/O handler tasks is created in line 5.330. The interrupt task for this job is created by the call in line 5.337.

The *do loop* starting at line 5.340 is executed to create eight semaphores to be used by the interrupt task to indicate the occurrence of an interrupt. Note that the initial value of the semaphore is zero (no interrupt pending) and the maximum value is one. Since the nature of the 8251 USART device does not support buffering, when a new character overruns the previous character before the interrupt can be serviced, the data is lost. Therefore, there is no need to indicate the occurrence of multiple interrupts pending on the same device.

The call at line 5.345 initializes the programmable devices on the iSBC 534 board. If execution has proceeded to line 5.346, the initialization is complete and a zero status is returned. If an error occurred at any point, the code in lines 5.348-5.356 will clean up the partial initialization.

The *finish534io* procedure (5.358-5.370) undoes the work of the *init534io* procedure. The segment, mailbox, interrupt task and semaphores are all deleted.

The *queue534io* procedure is shown in lines 6.1-6.382. In line 6.322 the function field of the I/O request segment is checked to see if it is within bounds. If it is not, a bad status code is returned. If the function is valid, a *do case* block is executed using the function code as the index.

If a read request is encountered, the auxiliary pointer is set to point to the *ret$data* structure (initialized earlier by the *init534io* procedure). In line 6.327 the segment is then sent to the request mailbox to be received and processed by an I/O processor task. In lines 6.330-6.334 the same action is taken with write requests.

Since this driver does not support seeking and special functions, the code for these two cases simply returns an error condition.

In the case of an *attach$device* call, the code in lines 6.341-6.361 is executed. First, two I/O processing tasks are created. All of these tasks execute identical code and each task is capable of servicing a read or a write request on any 8251. Two tasks are created for each 8251 device so that the peak load can always be handled (that is, all receivers and transmitters going simultaneously). Lines 6.346-6.357 perform the initialization of the 8251 USART and the baud rate generators for this channel. The calls in line 6.358 and 6.359 accept an interrupt and a character from the semaphore associated with the receiver just initialized. This is done to clear off an interrupt generated by the 8251 whenever it is initialized.

In the case of a *detach$device* call, the code in lines 6.363-6.367 sends the I/O request segment to the request mailbox twice. This is done to signal two of the I/O handler tasks to delete themselves. As discussed earlier in the *attach$device* section, none of the I/O handler tasks is any different from any of the others. There are two created for each 8251 device which is attached. The protocol set up for their deletion is shown here. When an I/O handler task receives a segment of type *"detach$device"* it will send the segment to the response mailbox and then delete itself.

The code for the open and close requests is the same. Both cases are supported but are NOPs since no specific action needs to be taken by the driver.

Lines 6.379-6.382 contain the code for the *cancel534io* procedure. As discussed earlier, this procedure is simply a placeholder and serves no particular purpose.

INTERRUPT CONTROL MODULE

The interrupt handler and interrupt task are shown in lines 7.1-7.329. The interrupt task is the first piece executed. It is created by the *init534io* procedure. It calls *RQsetinterrupt* in line 7.325 to indicate to the iRMX 86 nucleus that it is an interrupt task.

Once the initialization is complete, the task enters an infinite loop. The call to *RQ$wait$interrupt* in line 7.322 causes the task to be put into the asleep state until an interrupt occurrence is signaled. The task will be returned to the READY state when an interrupt occurs, the interrupt handler is started, and the call to *RQ$signal$interrupt* is executed at line 7.312. The current interrupt level is then determined by polling the 8259 chip on the iSBC 534 board. Using the encoded level number, a unit is sent to the appropriate semaphore to indicate that an interrupt is pending.

I/O TASK

The final procedure that makes up this driver contains the code for the tasks that perform the actual I/O to the iSBC 534 board. The loop executed by each task starts by waiting at the request mailbox for an I/O request segment. When the segment is sent by the *queue534IO* procedure, its function code is checked (line 8.327, 8.332, 8.340). If the function is *f$detach$device*, the task sends the segment to the response mailbox and then deletes itself.

If the request was for a read, the task fills the buffer with input data. The call at line 8.334 waits for a unit at the semaphore which will indicate a receiver ready on the input line. When the unit is sent by the interrupt task, the character is read in, the pointers and counts are updated, and another unit is requested.

The last request which is recognized by the I/O task is for a write operation. The code for this request is almost identical to the code for a read request. An interrupt from the transmitter is awaited, a character is output and the counts are updated in lines 8.341-8.346.

Once the request is fulfilled, the message is sent to the response exchange in line 8.350.

The configuration of this system is studied next. The code for the iSBC 534 driver is linked directly to the rest of the I/O system libraries. The entry point addresses for the *queue534io, cancel534io, init534io*, and *finish534io* procedures are declared in the IOCNFG.A86 file on the I/O system disk. This file also contains the device unit information block (DUIB) structures for the four units on the iSBC 534 board. The unique information for the iSBC 534 device and the units on the device is contained in the device and unit information tables. Pointers to these tables are contained in the DUIB structures. All of this information is shown in Figure 24.

The submit file used to build an I/O system using the iSBC 534 driver is shown in Figure 25. The file DRV534.LIB contains the object files generated by PL/M-86 and ASM-86 from the source code shown in modules 5-9.

SUMMARY

This application note is an introduction to the iRMX 86 Operating System. The requirements of operating systems were studied along with traditional solutions. Following this, the iRMX 86 Operating System was introduced and its correlation with the requirements was studied.

Later in the application note, the topic of system design was covered. Example solutions were studied to solidify a methodology for solving application problems and then the code for these solutions was discussed to gain insight into the details of implementing iRMX 86 systems.

The purpose of a configurable, real-time, multipurpose operating system is to provide a solid foundation for application software. The iRMX 86 system provides this foundation, giving the software engineer a means to quickly and easily implement new designs. In addition, the iRMX 86 architecture is the bridge to future technology providing the designer with an upgrade path to future hardware and software products.

```
        extrn   init534io: near
        extrn   queue534io: near
        extrn   cancel534io: near
        extrn   finish534io: near

        ;
        ; Duib(8): iSBC 534, unit 1
        ;
        define_duib     <
        &               'i534.1',               ; name (14)

        &               03H,                    ; supp$opt
        &               00033H,                 ; file drivers
        &               0,                      ; granularity
        &               0,0,                    ; device size

        &               3,                      ; device
        &               1,                      ; unit
        &               6,                      ; device_unit
        &               init534io,              ; init$io
        &               finish534io,            ; finish$io
        &               queue534io,             ; queue$io
        &               cancel534io,            ; cancel$io
        &               dev_534_info,           ; device_info
        &               unit_534_1_info         ; unit_info
        &>
        ; 534 device info
        ;
        dev_534_info    dw      48H             ; level
                        db      61              ; priority
                        db      040H            ; base address
        ;
        ; unit info: iSBC 534.0
        ;
        unit_534_0_info db      4EH             ; usart$cmd
                        dw      8               ; baud rate
        ;
        ; unit info: iSBC 534.1
        ;
        unit_534_1_info db      4EH             ; usart$cmd
                        dw      8               ; baud rate
        ;
        ; unit info: iSBC 534.2
        ;
        unit_534_2_info db      4EH             ; usart$cmd
                        dw      8               ; baud rate
        ;
        ; unit info: iSBC 534.3
        ;
        unit_534_3_info db      4EH             ; usart$cmd
                        dw      8               ; baud rate
```

Figure 24. IOCNFG A86 File Entries for iSBC 534™ Driver

```
; ios(date,origin)
;       Sample I/O System .csd file to link and locate an I/O System.
;
; This file links an I/O System with the timer included.
;
; This .csd file assumes the I/O System configuration module is
; iocnfg.a86 (found on the release diskette).
;
; The origin parameter sets the low address of the I/O System;
; all the segments are contiguous in memory.
;
asm86 :f1:iocnfg.a86 date(%0) print(:f5:iocnfg.lst)
link86 &
    :f1:ios.lib(ioinit), &
    :f1:iocnfg.obj, &
    :f1:ios.lib,    &
    :f1:drv534.lib, &
    :f4:rpifc.lib   &
 to :f1:ios.lnk map print(:f1:ios.mp1)
loc86 :f1:ios.lnk to :f1:ios map sc(3) print(:f1:ios.mp2) &
      oc(noli,nopl,nocm,nosb) &
      order(classes(code,data,stack,memory)) &
      addresses(classes(code(%1))) &
      segsize(stack(0))
```

