A CONCURRENT PROGRAMMING SYSTEM WITH A FLEXIBLE STRUCTURE

by

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ABSTRACT

This dissertation describes the design and implementation of a concurrent programming system called CPS/1100 which is a modelling language used in systems programming. Processor dedication and program trace capabilities are the distinguishing characteristics of the language. In addition to these features, the implementation scheme used in developing the language is such that it can easily be modified and extended to develop languages for specific applications. This flexible character of the language can be considered as the main contribution of the present work.

Structurally, CPS/1100 is an extension of a Pascal compiler by prescanner and postscanner routines. Prescanner routines provide syntax and semantic checks of the CPS/1100 statements and the control directives, while the postscanner routine modifies the assembler codes produced by the Pascal compiler. Concurrency primitives of Exec8, which is the system program of Univac 1100 machines, are utilized to maintain task creation, removal and control.

This dissertation provides an overview of concurrent programming and multitasking on Univac 1100 systems. Statements, structure and implementation details of CPS/1100 are explained. Typical concurrent programming problems are solved by using CPS/1100 to prove its capabilities. Finally, this study is evaluated.

Ö Z E T

Bu tez çalışmasında sistem programlamada kullanılacak bir modelleme dili olan bir eşanlı programlama sistemi CPS/1100'ün tasarım ve gerçekleştirilmesi anlatılmıştır. Dilin işleyici tahsisi ve program izleme olanakları ayrıcalık gösteren özellikleridir. Bu özelliklerin yanısıra, CPS/1100 kolay değiştirilebilir ve özel uygulamalar için dil hazırlamak üzere geliştirilebilir bir yapıda gerçekleştirilmiştir. Dilin bu değiştirilebilir özelliği bu çalışmanın ana özelliği sayılabilir.

Yapısal olarak, CPS/1100 bir Pascal derleyicisinin öntarayıcı ve arttarayıcı yordamlar vasıtasıyla geliştirilmiş şeklidir. Öntarayıcı dizgeler CPS/1100 cümlelerinin ve kontrol yönlendiricilerinin ifadesel ve anlamsal kontrolünü yapar. Arttarayıcı ise Pascal derleyicisinin ürettiği bütünleyici kodları değiştirir. Univac 1100 makinalarının sistem programı olan Exec8'in eşanlılık yapıları iş yaratımı, yokedilmesi ve kontrolu için kullanılmıştır.

Bu tezde eşanlı programlama ve Univac 1100 sistemlerinde çokişli çalışma üzerine bir genel bakış verilmektedir. CPS/1100'ün cümleleri, yapısı ve gerçekleştirilme detayları açıklanmaktadır. Tipik eşanlı programlama problemleri CPS/1100 kullanarak çözülmüş ve CPS/1100 ile yapılabilecekler gösterilmiştir. Son kısımda, bu çalışma değerlendirilmiştir.

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I. INTRODUCTION

Concurrent programming has become an important topic for the efficient use of existing hardware facilities of computer systems in recent years. Conceptually, concurrent programming is a technique for expressing parallelism and for solving synchronization and communication problems of systems programming. This technique is used to increase computer efficiency and to manage environments where many things need attention at the same time. It also provides an abstract setting for studying parallelism without considering the machine details.

Concurrent programming was born with the third generation computers. Multiactivity (concurrent) system programs were essential to manage slow speed peripherals connected to fast central processor(s) of these machines. Studies performed by Dijkstra [1,2,3]* have been the milestones on the subject in its enfancy. In the seventies, concepts and data structures proposed by Hoare [4], by Hansen [5] and by Dijkstra [6] were used in the concurrent language development studies. The present challange of programming methodology is a type of programming called "Distributed Programming" in which concurrent processes (activities) may communicate only by input/output operations.

It is observed that two different approaches exist in concurrent language development studies. The first, which may be called "professional approach", has a tendency either of enriching an already existing sequential language with concurrency features or to develop a language dedicated to specific hardware families. The enrichment of Algol and PL/1 with concurrency constructs and the development of a variety of machine dependent system programming languages are works belonging to this approach. The second approach which is mostly applied to academic studies, is aimed at developing machine independent language constructs

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* *Numbers enclosed in brackets refer to the references at the end.*

and new data structures. For this academic study presented in this dissertation, the methods of the professional approach are preferred.