Figure 25. Submit File for Generating an I/O System with the iSBC 534™ Driver

APPENDIX A
Code Listings

Module 1

```
ISIS-II PL/M-86 V2.0 COMPILATION OF MODULE LISTENERMODULE
OBJECT MODULE PLACED IN :F1:listen.OBJ
COMPILER INVOKED BY:  plm86 :F1:listen.plm PRINT(:F1:LISTEN.LST)
DEBUG COMPACT OPTIMIZE(3) ROM DATE(5/28/80

  1           listener$module:
                  do;

              /************************************************************************

                  LISTENER: TASK.

                  This task creates segments, sends them to the input service
                  job to be filled with input packet info. Upon response
                  the info is checked to see what action needs to be taken.
                  If a log$on request is sensed, a worker task, service
                  mailbox, and response mailbox are created and the packet is
                  sent along to the worker task. If a log$off is sensed all
                  local reference to the workstation is deleted and the packet
                  is sent along to tell the worker to delete himself. If an
                  I/O request is sensed the station ID is checked to make
                  sure it is logged on. If it is, the packet is sent along to
                  the worker. If it isn't an error packet is sent back to the
                  requesting workstation.

              ************************************************************************/

              $include(:f2:common.lit)
         =    $SAVE NOLIST
              $include(:f1:node.lit)
         =    /* literal declaration of node descriptor for list utilities */
         =
 11   1  =        declare
         =            node literally 'structure(
         =                link$f word,
         =                link$b word,
         =                work$station$ID word,
         =                service$mbox$t word,
         =                worker$task$t word,
         =                resp$mbox$t word)';
              $include(:f1:lstutl.ext)
         =    /* external declarations for list manipulation utilities */
         =
         =    $save nolist
              $include(:f1:pointr.ext)
         =    /* external declaration of pointerize procedure */
         =    $save nolist
              $include(:f1:rqpckt.lit)
         =    /* literal declaration for request packet structure */
         =
         =
 24   1  =        declare req$segment$struc literally 'structure(
         =            funct word,
         =            count word,
         =            actual word,
         =            ex$val word,
         =            work$station$ID word,
         =            cmd word,
         =            share word,
         =            mode word,
         =            status word,
         =            file$name (64) byte,
         =            buf (128) byte)';
              $include(:f2:nucprm.ext)
         =    $SAVE NOLIST

321   1       worker$task: procedure external;
322   2       end worker$task;
```

Module 1, continued

```
323    1          declare
                      begin$listener$task$data byte public,
                      begin$worker$task$data byte external,
                      log$on$info$mbox$t token public,
                      ex$val word,
                      log$on$mbox$name (7) byte data(6,'LOG$ON'),
                      packet$size literally '132',
                      f$read literally '5',
                      f$write literally '6',
                      log$on literally '0',
                      log$off literally '1',
                      not$logged$on literally '1',
                      (root$job$t,input$request$mbox$t) token,
                      (output$request$mbox$t,resp$mbox$t) token,
                      (work$station$list$root$t,req$segment$t) token,
                      (log$on$info$seg$t,dummy$t,ws$desc$t) token,
                      (req$segment$p,work$station$list$root$p) pointer,
                      (log$on$info$seg$p,data$seg$p,ws$desc$p) pointer,
                      (req$segment based req$segment$p) req$segment$struc,
                      (work$station$list$root based work$station$list$root$p) node,
                      (log$on$info$seg based log$on$info$seg$p) node,
                      data$seg$p$o structure(offset word, base word) at(@data$seg$p),
                      (ws$desc based ws$desc$p) node;

324    1      return$error$to$WS: procedure;

325    2          req$segment.funct=f$write;
326    2          req$segment.status=not$logged$on;
327    2          call rq$send$message(output$request$mbox$t,req$segment$t,0,@ex$val);
328    2          return;
329    2      end;

330    1      Listener: procedure public; /* task */

331    2          log$on$info$mbox$t=rq$create$mailbox(0,@ex$val);
332    2          root$job$t=rq$get$task$tokens(3,@ex$val);
333    2          input$request$mbox$t=rq$lookup$object(
                      /* job */          root$job$t,
                      /* name */         @(9,'INPUT$REQ'),
                      /* time limit */     0FFFFH,
                      /* status ptr */     @ex$val);

334    2          output$request$mbox$t=rq$lookup$object(
                      /* job */          root$job$t,
                      /* name */         @(10,'OUTPUT$REQ'),
                      /* time limit */     0FFFFH,
                      /* status ptr */     @ex$val);

335    2          resp$mbox$t=rq$create$mailbox(0,@ex$val);
336    2          work$station$list$root$t=rq$create$segment(16,@ex$val);
337    2          work$station$list$root$p=pointerize(work$station$list$root$t);
338    2          work$station$list$root.link$f,
                  work$station$list$root.link$b=work$station$list$root$t;
339    2          work$station$list$root.workstation$ID=0;

340    2          do forever;

341    3              req$segment$t = rq$receive$message(
                          /* mbox token */    input$request$mbox$t,
                          /* time limit */    0FFFFH,
                          /* response ptr */  @dummy$t,
                          /* status ptr */    @ex$val);
342    3              req$segment$p=pointerize(req$segment$t);

343    3              if req$segment.cmd= log$on then
344    3                  do;
```

Module 1, continued

```
345   4                    log$on$info$seg$t=rq$create$segment(
                               /* size */  16,
                               /* status ptr*/ @ex$val);
346   4                    log$on$info$seg$p=pointerize(
                               log$on$info$seg$t);
347   4                    log$on$info$seg.service$mbox$t=
                               rq$create$mailbox(0,@ex$val);
348   4                    log$on$info$seg.resp$mbox$t=
                               rq$create$mailbox(0,@ex$val);
349   4                    log$on$info$seg.work$station$ID=
                               req$segment.work$station$ID;
350   4                    data$seg$p=@begin$worker$task$data;
351   4                    log$on$info$seg.worker$task$t=
                           rq$create$task(
                           /* priority */      200,
                           /* start addr */    @worker$task,
                           /* data seg ptr */  data$seg$p$o.base,
                           /* stack pointer */ 0,
                           /* stack size */    500,
                           /* task flags */    0,
                           /* status ptr */    @ex$val);

352   4                    call rq$send$message(
                           /* mbox token */    log$on$info$mbox$t,
                           /* object token */  log$on$info$seg$t,
                           /* response token */    resp$mbox$t,
                           /* status ptr */    @ex$val);

353   4                    log$on$info$seg$t=rq$receive$message(
                           /* mailbox token */ resp$mbox$t,
                           /* time limit */    0FFFFH,
                           /* response token */    @dummy$t,
                           /* status ptr */    @ex$val);

354   4                    call insert$on$list(work$station$list$root$t,
                               log$on$info$seg$t);
355   4                    call rq$send$message(
                           /* mbox tok */  log$on$info$seg.service$mbox$t,
                           /* obj tok */   req$segment$t,
                           /* response */  0,
                           /* status */    @ex$val);

356   4                end;

357   3            else if req$segment.cmd = log$off then
358   3                do;
359   4                    ws$desc$t=search$list(work$station$list$root$t,
                               req$segment.work$station$ID);
360   4                    if ws$desc$t = 0 then
361   4                        call return$error$to$WS;
                           else
362   4                        do;
363   5                            ws$descp=pointerize(ws$desc$t);
364   5                            call delete$from$list(
                                       ws$desc$t);
365   5                            call rq$send$message(
                                       ws$desc.service$mbox$t,
                                       req$segment$t,
                                       0,
                                       @ex$val);
366   5                        end;

367   4                end;

               else
368   3                do;
369   4                    ws$desc$t=search$list(work$station$list$root$t,
                               req$segment.work$station$ID);
```

Module 1, continued

```
370   4                   if ws$desc$t=0 then
371   4                       call return$error$to$WS;
                          else
372   4                       do;
373   5                           ws$descp=pointerize(ws$desc$t);
374   5                           call rq$send$message(
                                      ws$desc.service$mbox$t,
                                      req$segment$t,
                                      0,
                                      @ex$val);
375   5                       end;
376   4               end;
377   3           call rq$delete$segment(req$segment$t,@ex$val);
378   3           end; /* of do forever */

379   2       end; /* of listener task */

380   1   end listener$module;


MODULE INFORMATION:

          CODE AREA SIZE     = 0281H     641D
          CONSTANT AREA SIZE = 0000H       0D
          VARIABLE AREA SIZE = 002BH      43D
          MAXIMUM STACK SIZE = 0018H      24D
          694 LINES READ
          0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 2

```
ISIS-II PL/M-86 V2.0 COMPILATION OF MODULE WORKERTASK
OBJECT MODULE PLACED IN :F1:worker.OBJ
COMPILER INVOKED BY:  plm86 :F1:worker.plm PRINT(:F1:WORKER.LST)
DEBUG COMPACT OPTIMIZE(3) ROM DATE(5/28/80)

  1          worker$task:
                 do;

             /***********************************************************************

                 WORKER$TASK: TASK.

                 This module contains the code executed by the worker tasks.
                 When started, the task goes to a mailbox to receive a segment
                 containing initialization information. Using this information
                 the task services a service mailbox performing any I/O functions
                 requested of it. When a log$off request comes in the worker
                 task closes and detaches the file and deletes itself.

             ***********************************************************************/

             $include(:f1:nucprm.ext)
           = $SAVE NOLIST
             $include(:f1:iosys.ext)
           = $save nolist
             $include(:f1:node.lit)
           = /* literal declaration of node descriptor for list utilities */
           = $save nolist
             $include(:f2:common.lit)
           = $SAVE NOLIST
             $include(:f1:pointr.ext)
           = /* external declaration of pointerize procedure */
           = $save nolist
             $include(:f1:rqpckt.lit)
           = /* literal declaration for request packet structure */
           =
           = $save nolist

239   1          declare
                     read literally '1',
                     write literally '5',
                     log$on literally '2',
                     log$off literally '3',
                     (log$on$info$mbox$t,output$request$mbox$t) token external;

240   1      worker$task: procedure reentrant public;

241   2          declare
                     (log$on$info$seg$t,log$on$resp$mbox$t,resp$mbox$t,
                     root$job$t,user$object$t,prefix$t,iors$t,
                     service$mbox$t,conn$t,req$seg$t) token,
                     (log$on$info$p,req$seg$p) pointer,
                     (req$seg based req$seg$p) req$segment$struc,
                     (log$on$info based log$on$info$p) node,
                     (dummy$t,ex$val,work$station$ID) word;


242   2          log$on$info$seg$t=rq$receive$message(
                 /* mbox token */    log$on$info$mbox$t,
                 /* time limit */    0FFFFH,
                 /* response ptr */  @log$on$resp$mbox$t,
                 /* status ptr */    @ex$val);

243   2          log$on$info$p=pointerize(log$on$info$seg$t);
244   2          service$mbox$t=log$on$info.service$mbox$t;
245   2          resp$mbox$t=log$on$info.resp$mbox$t;
246   2          work$station$ID=log$on$info.work$station$ID;
```

Module 2, continued

```
247    2          call rq$send$message(
                  /* mbox token */     log$on$resp$mbox$t,
                  /* object token */  log$on$info$seg$t,
                  /* response token */    0,
                  /* status ptr */    @ex$val);

248    2          root$job$t=rq$get$task$tokens(3,@ex$val);
249.   2          user$object$t=rq$lookup$object(
                  /* job token */     root$job$t,
                  /* name */      @(11,'USER$OBJECT'),
                  /* time limit */    0FFFFH,
                  /* status ptr */    @ex$val);
250    2          prefix$t=rq$lookup$object(
                  /* job token */     root$job$t,
                  /* name */      @(6,'PREFIX'),
                  /* time limit */    0FFFFH,
                  /* status ptr */    @ex$val);

251    2          do forever;

252    3              req$seg$t=rq$receive$message(
                      /* mailbox token */ service$mbox$t,
                      /* time limit */    0FFFFH,
                      /* response ptr */  @dummy$t,
                      /* status ptr */    @ex$val);

253    3              req$seg$p=pointerize(req$seg$t);

254    3              if req$seg.cmd=log$on then
255    3                  do;
256    4                      call rq$a$attach$file(
                          /* user object */   user$object$t,
                          /* prefix token */  prefix$t,
                          /* pathname */      @req$seg.file$name,
                          /* resp token */    resp$mbox$t,
                          /* status ptr */    @ex$val);
257    4                  iors$t=rq$receive$message(
                          /* mbox token */    resp$mbox$t,
                          /* time limit */    0FFFFH,
                          /* resp ptr */      @dummy$t,
                          /* status ptr */    @ex$val);
258    4                  call rq$delete$segment(iors$t,@ex$val);
259    4                  call rq$a$open(
                          /* connection */    conn$t,
                          /* mode */      req$seg.mode,
                          /* share */     req$seg.share,
                          /* resp token */    resp$mbox$t,
                          /* status ptr */    @ex$val);
260    4                  iors$t=rq$receive$message(
                          /* mbox token */    resp$mbox$t,
                          /* time limit */    0FFFFH,
                          /* resp ptr */      @dummy$t,
                          /* status ptr */    @ex$val);
261    4                  call rq$delete$segment(iors$t,@ex$val);
262    4                  req$seg.status=0;
263    4                  call rq$send$message(
                          /* mbox token */    output$request$mbox$t,
                          /* object token */  req$seg$t,
                          /* resp ptr */      0,
                          /* status ptr */    @ex$val);
264    4              end;

265    3              else if req$seg.cmd=log$off then
266    3                  do;
267    4                  call rq$a$close(
                          /* connection */    conn$t,
                          /* resp token */    resp$mbox$t,
                          /* status ptr */    @ex$val);
```

Module 2, continued

```
268   4                  iors$t= rq$receive$message(
                         /* mbox token */    resp$mbox$t,
                         /* time limit */    0FFFFH,
                         /* resp ptr */      @dummy$t,
                         /* status ptr */    @ex$val);
269   4                  call rq$delete$segment(iors$t,@ex$val);
270   4                  call rq$a$delete$connection(
                         /* connection */    conn$t,
                         /* response ptr */  resp$mbox$t,
                         /* status ptr */    @ex$val);
271   4                  iors$t=rq$receive$message(
                         /* mbox token */    resp$mbox$t,
                         /* time limit */    0FFFFH,
                         /* response ptr */  @dummy$t,
                         /* status ptr */    @ex$val);
272   4                  call rq$delete$segment(iors$t,@ex$val);
273   4                  call rq$delete$mailbox(service$mbox$t,@ex$val);
274   4                  call rq$delete$mailbox(resp$mbox$t,@ex$val);
275   4                  req$seg.status=0;
276   4                  call rq$send$message(
                         /* mbox token */    output$request$mbox$t,
                         /* object token */  req$seg$t,
                         /* resp token */    0,
                         /* status ptr */    @ex$val);
277   4                  call rq$delete$task(0,@ex$val);
278   4              end;

279   3          else if req$seg.cmd=read then
280   3              do;

281   4                  call rq$a$read(
                         /* connection */    conn$t,
                         /* buf ptr */       @req$seg.buf,
                         /* count */     req$seg.count,
                         /* resp token */    resp$mbox$t,
                         /* status ptr */    @ex$val);
282   4                  iors$t=rq$receive$message(
                         /* mbox token */    resp$mbox$t,
                         /* time limit */    0FFFFH,
                         /* resp ptr */      @dummy$t,
                         /* status ptr */    @ex$val);
283   4                  call rq$delete$segment(iors$t,@ex$val);
284   4                  req$seg.status=0;
285   4                  call rq$send$message(
                         /* mbox token */    output$request$mbox$t,
                         /* object token */  req$seg$t,
                         /* resp token */    0,
                         /* status ptr */    @ex$val);
286   4              end;

287   3          else if req$seg.cmd=write then
288   3              do;

289   4                  call rq$a$write(
                         /* connection */    conn$t,
                         /* buf ptr */       @req$seg.buf,
                         /* count */     req$seg.count,
                         /* resp token */    resp$mbox$t,
                         /* status ptr */    @ex$val);
290   4                  iors$t=rq$receive$message(
                         /* mbox token */    resp$mbox$t,
                         /* time limit */    0FFFFH,
                         /* resp ptr */      @dummy$t,
                         /* status ptr */    @ex$val);
291   4                  call rq$delete$segment(iors$t,@ex$val);
```

Module 2, continued

```
292   4                        call rq$send$message(
                               /* mbox token */    output$request$mbox$t,
                               /* object token */  req$seg$t,
                               /* resp token */    0,
                               /* status ptr */    @ex$val);
293   4                    end;
                       end; /* of do forever */

295   2          end; /* of task */

296   1      end worker$task;