In fact, existing concurrent languages are the results of extensive works which are usually carried out by software teams. The syntax and capabilities of these languages were strictly defined. Therefore, modifications on such languages can not be easily done. The absence of "processor dedication" and "program trace" capabilities are the major deficiencies of these languages.

At present, every medium or large scale computer system does not have user accesible concurrent programming languages. But, in almost all of these systems, there exist high level sequential languages and primitives (mostly assembler instructions) that provide concurrency on program control flow. Therefore, a practical method to develop a powerful and flexible concurrent language is to enrich a high level sequential language with concurrency primitives. This is the design philosophy of the concurrent language developed in the present study.

In Univac 1100 series computers, the operating system, Exec 8 [7,8], controls and manages operations in several modes including real-time. Users may write multiactivity (concurrent) assembler programs by using low level concurrency primitives of Exec 8. On the other hand, concurrent program modules can be written by using PL/1, Cobol and PLUS [10,11] the latter being a special system programming language. But, Univac Cobol [12] and PL/1 [13] compilers are not suitable for sophisticated concurrent programming applications. Although both PLUS and 1100 Assembler provide concurrent programming structures, they are not convenient for average programmers. The concurrent language developed in this study was designed to satisfy the needs of these average programmers.

This dissertation describes the design and implementation details of a concurrent programming system, CPS/1100, which is a "Pascal like" modelling language suitable for system programming. The syntax of CPS/1100 statements is similar to that of Pascal statements, because CPS/1100 is an extension of a Pascal compiler. CPS/1100 was developed as a multiphase translator. Its prescanner routines recognize "CPS/1100 control directives" and analyse the "input program stream". These

routines were written in Macro [14] which is a string manipulation language. The program stream processed by the prescanner routines is compiled by using Pascal 8R1 compiler [15] and then an assembler program text is obtained. This assembler program is further processed by the CPS/1100 postscanner routine to generate a multitask (concurrent) assembler program. After these steps, the program is assembled, linked and executed.

The "processor dedication" and the "program trace" capabilities are the distinguishing characteristics of CPS/1100. In addition to these features, the implementation scheme which permits easy modification and extension of the language for specific applications has been preferred. This flexible character of the language together with the "processor dedication" and "trace" capabilities can be considered as the main contribution of the present work to the field of concurrent programming.

Following this introduction, the second chapter gives an overview about concurrent programming; its historical development including the concepts and the problems related with concurrency and its relationship with the operating systems are explained. Synchronization techniques, deadlock and deadlock detection methods are stated. Explanations about objective and structural description of CPS/1100 conclude the second chapter.

Multitasking (concurrent programming) on Univac 1100 machines and the Exec 8 concurrency constructs for the "activity creation, control and removal" and for the "activity synchronization" are explained in Chapter three.

Chapter four is devoted to CPS/1100 statements, keywords and control directives. Implementation details of CPS/1100 are given in this chapter.

Chapter five consists of case studies about concurrent programming. Case one is a "monitor" implementation where the "producer/consumer" problem [16] is solved. Case two is the well-known "dining philosophers" problem [3] which is a resource allocation problem. Case three is the implementation of a parallel sorting algorithm. The "quicksort" algorithm [17] is modified for a dual processor system in this case study. Case four is the implementation of a parallel algorithm applied to a matrix operation [18]. Case three and case four are the demonstrative examples of the CPS/1100 "processor dedication" feature. Case five is a model for

a "timesharing" and "multiprogramming" operating system in which the "minimum response time" scheduling strategy is applied.

Chapter six is devoted to the discussion of the study. Comparison of CPS/1100 with some of the existing concurrent languages and recommendations for future research are given in this chapter.

Chapter seven contains the conclusion of the study.

Six appendices are devoted to presenting details.

II. AN OVERVIEW OF CONCURRENT PROGRAMMING AND CPS/1100

An overview of concurrent programming is given in this chapter. Previous studies on concurrent programming are summarized in chronological order. Concepts and basic problems due to concurrency are introduced. Methods and data structures that have been developed for solving concurrency problems are briefly explained. Characteristics of existing concurrent languages and application areas of concurrent software are given. The design aims and structure of CPS/1100 are described in detail.