MODULE INFORMATION:

             CODE AREA SIZE     = 0288H    648D
             CONSTANT AREA SIZE = 0000H      0D
             VARIABLE AREA SIZE = 0000H      0D
             MAXIMUM STACK SIZE = 0034H     52D
             717 LINES READ
             0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 3

```
ISIS-II MCS-86 MACRO ASSEMBLER V2.0 ASSEMBLY OF MODULE POINTR
OBJECT MODULE PLACED IN :F1:POINTR.OBJ
ASSEMBLER INVOKED BY: asm86 :f1:pointr.a86 debug pr(:f5:pointr.lst)

LOC  OBJ        LINE    SOURCE

                  1     $title(pointerize Utility)
  0004            2     arg_off         equ      4                 ; set args for "DELUXE"
                  3
----              4     code            segment word public 'CODE'
----              5     code            ends
                  6
                  7     cgroup          group    code
----              8     code            segment
                  9                     assume   cs: cgroup
                 10
0000             11     pointerize      proc     near
                 12                     public   pointerize
0000 55          13                     push     bp                ; save
0001 8BEC        14                     mov      bp, sp            ; mark stack
                 15
  0004[]         16     token           equ      word ptr [bp + arg_off + 0]
                 17
0003 8E4604      18                     mov      es, token         ; get base
0006 33DB        19                     xor      bx, bx            ; zap offset
                 20
                 21     ;               mov      sp, bp            ; restore stack
0008 5D          22                     pop      bp
0009 C20200      23                     ret      2
                 24     pointerize      endp
----             25     code            ends
                 26     end

ASSEMBLY COMPLETE, NO ERRORS FOUND
```

Module 4

```
ISIS-II PL/M-86 X167 COMPILATION OF MODULE LISTUTILITIESMODULE
OBJECT MODULE PLACED IN :F1:lstutl.OBJ
COMPILER INVOKED BY:  plm86 :F1:lstutl.plm PRINT(:F5:LSTUTL.LST)
DEBUG COMPACT OPTIMIZE(3) ROM DATE(3/7/80)

  1            list$utilities$module:
                   do;

               /***********************************************************************

                   LIST$UTILITIES: PUBLIC PROCEDURES.

                   This module contains three list manipulation utilities.
                   Insert$on$list takes the given node and inserts it on the
                   list indicated by the root node parameter. Delete$from
                   list unlinks the indicated node from the list it is
                   linked to. Search$list scans the list from the root looking
                   for the indicated node. If found, the token for the node
                   is returned. If not found, a zero is returned.

               ***********************************************************************/

               $include(:f4:common.lit)
           =   $SAVE NOLIST
               $include(:fl:node.lit)
           =   /* literal declaration of node descriptor for list utilities */
           =   $save nolist
               $include(:fl:pointr.ext)
           =   /* external declaration of pointerize procedure */
           =   $save nolist

 15    1       Insert$on$list: procedure( root$t,new$desc$t) reentrant public;

 16    2           declare
                       (root$t,new$desc$t,fwd$desc$t) token,
                       (root$p,new$desc$p,fwd$desc$p) pointer,
                       (root based root$p) node,
                       (new$desc based new$desc$p) node,
                       (fwd$desc based fwd$desc$p) node;

 17    2           root$p=pointerize(root$t);
 18    2           new$desc$p=pointerize(new$desc$t);
 19    2           fwd$desc$t=root.link$f;
 20    2           fwd$desc$p=pointerize(fwd$desc$t);
 21    2           root.link$f=new$desc$t;
 22    2           new$desc.link$f=fwd$desc$t;
 23    2           new$desc.link$b=root$t;
 24    2           fwd$desc.link$b=new$desc$t;
 25    2           return;

 26    2       end; /* insert$on$list */

 27    1       Delete$from$list: procedure(desc$t) reentrant public;

 28    2           declare
                       desc$t token,
                       (desc$p,b$desc$p,f$desc$p) pointer,
                       (desc based desc$p) node,
                       (b$desc based b$desc$p) node,
                       (f$desc based f$desc$p) node;

 29    2           desc$p=pointerize(desc$t);
 30    2           b$desc$p=pointerize(desc.link$b);
 31    2           f$desc$p=pointerize(desc.link$f);
 32    2           b$desc.link$f=desc.link$f;
 33    2           f$desc.link$b=desc.link$b;
 34    2           return;
```

Module 4, continued

```
 35    2       end; /* delete$from$list */

 36    1       search$list: procedure(root$t,WS$ID) word reentrant public;

 37    2           declare
                       (root$t,WS$ID) word,
                       (s$desc$p,root$p) pointer,
                       (root based root$p) node,
                       (s$desc based s$desc$p) node,
                       s$desc$p$o structure (offset word, base word) at(@s$desc$p),
                       temp pointer;

 38    2           s$desc$p=pointerize(root$t);
 39    2       next$node:
                   if s$desc.work$station$ID=WS$ID then
 40    2               return s$desc$p$o.base;
 41    2           if s$desc.link$f = root$t then
 42    2               return 0;
 43    2           temp=pointerize(s$desc.link$f);
 44    2           s$desc$p=temp;
 45    2           goto next$node;

 46    2       end; /* search$list */

 47    1       end list$utilities$module;


MODULE INFORMATION:

               CODE AREA SIZE     = 00FEH     254D
               CONSTANT AREA SIZE = 0000H       0D
               VARIABLE AREA SIZE = 0000H       0D
               MAXIMUM STACK SIZE = 0018H      24D
               114 LINES READ
               0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 5

```
ISIS-II PL/M-86 X167 COMPILATION OF MODULE STARTANDFINISH
OBJECT MODULE PLACED IN :Fl:strfin.OBJ
COMPILER INVOKED BY:  plm86 :Fl:strfin.plm PRINT(:F5:STRFIN.LST)
DEBUG COMPACT OPTIMIZE(2) ROM DATE(4/28/80)

  1             start$and$finish:
                    do;

                /**********************************************************************

                    INIT$534$IO and FINISH$534$IO: PUBLIC PROCEDURES.


                    This module contains the init$534$IO and the FINISH$534$IO
                    procedures which can be called by the RMX/86 I/O system. START$IO
                    is called just before the first attach$device is performed.
                    It will create the interrupt task and the eight interrupt$pending
                    semaphores. The FINISH$IO procedure is called just after the
                    last detach$device is performed. It undoes everything the START$IO
                    call did.

                **********************************************************************/

                $include(:f4:nucprm.ext)
          =     $SAVE NOLIST
                $include(:f4:common.lit)
          =     $SAVE NOLIST
                $include(:fl:duib.lit)
          =     /* duib structure definition */
          =     $save nolist
                $include(:f4:nerror.lit)
          =
          =     $SAVE NOLIST
                $include(:fl:pointr.ext)
          =     /* external declaration of pointerize procedure */
          =     $save nolist
                $include(:fl:retdta.lit)
          =     /* literal declaration of ret$data structure for init$534$io */
          =     $save nolist

314    1        init$534$hw: procedure(data$p) external;
315    2            declare data$p pointer;
316    2        end init$534$hw; /* initializes 534 hardware */

317    1        int$534$task: procedure external;
318    2        end int$534$task;

319    1            declare
                        begin$int$534$data byte external,
                        IO$base$addr byte public,
                        int$level word public,
                        g$ret$data$p pointer public,
                        req$mbox$t token public;

320    1        init$534$IO: procedure(duib$p,ret$data$t$p,status$p) reentrant public;

321    2            declare
                        (duib$p,ret$data$t$p,status$p) pointer,
                        (duib based duib$p) dev$unit$info$block,
                        (ret$data$t based ret$data$t$p) token,
                        (status based status$p) word,
                        dev$info$p pointer,
                        dev$info based dev$info$p structure(
                            level word,
                            priority byte,
                            IO$base$addr byte),
```

Module 5, continued

```
                    ex$val word,
                    data$seg$p pointer,
                    data$seg$p$o structure(offset word,base word) at(@data$seg$p),
                    (i,j) byte;

322   2         declare
                    ret$data$p pointer,
                    ret$data based ret$data$p structure(ret$data$struc);

323   2         ret$data$t=rq$create$segment(size(ret$data),@ex$val);
324   2         if ex$val <> 0 then
325   2             goto err0;
326   2         g$ret$data$p,ret$data$p=pointerize(ret$data$t);
327   2         dev$info$p=duib.dev$info$p;
328   2         IO$base$addr,ret$data.IO$base=dev$info.IO$base$addr;
329   2         int$level,ret$data.int$level=dev$info.level;

            /* create the request mailbox */

330   2         ret$data.request$mbox$t,req$mbox$t
                    =rq$create$mailbox(0,@ex$val);
331   2         if ex$val <> 0 then
332   2             goto err1;

333   2         ret$data.resp$mbox$t=rq$create$mailbox(0,@ex$val);
334   2         if ex$val <> 0 then
335   2             goto err2; /* clean up partial creation */

336   2         data$seg$p=@begin$int$534$data;
337   2         ret$data.int$task$t=rq$create$task(
                    /* priority */      dev$info.priority,
                    /* entry point */   @int$534$task,
                    /* data segment */  data$seg$p$o.base,
                    /* stack pointer */ 0,
                    /* stack size */    400,
                    /* task flags */    0,
                    /* status pointer */    @ex$val);
338   2         if ex$val <> 0 then
339   2             goto err3; /* can't create. clean up partial creation */

340   2         do i=0 to 7; /* create semaphores */
341   3             ret$data.int$sema(i)=rq$create$semaphore(
                        /* initial value */ 0,
                        /* max value */     1,
                        /* priority queue */    1,
                        /* status ptr */    @ex$val);

342   3             if ex$val <> 0 then


343   3                 goto err4; /* clean up partial creation */

344   3         end;
345   2         call init$534$hw(ret$data$p);
346   2         status=E$OK;
347   2         return;

348   2     err4:
                do j=0 to i;
349   3             call rq$delete$semaphore(ret$data.int$sema(j),status$p);
350   3         end;
351   2         call rq$reset$interrupt(dev$info.level,status$p);
352   2     err3:
                call rq$delete$mailbox(ret$data.resp$mbox$t,status$p);
353   2     err2:
                call rq$delete$mailbox(ret$data.request$mbox$t,status$p);
354   2     err1:
                call rq$delete$segment(ret$data$t,status$p);
```

Module 5, continued

```
355   2      errØ:
                 status=ex$val; /* restore original status condition */
356   2          return;
357   2      end; /* of procedure */

358   1      finish$534$IO: procedure(duib$p,ret$data$t) reentrant public;
359   2          declare
                     duib$p pointer,
                     dev$info$p pointer,
                     dev$info based dev$info$p structure(
                         level word,
                         priority byte,
                         IO$base$addr byte),
                     ret$data$p pointer,
                     ret$data based ret$data$p structure(ret$data$struc),
                     (duib based duib$p) dev$unit$info$block,
                     ret$data$t token,
                     i byte,
                     ex$val word;

36Ø   2          dev$info$p=duib.dev$info$p;
361   2          ret$data$p=pointerize(ret$data$t);
362   2          call rq$reset$interrupt(dev$info.level,@ex$val);
363   2          call rq$delete$mailbox(ret$data.request$mbox$t,@ex$val);
364   2          call rq$delete$mailbox(ret$data.resp$mbox$t,@ex$val);
365   2          do i=Ø to 7;
366   3              call rq$delete$semaphore(
                         ret$data.int$sema(i),
                         @ex$val);
367   3          end;
368   2          call rq$delete$segment(ret$data$t,@ex$val);
369   2          return;
37Ø   2      end; /* of procedure */
371   1      end start$and$finish;

MODULE INFORMATION:

             CODE AREA SIZE     = Ø22ØH     544D
             CONSTANT AREA SIZE = ØØØØH       ØD
             VARIABLE AREA SIZE = ØØØ9H       9D
             MAXIMUM STACK SIZE = ØØ34H      52D
             671 LINES READ
             Ø PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 6

```
ISIS-II PL/M-86 X167 COMPILATION OF MODULE QUEUE534IOMODULE
OBJECT·MODULE PLACED IN :F1:queio.OBJ
COMPILER INVOKED BY:  plm86 :F1:queio.plm PRINT(:F5:QUEIO.LST)
DEBUG COMPACT OPTIMIZE(2) ROM DATE(4/25/80)


  1           queue$534$io$module:
                  do;

              /*****************************************************************

                  QUEUE$534$IO. PUBLIC PROCEDURE.

                  This procedure is called by the I/O System to queue
                  an I/O request to the 534 board. The function field
                  in the IORS is used to determine what specific action
                  to take. Module also contains a dummy cancel$534$io
                  procedure.

              *****************************************************************/

              $include(:f4:nucprm.ext)
          =   $SAVE NOLIST
              $include(:f4:common.lit)
          =   $SAVE NOLIST
              $include(:f4:nerror.lit)
          =
          =   $SAVE NOLIST
              $include(:f1:pointr.ext)
          =   /* external declaration of pointerize procedure */
          =   $save nolist
              $include(:f1:duib.lit)
          =   /* duib structure definition */
          =   $save nolist
              $include(:f1:iors.lit)
          =   /* literal declaration for iors */
          =   $save nolist
              $include(:f1:retdta.lit)
          =   /* literal declaration of ret$data structure for init$534$io */
          =   $save nolist

315     1     io$534$task: procedure external;
316     2     end io$534$task;

317     1         declare
                      begin$io$task$data byte external;

318     1     queue$534$io: procedure(iors$t,duib$p,ret$data$t) reentrant public;

319     2         declare
                      (iors$t,ret$data$t) token,
                      data$seg$p pointer,
                      data$seg$p$o structure(offset word,base word) at(@data$seg$p),
                      IDDR literally '2AH',
                      (duib$p,ret$data$p,iors$p) pointer,
                      (duib based duib$p) dev$unit$info$block,
                      (ret$data based ret$data$p) structure(ret$data$struc),
                      (iors based iors$p) IO$request$result$segment,
                      io$task$t token,
                      unit$info$p pointer,
                      unit$info based unit$info$p structure(
                          usart$cmd byte,
                          baud$rate word),
                      i byte,
                      dummy$t token,
                      ex$val word;
```

Module 6, continued

```
320   2          iors$p=pointerize(iors$t);
321   2          ret$data$p=pointerize(ret$data$t);

322   2          if iors.funct > 7 then
323   2              goto bad$request;

324   2          do case iors.funct;

325   3              do; /* case 0-- read */
326   4                  iors.aux$p=ret$data$p;
327   4                  call rq$send$message(
                               /* mbox */  ret$data.request$mbox$t,
                               /* token */ iors$t,
                               /* resp */  0,
                               /* status ptr*/ @ex$val);
328   4                  return;
329   4              end;

330   3              do; /* case 1-- write */
331   4                  iors.aux$p=ret$data$p;
332   4                  call rq$send$message(
                               /* mbox */  ret$data.request$mbox$t,
                               /* token */ iors$t,
                               /* resp */  0,
                               /* status ptr*/ @ex$val);
333   4                  return;
334   4              end;

335   3              do; /* case 2--seek (illegal) */
336   4                  goto bad$request;
337   4              end;

338   3              do; /* case 3-- special (illegal) */
339   4                  goto bad$request;
340   4              end;

341   3              do; /* case 4-- attach$device */

                 /* create two I/O tasks */

342   4                  data$seg$p=@begin$IO$task$data;
343   4                  do i=0 to 1;
344   5                      io$task$t= rq$create$task(
                                   /* priority */  150,
                                   /* entry pnt */ @io$534$task,
                                   /* data seg */  data$seg$p$o.base,
                                   /* stack ptr */ 0,
                                   /* stack size */    500,
                                   /* task flags */    0,
                                   /* status ptr */    @ex$val);
345   5                  end;

346   4                  unit$info$p=duib.unit$info$p;
347   4                  do i=0 to 3;
348   5                      output(ret$data.usart$cmd$port(iors.unit))=0;
349   5                  end;
350   4                  output(ret$data.usart$cmd$port(iors.unit))=40H;
351   4                  output(ret$data.usart$cmd$port(iors.unit))=
                             unit$info.usart$cmd;
352   4                  output(ret$data.usart$cmd$port(iors.unit))=27H;
353   4                  output(ret$data.IO$base+0CH)=0; /* select cntrl blk */
354   4                  output(ret$data.timer$cmd$port(iors.unit))=
                             ret$data.timer$cmd(iors.unit);
355   4                  output(ret$data.timer$load$port(iors.unit))=
                             low(unit$info.baud$rate);
356   4                  output(ret$data.timer$load$port(iors.unit))=
                             high(unit$info.baud$rate);
```