In this chapter and the succeeding ones, the terms *process*, *activity* and *task* are used to denote a computation in which the operations are carried out strictly one at a time. The term *concurrent processes* is used to specify that the processes overlap in time. The term *resource* is used to describe a set of objects (such as processor, memory, programs) that a process can use. The term *synchronization* is used to denote any constraint on the order in which operations are carried out. The term *quasiparallel* means that program control, in a single processor system, passes to another process only at places where the current process explicitly specifies its own suspension. The other terms related with concurrent programming are described within this chapter.

2.1 Historical Development of Concurrent Programming

In the mid 1950's computer architecture changed with the invention of large magnetic stores and asynchronous operating peripheral devices. Slow speeds of peripheral devices made asynchronous operations essential in computer systems. Operating systems became complex beyond human

comprehension and due to their size they became unreliable. Then a search for abstraction began.

In the late 1960's, high level languages were used in the programming of operating systems as a result of these abstraction studies [19,20]. Through the use of high level programming languages, system programmers were able to concentrate their productivity on the problem being solved rather than on machine details. They were able to produce readable texts, therefore testing and maintenance of programs became easy. The extraordinality of these systems programming languages is the coordination and controlling capabilities of concurrent activities and the convenience of representing tables, queues, lists and similar data structures.

The developments on design and programming of operating systems were driven by the conceptual innovations on concurrent programming. In early 1960's the operating systems, such as Atlas (1961) and Exec II (1962) were not reliable because in those years the deadlock problem was not understood clearly enough [21,22]. Dividing a concurrent program into asynchronous modules with time independent behaviour was an important innovation and was first implemented in MIT's CTSS project [23].

In 1965, Dijkstra introduced the critical region concept [2]. Processes of concurrent programs usually operate on common variables for synchronization. Such common variables must be available to a single process at a time. Critical regions are used to prevent competing processes from using common variables simultaneously. Dijkstra proposed a special data type, named semaphore, for solving communication problems among processes. He used a hierarchical program structure [3] on THE operating system [1].

In 1971, Hoare introduced the concept of conditional critical region [4] by which execution of processes may be delayed until a shared variable satisfies some conditions. Process queues associated with shared variables were proposed by Hansen [24] to implement conditional critical regions. Hansen proposed a language notation monitor [5]. Hoare developed the monitor concept as a method on structured system programming [25].

In 1974, Concurrent Pascal [16,26,27,28,29] was defined and implemented. It was the first concurrent programming language based on

the monitor concept. Another language suitable for the design and testing of operating system algorithms, Simone, was implemented by Kaubisch [30]. Pascal has been used as basis language in the Simone project. Modula which is also based on the process and monitor concepts was proposed by Wirth in 1977 [31,32,33]. Pascal-plus, which is a realtime and simulation purpose language was implemented by Welsh and Busthard [34]. In those years Dijkstra proposed another control structure, called guarded commands, for process synchronization [6]. The coroutine approach has been used to simulate parallelism in some studies [35,36,37]. CSP/k was developed by extending Holt's SP/k system [38].

In the late seventies, efforts were concentrated to develop "program verification rules" [39,40] and new languages for distributed systems. Hoare proposed a language named Communicating Sequential Processes [41] and Hansen proposed another language named Distributed Processes [42] to satisfy the constraints of distributed storing, in 1978. On both languages Dijkstra's guarded commands [6] are adopted as sequential control structures.

The Ada programming language [43,44], which will probably be a widely used language in concurrent programming, was announced by U.S. Department of Defence in 1980. Edison [45,46], SR (Synchronizing Resources) [47], *Mod [48], Platon [49], Implementation of Communicating Sequential Processes [50] are some of the recently developed concurrent languages. Efforts to design an ideal abstraction for parallel activities and concurrent programming still continue.

2.2 Concurrent Programming: Concepts, Problems and Solutions

Concurrent programming is a programming technique in which several parts of a program may be in execution at a given time. For many years, it has been used for writing parts of operating systems. But, it is only recently that appropriate high level concurrent programming constructs have been developed and used in writing operating systems.