Module 6, continued

```
357   4              output(ret$data.IO$base+0DH)=0; /* select data blk */

          /* accept interrupt and character from receiver */

358   4              dummy$t=rq$receive$units(
                     /* sema */  ret$data.int$sema( 2 * iors.unit),
                     /* units */ 1,
                     /* time$out */  0,
                     /* status */    @ex$val);
359   4              i=input(ret$data.usart$data$port( iors.unit ));
360   4              goto ok$send$resp;
361   4          end;

362   3          do; /* case 5-- detach$device */

      /* send two copies of the detach request to the request mailbox.
         This will signal to two of the I/O tasks that they are to
         delete themselves */

363   4              call rq$send$message(
                     /* mbox token */    ret$data.request$mbox$t,
                     /* object token */  iors$t,
                     /* response */      ret$data.resp$mbox$t,
                     /* status */        @ex$val);
364   4              dummy$t=rq$receive$message(
                     /* mbox token */    ret$data.resp$mbox$t,
                     /* time$limit */    0FFFFH,
                     /* response ptr */  @dummy$t,
                     /* status ptr */    @ex$val);
365   4              call rq$send$message(
                     /* mbox token */    ret$data.request$mbox$t,
                     /* object token */  iors$t,
                     /* response */      ret$data.resp$mbox$t,
                     /* status */        @ex$val);
366   4              dummy$t=rq$receive$message(
                     /* mbox token */    ret$data.resp$mbox$t,
                     /* time$limit */    0FFFFH,
                     /* response ptr */  @dummy$t,
                     /* status ptr */    @ex$val);
367   4              goto ok$send$resp;
368   4          end;

369   3          do; /* case 6-- open */
370   4              goto ok$send$resp;
371   4          end;

372   3          do; /* case 7-- close */
373   4              goto ok$send$resp;
374   4          end;
375   3      end; /* do case */
376   2      return;
377   2  bad$request:
             iors.status=IDDR;
378   2      goto send$resp;
379   2  ok$send$resp:
             iors.status=E$OK;
380   2  send$resp:
             call rq$send$message(iors.resp$mbox,iors$t,0,@ex$val);
381   2      return;
382   2  end; /* procedure */

383   1  cancel$534$io: procedure(iors$t,duib$p,ret$data$t) public;

384   2      declare
                 (iors$t,ret$data$t) token,
                 duib$p pointer;

385   2      return;
```

Module 6, continued

```
386   2         end;
387   1     end queue$534$io$module;

MODULE INFORMATION:

            CODE AREA SIZE     = 020CH     524D
            CONSTANT AREA SIZE = 0000H       0D
            VARIABLE AREA SIZE = 0000H       0D
            MAXIMUM STACK SIZE = 0038H      56D
            729 LINES READ
            0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 7

```
ISIS-II PL/M-86 V2.0 COMPILATION OF MODULE INTERRUPT534MODULE
OBJECT MODULE PLACED IN :F1:int534.OBJ
COMPILER INVOKED BY:  plm86 :F1:int534.plm PRINT(:F1:INT534.LST)
DEBUG COMPACT OPTIMIZE(2) ROM DATE(5/28/80)

                  $nointvector
  1               Interrupt$534$module:
                      do;

                  /**********************************************************************

                      INT$534$TASK and INT$534$HND:
                          PUBLIC PROCEDURES:

                      This module contains the interrupt handler and the interrupt
                      task for the 534 board interrupt. The handler simply calls
                      signal$interrupt and the task reads the ISR on the 534
                      board's 8259 and sends a unit to one of eight interrupt$
                      pending semaphores to signal the occurrence of the event.

                  **********************************************************************/

                  $include(:f2:nucprm.ext)
              =   $SAVE NOLIST
                  $include(:f1:retdta.lit)
              =   /* literal declaration of ret$data structure for init$534$io */
              =   $save nolist
                  $include(:f2:common.lit)
              =   $SAVE NOLIST

308    1              declare
                          begin$int$534$data byte public,
                          g$ret$data$p pointer external,
                          IO$base$addr byte external,
                          int$level word external;

309    1          int$534$hnd: procedure interrupt 5;

310    2              declare
                          l word,
                          ex$val word;

311    2              l=rq$get$level(@ex$val);
312    2              call rq$signal$interrupt(l,@ex$val);
313    2              return;
314    2              end;

315    1          int$534$task: procedure reentrant public;

316    2              declare
                          IO$534$base byte,
                          int$534$level word,
                          ret$data$p pointer,
                          ret$data based ret$data$p structure(ret$data$struc),
                          c$level byte,
                          ex$val word,
                          eoi literally '20H';

317    2              IO$534$base=IO$base$addr;
318    2              int$534$level=int$level;
319    2              ret$data$p=g$ret$data$p;
320    2              call rq$set$interrupt(
                          /* level */       int$534$level,
                          /* flags */       1,
                          /* entry point */   interrupt$ptr(int$534$hnd),
                          /* data segment */  0,
                          /* status ptr */    @ex$val);
```

Module 7, continued

```
321   2          do forever;
322   3              call rq$wait$interrupt(int$534$level,@ex$val);
323   3              output(IO$534$base+8)=0CH;
324   3              c$level=input(IO$534$base+8) and 07H;
325   3              call rq$send$units(ret$data.int$sema(c$level),1,@ex$val);
326   3              output(IO$534$base+8)=EOI;
327   3          end; /* of do forever */
328   2      end; /* of procedure */

329   1      end interrupt$534$module;

MODULE INFORMATION:

             CODE AREA SIZE     = 00B5H    181D
             CONSTANT AREA SIZE = 0000H      0D
             VARIABLE AREA SIZE = 0005H      5D
             MAXIMUM STACK SIZE = 0026H     38D
             541 LINES READ
             0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 8

```
ISIS-II PL/M-86 X167 COMPILATION OF MODULE IO534TASKMODULE
OBJECT MODULE PLACED IN :F1:iotask.OBJ
COMPILER INVOKED BY:  plm86 :F1:iotask.plm PRINT(:F5:IOTASK.LST)
DEBUG COMPACT OPTIMIZE(2) ROM DATE(4/25/80)

  1           io$534$task$module:
                  do;

              /**********************************************************************

                  IO$534$TASK: TASK.

                  This task receives IORS segments from the queue$io
                  procedure and performs the necessary input or
                  output operations on the iSBC 534 board.

              **********************************************************************/

              $include(:f4:common.lit)
          =   $SAVE NOLIST
              $include(:f1:pointr.ext)
          =   /* external declaration of pointerize procedure */
          =   $save nolist
              $include(:f4:nucprm.ext)
          =   $SAVE NOLIST
              $include(:f4:nerror.lit)
          =
          =   $SAVE NOLIST
              $include(:f1:retdta.lit)
          =   /* literal declaration of ret$data structure for init$534$io */
          =   $save nolist
              $include(:f1:iors.lit)
          =   /* literal declaration for iors */
          =   $save nolist

314   1           declare
                      begin$io$task$data byte public,
                      req$mbox$t token external,
                      f$detach$device literally '5',
                      f$read literally '0',
                      f$write literally '1';

315   1       IO$534$task: procedure reentrant public;

316   2           declare
                      iors$t token,
                      iors$p pointer,
                      iors based iors$p IO$request$result$segment,
                      ex$val word,
                      resp$t token,
                      buff$p pointer,
                      buf based buff$p (1) byte,
                      i word,
                      unit byte,
                      ret$data$p pointer,
                      ret$data based ret$data$p structure(ret$data$struc),
                      c$val word;

317   2           do forever;
318   3               iors$t=rq$receive$message(req$mbox$t,0FFFFH,@resp$t,@ex$val);

              /* check for non-existence of mailbox. IF last device has been detached
                 the mailbox will be deleted  In this case, delete thyself */

319   3               if ex$val= E$exist then
320   3                   call rq$delete$task(0,@ex$val);
321   3               iors$p=pointerize(iors$t);
```

Module 8, continued

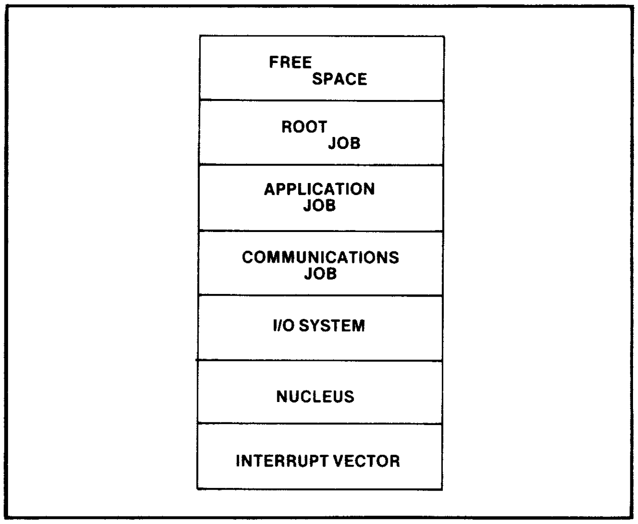
```
322   3              buff$p=iors.buff$p;
323   3              unit=iors.unit;
324   3              iors.actual=0;
325   3              i=0;
326   3              ret$data$p=iors.aux$p;

327   3              if iors.funct = f$detach$device then
328   3                  do;
329   4                      call rq$send$message(
                           /* mbox token */    resp$t,
                           /* object token */  iors$t,
                           /* response token */    0,
                           /* status ptr */    @ex$val);
330   4                      call rq$delete$task(0,@ex$val);
331   4                  end;

332   3              if iors.funct= f$read then
333   3                  do while iors.count >0;
334   4                      c$val=rq$receive$units(
                                   /* sema */  ret$data.int$sema(2*unit),
                               /* units */ 1,
                               /* time */  0FFFFH,
                               /* status*/ @ex$val);

335   4                      buf(i)=input(ret$data.usart$data$port(unit)) and 07FH;
336   4                      i=i+1;
337   4                      iors.count=iors.count-1;
338   4                      iors.actual=iors.actual+1;
339   4                  end;

340   3              else if iors.funct= f$write then
341   3                  do while iors.count >0;
342   4                      c$val=rq$receive$units(
                               /* sema */  ret$data.int$sema(2*unit+1),
                               /* units */ 1,
                               /* time */  0FFFFH,
                               /* status*/ @ex$val);
343   4                      output(ret$data.usart$data$port(unit))=buf(i);
344   4                      i=i+1;
345   4                      iors.count=iors.count-1;
346   4                      iors.actual=iors.actual+1;
347   4                  end;
                     iors.status=E$OK;
349   3              iors.done=TRUE;
350   3              call rq$send$message(iors.resp$mbox,iors$t,0,@ex$val);
351   3          end; /* of do forever */

352   2      end; /* of procedure */

353   1      end io$534$task$module;
```

```
MODULE INFORMATION:

          CODE AREA SIZE     = 018DH    397D
          CONSTANT AREA SIZE = 0000H      0D
          VARIABLE AREA SIZE = 0001H      1D
          MAXIMUM STACK SIZE = 0028H     40D
          624 LINES READ
          0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

Module 9

```
ISIS-II PL/M-86 X167 COMPILATION OF MODULE INIT534HW
OBJECT MODULE PLACED IN :F1:inithw.OBJ
COMPILER INVOKED BY:  plm86 :F1:inithw.plm PRINT(:F5:INITHW.LST)
DEBUG COMPACT OPTIMIZE(2) ROM DATE(4/25/80)

  1           init$534$hw:
                  do;

              /*************************************************************************

                  init$534$hw: PUBLIC PROCEDURE.

                  This procedure initializes the iSBC 534 hardware and
                  sets up the device dependent fields of the ret$data
                  segment which will be used by the queue$io procedures.

              *************************************************************************/

              $include(:f4:common.lit)
          =   $SAVE NOLIST
              $include(:f1:retdta.lit)
          =   /* literal declaration of ret$data structure for init$534$io */
          =   $save nolist

 12    1      init$534$hw: procedure(ret$data$p) reentrant public;

 13    2          declare
                      ret$data$p pointer,
                      ret$data based ret$data$p structure(ret$data$struc),
                      (base,i) byte;

 14    2          base=ret$data.io$base;
 15    2          output(base+0FH)=0; /* board reset */
 16    2          output(base+0DH)=0; /* select data block */
 17    2          output(base+8)=16H; /* output ICW1 */
 18    2          output(base+9)=0;   /* output ICW2 */
 19    2          output(base+9)=0;   /* output mask word */

              /* attach$device calls will initialize usarts and timers */
              /* set up tables of port addresses for use by queue$io procs */

 20    2          ret$data.timer$cmd(0),ret$data.timer$cmd(3)=36H;
 21    2          ret$data.timer$cmd(1)=76H;
 22    2          ret$data.timer$cmd(2)=0B6H;
 23    2          do i=0 to 3;
 24    3              ret$data.usart$cmd$port(i)=base+2*i+1;
 25    3              ret$data.usart$data$port(i)=base+2*i;
 26    3              ret$data.timer$load$port(i)=base+i;
 27    3          end;
 28    2          ret$data.timer$load$port(3)=base+4;
 29    2          ret$data.timer$cmd$port(0),
                  ret$data.timer$cmd$port(1),
                  ret$data.timer$cmd$port(2)=base+3;
 30    2          ret$data.timer$cmd$port(3)=base+7;
 31    2          return;
 32    2      end;
 33    1      end init$534$hw;

MODULE INFORMATION:

              CODE AREA SIZE      = 00E4H     228D
              CONSTANT AREA SIZE  = 0000H       0D
              VARIABLE AREA SIZE  = 0000H       0D
              MAXIMUM STACK SIZE  = 0008H       8D
              77 LINES READ
              0 PROGRAM ERROR(S)

END OF PL/M-86 COMPILATION
```

APPENDIX B
Configuration Listings/Worksheets



System Memory Map

```
;
;   *-*-*-*-*-*-*-*-*-*-*-*-*--   NUCLNK.CSD   --*-*-*-*-*-*-*-*-*-*-*-*-*
;
;THIS SUBMIT FILE LINKS THE NUCLEUS.
;
:F0:LINK86 &
:F1:NUC86.LIB(NENTRY), &
:F1:NUC86.LIB &
TO :F1:NUCLUS.LNK MAP PRINT(:F1:NUCLUS.MP1) NAME(NUCLEUS)
;
;
;   *-*-*-*-*-*-*-*-*-*-*-*-*--   NUCLOC.CSD   --*-*-*-*-*-*-*-*-*-*-*-*-*
;
;THIS SUBMIT FILE LOCATES THE NUCLEUS IN MEMORY.
;
;
:F0:LOC86 &
:F1:NUCLUS.LNK TO :F1:NUCLUS MAP PRINT(:F1:NUCLUS.MP2) SC(3) &
RESERVE(0 TO 7FFH) SEGSIZE(STACK(0)) &
ORDER(CLASSES(CODE,DATA,STACK,MEMORY)) &
OBJECTCONTROLS(NOLINES,NOCOMMENTS,NOPUBLICS,NOSYMBOLS)
```

Nucleus Link and Locate Commands

```
;
; ios(date,origin)
;       Sample I/O System .csd file to link and locate an I/O System.
;
; This file links an I/O System with the timer included.
;
; This .csd file assumes the I/O System configuration module is
; iocnfg.a86 (found on the release diskette).
;
; The origin parameter sets the low address of the I/O System;
; all the segments are contiguous in memory.
;
asm86 :fl:iocnfg.a86 date(%0)
link86 &
    :fl:ios.lib(ioinit), &
    :fl:iocnfg.obj, &
    :fl:ios.lib,    &
    :fl:rpifc.lib   &
 to :fl:ios.lnk map print(:fl:ios.mpl)
loc86 :fl:ios.lnk to :fl:ios map sc(3) print(:fl:ios.mp2) &
      oc(noli,nopl,nocm,nosb) &
      order(classes(code,data,stack,memory)) &
      addresses(classes(code(%1))) &
      segsize(stack(0))
```

I/O System Link and Locate Commands

```
;    Submit file to generate located version of file transaction job
;
link86 &
    :fl:ftinit.obj, &
    :fl:listen.obj, &
    :fl:worker.obj, &
    :fl:pointr.obj, &
    :fl:rpifc.lib   &
 to :fl:apexl.lnk map print(:fl:apexl.mpl)

loc86 :fl:apexl.lnk to :fl:apexl map sc(3) print(:fl:apexl.mp2) &
      oc(noli,nopl,nocm,nosb) &
      order(classes(code,data,stack,memory)) &
      addresses(classes(code(%1))) &
      segsize(stack(0))
```

File Transaction Job; Link and Locate Commands