Operating systems of third generation computers are collections of asynchronous, interruptable software modules which are called processes. The functionally fundamental module of an operating system, called the

kernel, schedules the CPU among processes, receives i/o interrupts, transmits them to the devices and supports interprocess communication. The kernel uses clock interrupts to distribute the CPU time among processes. It gives each process the appearance of having its own CPU. Each of these virtual CPUs behaves like a real CPU except that there is a variable rate of progress. Use of multiple CPUs is called multiprocessing. The kernel and the physical (single processor) machine simulate a multiprocessor non-existing machine which is called virtual machine. The kernel's responsibilities can be implemented by hardware or microprogramming. Such an implementation makes asynchronous interrupts indivisible to all software modules.

Control problems of concurrency arise in systems where tasks operate in a parallel manner. Typical control problems are nondeterminacy in the system, deadlocks in the system, mutual exclusion and synchronization of tasks. Determinacy of a system is the independence of the system's outcome to the relative speeds of the processes within the system. Time dependent errors exist in a nondeterminate system. Deadlocks may frequently appear in limited resource systems. The mutual exclusion problem arises when two or more processes request the same resource in a system. When a resource is shared by processes in an uncontrolled manner, the processes modify the internal state of the resource and this causes nondeterminacy or deadlock in the whole system. Synchronization problems appear whenever the processes are dependent upon each other. Such processes must have a means to communicate with each other.

Dijkstra's THE operating system [1] may be used to demonstrate the basic concepts of concurrent programming. THE system has a hierarchical organization with five levels. Level one, which is the lowest level, is the kernel. It implements a virtual CPU for each process, i.e. the timesharing facility. Level two implements virtual memories to the processes on higher levels. Level three enables processes on higher levels to communicate with the operator. Level four consists of one process per i/o device. Level five consists of one process per allowed user program.

The outcome of a program, which consists of concurrently executing processes, depends on the speed of processes, i.e. some parts of the

program are time critical. If the outcome does not depend on the speed of the process, then the processes are called "independent processes".

When processes of a program have a shared data (or resource), they must access and update the data one by one. Otherwise, the final state of the shared data is unpredictable. As an illustration:

"Let, P1 and P2, which are the processes of a program, have a shared data, named CLOCK. P1 updates CLOCK while P2 clears it. P1 and P2 do not communicate with each other.

Process P1:	Process P2:
-	-
-	-
clock:= clock + increment;	clock:= Ø;
-	-
-	-

The outcome of the program absolutely depends on the speed of the processes. If the execution sequence of processes is P1, P2 then the result stored in the variable CLOCK is zero, otherwise it is different from zero."

The result is unpredictable and may not be the desired one, in this example. Such disasterous cases, called race conditions, can occur whether the processes execute physically or logically in parallel. In the physical parallelism, each process has its own processor and is simultaneously running. But, in the case of logical parallelism, processes are timesharing on a single processor and one process can be running at a time.

Race conditions may occur at the hardware level. As an example:

"Two processors, a CPU and a channel (or an i/o processor) can access a memory location. CPU tries to update the memory location, while the channel tries to store information to that location."

In practice, memory interlocking circuits allow only one process at a time to access the memory. Thus, the confusion described above is prevented.

Time critical parts of the concurrent programs are called critical sections or critical regions. Mutual exclusive access to these sections must be guaranteed either by software or by hardware tools.

Another fundamental concept, conditional critical region, [4] is used to explain permissibility of an operation on a critical region. The original suggested form for the conditional critical region is:

with r when B do C

where

r: common resource or data

B: boolean expression which tests the permissibility of an operation on critical region

C: critical region.

Concurrent programming software provides services for creating multiple activities and communication between activities. It is significantly difficult to understand and debug multiactivity programs. They should be approached with caution, because several activities could simultaneously access the same data and programs may work one day but may fail the next. Therefore, the problems of concurrency originate from the difference between timing of the asynchronous activities. Several synchronization techniques are used to solve the problems arising from concurrency in systems. Any synchronization technique must ensure that determinacy of the system is preserved and each activity is completed in a finite time interval.

Semaphores are the oldest process synchronization tools [2]. A semaphore is a synchronization variable and only two operations on it are allowed. These operations allow a process to block itself to wait for a certain event and then to be awakened by another process when the event occurs. These operations are called P and V operations. P operation, also called wait operation, and V operation, also called signal operation, can be characterized as:

P(s): wait until s > Ø and then subtract 1 from s.