```
;
;    Submit file to generate located version of communications job
;
link86 &
    :fl:cminit.obj, &
    :fl:comm.lib, &
    :fl:pointr.obj, &
    :fl:rpifc.lib   &
 to :fl:comm.lnk map print(:fl:apexl.mpl)
loc86 :fl:comm.lnk to :fl:comm map sc(3) print(:fl:comm.mp2) &
      oc(noli,nopl,nocm,nosb) &
      order(classes(code,data,stack,memory)) &
      addresses(classes(code(%1))) &
      segsize(stack(0))
```

Communications Job; Link and Locate Commands

```
  Ø77EH  1ØE4H  PUB  INITDEVICETABLES       Ø77EH  ØFBCH  PUB  NAMEDDELETE
  Ø77EH  ØEB3H  PUB  DECRUSECOUNT           Ø77EH  ØE51H  PUB  UNLINKCONN
  Ø77EH  ØCA8H  PUB  NAMEDCHANGEACCES       Ø77EH  ØB5AH  PUB  ATTACHNAMEDFILE
                    -S
→ Ø77EH  Ø73EH  PUB  ATTACHDEVICETASK       Ø77EH  Ø574H  PUB  ILLEGALFUNCT
  Ø77EH  ØØ3EH  PUB  RQAIOSINITTASK         Ø77EH  ØØØ6H  PUB  COPYRIGHT

  SEGMENT MAP

  START     STOP      LENGTH ALIGN NAME              CLASS

  Ø77EØH    1453EH     CD5FH   W    CODE              CODE
  1454ØH    145FFH     ØØCØH   W    REQ_TABLE         CODE
  146ØØH    146DFH     ØØEØH   W    IOS_TABLE         CODE
→ 146EØH    14745H     ØØ66H   W    DATA              DATA
  14746H    14746H     ØØØØH   W    STACK             STACK
  1475ØH    1475ØH     ØØØØH   G    ??SEG
→ 1475ØH    1475ØH     ØØØØH   W    MEMORY            MEMORY
```

Locate Map for I/O System

(The "→" indicates entries for job macros and memory map)

```
  1475H  Ø79EH  PUB  SETUP544            1475H  Ø6C5H  PUB  PACKETINPUT

  1475H  Ø5B5H  PUB  INDEX             → 1475H  Ø572H  PUB  COMMINITTASKENTRY
                                                          -ESS
  SEGMENT MAP

  START     STOP      LENGTH ALIGN NAME              CLASS

  1475ØH    15BCDH     147DH   W    CODE              CODE
→ 15BDØH    17ØD2H     15Ø2H   W    DATA              DATA
  17ØD2H    1712EH     ØØ4CH   W    STACK             STACK
  1713ØH    1713ØH     ØØØØH   G    ??SEG
→ 1713ØH    1713ØH     ØØØØH   W    MEMORY            MEMORY
```

Locate Map for Communications Job

```
  17D6H  Ø3B5H  PUB  BEGINLISTENERTASKDATA1713H  Ø153H  PUB  POINTERIZE
→ 1713H  Ø112H  PUB  INITTASKENTRY          1713H  Ø4Ø1H  PUB  WORKERTASK
  SEGMENT MAP

  START     STOP      LENGTH ALIGN NAME              CLASS

  1713ØH    17D59H     ØC29H   W    CODE              CODE
  17D6ØH    17E28H     ØØC8H   W    DATA              DATA
  17E3ØH    17E9AH     ØØ6AH   W    STACK             STACK
```

Locate Map for File Transaction Job

Macro call: **SYSTEM (system parameters)**

Number of calls required: **exactly one**

CONFIGURATION FILE NAME ____________

FORMAT:

	parameter	type	suggested default	value
%SYSTEM	(nucleus_entry,	base		**80:0**
	rod_size,	word	(0)	**10**
	min_trans_size,	work	(64)	**64**
	debugger,	see note 1	(A)	**N**
	default_e_h_provided,	see note 2	(N)	**N**
	mode)	word		**1**

NOTES:

1. Valid entries for the debugger parameter include:

   A Debugger available
   N No debugger available

2. Valid entries for the default_e_h_provided parameter include:

   Y Yes
   D Debugger
   N No

%SYSTEM Macro Worksheet

Macro call: **SAB (for system address blocks)**

Number of calls required: **one or more**

CONFIGURATION FILE NAME: **APEX1**

FORMAT:

	parameter	type	suggested default	value
%SAB	(start__base,	base		**0**
	end__base,	base		**1900**
	type)	see note 1	U	**U**

NOTES:

1. The type parameter is reserved for future use. Enter the character U for this parameter.

2. A SAB is declared between start__base:0 and end__base:F, inclusive.

%SAB Macro Worksheet

Macro call: **JOB (defines first-level jobs)**

Number of calls required: **one for each first-level job**

CONFIGURATION FILE NAME: **APEX 1**

FORMAT:

	parameter	suggested type	default	value
%JOB	(directory__size,	word	(0)	**0**
	pool__min,	word		**OFFFF**
	pool__max,	word	(OFFFFH)	**OFFFF**
	max__objects,	word		**FFFF**
	max__tasks,	word		**FFFF**
	max__job__priority,	byte		**129**
	exception__handler__entry,	addr	(0:0)	**0:0**
	exception__handler__mode,	byte	(1)	**1**
	job__flags,	word	(0)	**0**
	init__task__priority,	byte		**1713:112**
	data__segment__base,	base	(0)	**17D6**
	stack__pointer,	addr	(0:0)	**0:0**
	stack__size,	word	(512)	**512**
	task__flags)	word	(0)	**0**

NOTE:

1. addr is specified as base:offset

%JOB Macro Worksheet

```
%sab(0,1900,U)
%job(0,300h,0FFFh,0ffffh,0ffffh,0,0:0,0,0,128,77e:3e,146e,0:0,512,0)
%job(0,1FFH,0FFFH,0FFFFH,0FFFFH,128,0:0,0,0,131,1475:572,15bd,0:0,400,0)
%job(0,300H,0FFFFH,0FFFFH,0FFFFH,128,0:0,1,0,130,1713:112,17d6,0:0,400H,0)
%system(80,10,64,N,N,1)
```

Configuration File Apex 1.CNF

```
;
;*-*-*-*-*-*-*-*-*-*-*-*-- CTABLE.CSD --*-*-*-*-*-*-*-*-*-*-*-*
;
; SUBMIT :Fx:CTABLE( fsys, fin, fout, config_file, date )
;
; This submit file assembles the CTABLE module, where:
;       fsys        = the system disk containing ASM86
;       fin         = the source/input disk (F1 is assumed)
;       fout        = the object/listing/output disk
;       config_file = the path-name of the configuration file
;       date        = the date
;
copy %3 to :f1:config.cnf b

:%0:asm86 :%1:ctable.a86 pr(:%2:ctable.lst) oj(:%2:ctable.obj) date(%4) &
xref debug ep
```

Submit File to Generate Configuration Table

```
;
;
;*-*-*-*-*-*-*-*-*-*-*-*-- CLNKRJ.CSD --*-*-*-*-*-*-*-*-*-*-*-*
;
; SUBMIT :Fx:CLNKRJ( fsys, fin, fout )
;
; This submit file links the Root-Job, where:
;       fsys  = the system disk containing LINK86
;       fin   = the source/input disk
;       fout  = the object/listing/output disk
;
:%0:link86 :%1:croot.lib(root),&
       :%2:ctable.obj,&
       :%1:croot.lib &
to  :%2:rootjb.lnk  map pr(:%2:rootjb.mpl)
;
```

Submit File to Link the Root Job

```
;
;*-*-*-*-*-*-*-*-*-*-*-*-- CLOCRJ.CSD --*-*-*-*-*-*-*-*-*-*-*
;
; SUBMIT :Fx:CLOCRJ( fsys, fin, fout )
;
; This submit file locates the Root-Job, where:
;      fsys  = the system disk containing LOC86
;      fin   = source/input disk
;      fout  = object/listing/output disk
;
;-- NOTE: BE SURE TO REPLACE THE "?????" BELOW WITH THE APPROPRIATE
;-- ADDRESS THE ROOT-JOB IS TO BE LOCATED AT!!
;
:%0:loc86 :%2:rootjb.lnk to :%2:rootjb &
map pr(:%2:rootjb.mp2) sc(3) &
name(ROOT_JOB) oc(nocm,noli,nopl,nosb) &
segsize(stack(200h)) &
order(classes(data,stack,memory,code)) &
addresses(classes(data(12C00H)))
```

Submit File to Locate Root Job

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