V(s): add 1 to s.

where s is a semaphore variable.

Both P and V operations are indivisible. If the processes share CPU by time slicing, the P and V operations can be implemented via a software kernel. If the value of a semaphore is only 0 or 1 then such a semaphore is called a binary semaphore.

Locking scheme [51] is a synchronization method applicable to concurrent programming. A process may lock a shared data structure to ensure its inaccessibility while it is a temporarily inconsistent state. If a process attempts to lock an object that has already been locked it must either wait, abort itself or preempt the other process. Processes unlock the data structure after they complete their works on it.

Lock and unlock primitives [38] are used to guarantee mutually exclusive access to the shared data or resources. Lock/unlock mechanism, functionally, is a gate for a critical region. Before entering a critical region, a program should lock its corresponding gate, and afterwards should unlock it.

```
lock ( < lock identifier >) ;
  critical region
unlock (<lock identifier>) ;
```

A typical implementation of lock/unlock mechanism can be seen in PL/1 [13]. Lock/unlock statements and event variables of PL/1 can be used to create critical regions. In PL/1, an event variable can be declared as:

```
declare (<event variable>) event;
```

A built-in PL/1 function, completion, can be used to change the state of an event variable, such as:

```
completion (<event variable>) = true;
```

or

completion (<event variable>) = false;

The wait statement of PL/1 can be used to suspend program control of a task until status of corresponding event variable become true.

wait (<event variable>) ;

The task which is in the wait state can not change the status of an event variable, therefore resetting of an event variable to false should be performed explicitly. A task in PL/1 can be created by a call statement

call (<procedure name>(<parameter>) task (<taskname>)
event (<event variable>);

Call statement with task and event options starts up a child process to the caller. At that moment, the event variable in the call statement is set to false. When the child process has completed its job, it can be terminated by executing an exit statement. This sets the event variable used in the call statement to true. Parent process can wait for the completion of the child process by executing a wait statement which uses the event variable that is used in the call statement.

A PL/1 built-in function, status, can be used for interprocess communications. For example:

In process P1:

status (<event variable>) = integer variable ;

In process P2:

if status (<event variable>) > <integer variable> then ...

Monitor [25] is another synchronization tool for concurrent programming. A monitor can be thought of as a combination of a set of shared data and the critical sections for that particular set. A monitor provides appropriate facilities for guaranteeing mutual exclusion

and for blocking and waking up processes. A monitor may have more than one entry point. If a process enters into a monitor and finds that a required condition, related with shared data, is not true, then it enters into a wait state by executing a wait statement. When another process enters the monitor and finds the condition to be true, it executes a signal statement that removes a waiting process, if any, from the queue and wakes it up. The following Concurrent Pascal codes were used to implement a monitor which represents a clock keeping track of real-time. Explanations for some statements are given in quotation marks.

```
const  one min = 60.0; onehour = 3600;      "constant declaration"
       halfday = 43200; oneday = 8640000;
type   clock = monitor                       "monitor declaration"
var    seconds: real;
function entry value: real;                  "defines the present"
   begin   value: = seconds end;             "value of time"
procedure entry correct (time:real);         "sets the time to"
   begin   seconds: = time end;              "a given value"
procedure entry tick;                        "increments the time"
   begin
        seconds: = seconds + 1.0;            "by one second"
          if seconds > = oneday
              then seconds:= seconds - oneday;
   end;
begin  seconds: = 0.0 end;                   "sets time zero"
```

Processes enter a monitor to test or update a set of critical data, thus, they communicate with each other. Monitors are very useful and understandable structures for interprocess communication. Another way of interprocess communication is message passing mechanisms. Send and receive operations are used to specify desired i/o operations.

The send primitive is used to pass a message to another process. The receive primitive is used to block the user process until a message is accepted from the sender process. In most of the message passing

systems, the transmitted message is stored until received in some special buffer, sometimes called a mailbox. Many systems allow multiple-slot mailboxes in which messages are arranged on a first-in-first-out basis. In a zero-slot message transmission mechanism, if a send operation occurs first, the sender is blocked until a receive operation occurs. Conversely, if the receive occurs first, the receiver is blocked until the send occurs.

Coroutines [37] are process synchronization tools by which a quasi-parellel programming environment can be built. A coroutine starts with its first statement when it is activated the first time. It continues the execution until it suspends itself by transferring the control to another coroutine. The suspended coroutine can only be reactivated when an explicit transfer back to it is performed by one of the other coroutines. Then, it resumes its execution at the statement following the point of suspension.

Guarded commands and guarded regions [6] are the statements which are used to control program execution in recent parallel programming studies [41,42]. Guarded commands have the following syntax:

```
if  B1:S1 | B2:S2 |.. end
do  B1:S1 | B2:S2 |.. end
```

where B_i is a boolean, S_i is a sequence of statements and | denotes operator 'or'.

Meaning of the if statement is:

If some of the conditions B1,B2,... are true, then select one of the true condition B_i, and execute the statement S_i that follows it; otherwise stop the program.

Meaning of the do statement is:

While some of the conditions are true, select one of them arbitrarily and execute the corresponding statement.

The guarded regions have the following syntax:

when B1:S1 | B2:S2 |... end
cycle B1:S1 | B2:S2 |... end

Meaning of the when statement is:

Wait until one of the conditions is true and execute the corresponding statement.

Meaning of the cycle statement is:

Endless repetition of a when statement.

If several conditions are true within a guarded command or region, the statement that the machine will select is unpredictable.

Uncontrolled usage of lock/unlock or wait/signal mechanisms may cause deadlock in the system. Deadlock is a state in which two or more processes are waiting indefinitely for conditions which will never hold. It involves circular waiting such that each process is waiting for a condition which can only be satisfied by one of the others. But, since each process expects one of the others to resolve the conflict, they are all unable to continue. The deadlock problem was first recognized and analysed by Dijkstra [2]. A typical example of deadlock is explained below.

"Process P1 and P2 lock resources R1 and R2 respectively. After a while, process P1 tries to access the resource R2, while process P2 tries to access the resource R1. Both resources are not available to the requests of processes P1 and P2."

To analyse a deadlock problem in a system, the system is considered as a combination of a set of states and a set of processes, where each process is a function that maps states into states. A process is blocked in a state if it cannot continue execution when it is in that state. A process is deadlocked in a state if it is blocked in that state and in all future states which the system can reach. A state is safe if no process can map that state into a deadlock state. In a system with many different kinds of resources, deadlock is a difficult problem. If

a resource in a system can be used repeatedly by many processes, it can be called a permanent resource. If the resource is produced by one process and consumed by another, this resource can be called a temporary resource. A disk device and a message are examples for permanent and temporary resources respectively.

Necessary conditions for the occurrence of a deadlock with respect to permanent resources are the abscence of a mutual exclusive access mechanism to the resource, or having a nonpreemptive scheduling strategy on the resource, or allowing piecemeal allocation of the resource, or circular waiting of processes to acquire each other's resources. Preemptive scheduling strategy is a useful way to prevent deadlock but it leads to a less efficient utilization of resources. Another way of deadlock prevention is to allocate all resources needed by a process in advance of its execution. For example, all tape unit requests of a process can be satisfied just before the execution of the process starts, however this leads to the inefficient utilization of resources. A way of deadlock prevention, due to circular waiting of processes, is sequentially, hierarchically, ordering requests. The requests and releases of hierarchal allocated permanent resource are subject to a fixed sequential ordering [52]. Also, temporary resources can be allocated in a hierarchal manner to prevent deadlocks. Message transmission between processes can be organized hierarchally with finite process levels. Processes at lower levels, called masters, can supply processes at higher levels, called servants, with messages. Servants can return answers to their masters in response to messages. Thus, messages are sent in one direction only and answers are sent in the opposite direction.

Special models of parallel executing systems, such as Petri nets and computational schemata [52] have been developed to analyse and formalize the deadlock problem. Reusable resource graph [38] is an example of the modelling approach for the deadlock problem. This method concentrates on specific problems related to resource sharing. Resources such as tape drives are called reusable,because after they have been used by one process, they can be re-used by another process. The physical devices of computer systems, such as memory, tape drives and disks, can be thought

of as reusable resources. A system can be represented as a collection of processes and reusable resources by a graph having nodes for each process and resource. The units of a resource are shown by small triangles inside the resource nodes as illustrated below:

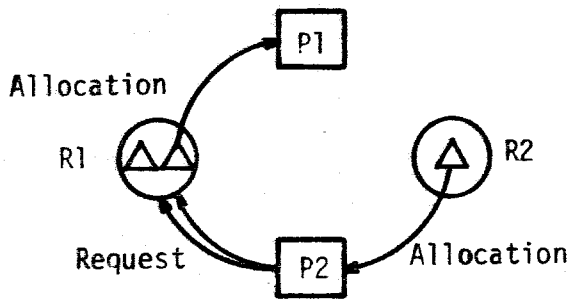
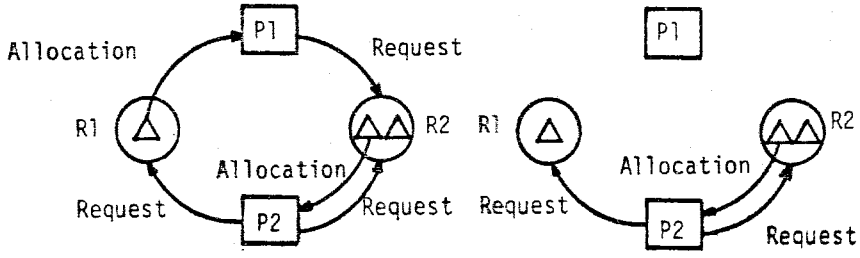


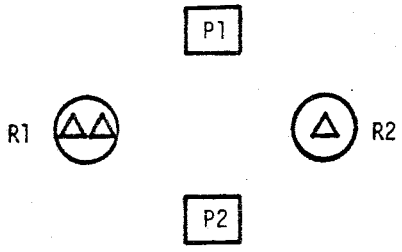
Figure 2.1 - Graph representation of reusable resources.

In this graph, resource R1 has two units and R2 has one unit. One of the units of R1 has been allocated to P1. P2 has acquired the unit of R2 and has requested both units of R1. P2 will be blocked until P1 releases its unit of R1. The reusable resource graph method is used to analyse such a graph to determine if there is a deadlock, i.e. to see if some processes can never be granted their requests. A graph can be reduced if the request of its processes can be granted. An example of a reduction operation is given below:



a) Initial state: One of the units of R2 has been allocated to P2, P2 has been requested one unit of R1 and one unit of R2. One unit of R1 has been allocated to P1. P1 has requested one unit of R2.

b) Process P1 has been satisfied by using one unit of R1 and one unit of R2. Therefore, the arrow linking R1 to P1 and P1 to R2 are removed to simplify the graph.



c) Process P2 has been satisfied by using one unit of R1 and two units of R2. The arrows linking P1 to R1, R2 to P2 and P2 to R2 are removed. Therefore, the graph is completely reduced.

Fig. 2.2 - Reduction of a reusable resources graph.

There are no deadlocked processes if and only if the graph is completely reducible. The order of reductions is immaterial because the same final graph is obtained regardless of the order.

Deadlocks can be broken by using time-outs to rewoke waits after a specified time interval. However, it is significantly difficult to pick a workable time-out interval. Another approach for deadlock protection is to use a locking strategy where locking rights of resources are determined in hierarchical manner. An alternative locking method, called predicate locks, is locking resources internally against external access when certain values related with resources satisfy predicates [51]. More on the theory of deadlock and related bibliography can be found in Holt's survey [53].

Communications between processes can be performed either by copying parameters within a common store or by i/o between seperate stores. Two major classes, procedure calls and message passing, have been evolved for process interaction. Communication between processes may be synchronous or asynchronous. In the case of asynchronous communication, one of the processes can deliver a value and go on; at some later time, another process may pick up this value. Interprocess communication scheme of Concurrent Pascal is an example of asynchronous strategy. Concurrent Pascal uses monitors for process communication. In the case of synchronous, processes must send and receive values simultaneously. The synchronous communication technique was proposed as the communication

method in Communicating Sequential Processes and Distributed Processes. Classification and comparison of communication techniques are discussed by Straunstup [49].

2.3 Concurrent Software

The cheap processing power provided by present computer technology has led to a variety of proposals for concurrent programming methodology. In the last decade, many concurrent languages have been proposed, such as Concurrent Pascal, Pascal-plus, CSP/k, Modula, Simone, Communicating Sequential Processes, Distributed Processes, Edison, *Mod, Ada, SR, Platon and most of these languages have been implemented for different machines. Some of them, such as Concurrent Pascal, Simone, Pascal Plus, Modula, Communicating Sequential Processes, Distributed Processes, Ada are worth discussing because of their structural and functional properties.

Concurrent Pascal [16] is an extension of sequential Pascal with concurrent processes, monitors and classes. It is primarily implemented for a PDP 11/45 machine. Concurrent Pascal compiler generates pseudo codes for a virtual machine that can be simulated in any other physical machine. An interpreter program may analyse and executes those virtual codes. Kernel, in the original Concurrent Pascal implementation, is an assembler program that multiplexes the processor among concurrent processes and gives them exclusive access to monitors. Concurrent Pascal consists of three kinds of system types: process, monitor and class. A process is a combination of a private data structure, a sequential program and access rights. Processes can only operate on their own private data. But, they can share certain data structures in monitors. The other system type monitor consists of shared data structures and procedures called monitor procedures. Synchronization operation are controlled by monitor procedures. A monitor also has an initial operation section for the shared data structure. Concurrent Pascal has a special data type, called queue, which can be used by monitor procedures to control execution of processes. A monitor can either delay the execution of a process and place it in a queue or resume the execution of

a process waiting in a queue. Only one process at a time can wait in a queue. A class defines a data structure and possible operations on it. The machine does not have to schedule simultaneous calls of class procedures in run time. A class can only be initialized once, and then, its parameters and private variables exist forever. Concurrent Pascal checks that the private data of a process is accessible only by that process. It also checks that the data structure of a class or monitor is accessed only by its procedures. There is one restriction due to storage allocation and deallocation mechanism, that a Concurrent Pascal program consists of a fixed number of processes, monitors and classes. These components and their data structures will exist forever after program initialization.

Simone [30] is also an extension of Pascal with three basic features: process, monitor and condition variables. Condition variables are used to synchronize processes by means of wait and signal operations. They can be declared within a monitor only. There is a queue for each condition variable in which two or more processes can wait for their activation. Processes are those parts of Simone programs which can be executed in quasiparallel fashion. In a quasiparallel system, there is by definition only one processor, the program control passes to another process only at places where the current process explicitly specifies its own suspension. As they are activated, processes are pushed onto a sequencing stack and commence execution. Eventually when the sequencing stack becomes empty, the first process on the time queue is moved onto the sequencing stack, simulated time is advanced to its restart time. When a currently executing process performs a signal operation, the reactivated process is moved from the condition variable queue to the sequencing stack and immediately resumes execution in place of the signalling process. The fundamental assumption on Simone store management is that all the processes will be active simultaneously. Therefore, the storage allocation mechanism is static and there exists no storage recovery operation.

Pascal-plus [34] is an extension of Pascal which can be used in either realtime or simulation mode. It has a block structure construct, called envelope, which provides modularity of programs. Essential

programming structures are processes, monitors and condition variables. Condition variables have single first-in-first-out queues. Pascal-plus, being a successor of Simone, provides simulation facilities. It consists of a simulation monitor on which processes may suspend themselves for a period of pseudo time. The programs ultimately intended for real-time use can be tested by simulation facilities of the language. In realtime mode, the actual realtime devices are connected to a system instead of simulation processes that correspond to those devices. The input/output handling of the language is dependent on implementations for specific machines. For example, input/output handling operations are expressed in terms of standard Pascal file operations in the original implementation of Pascal-plus. Pascal-plus allows a static memory allocation system for processes and monitors which are exploited during compilation of the program.

Modula [31] which is based on module concept is intended primarily for programming dedicated computer systems, including process control systems on smaller machines. It relies very strongly on Pascal. The module concept has been introduced as an essential supplement to the block concept. A module is a collection of constant, type, variable and procedure declarations called objects of the module. A module contains two lists of identifiers. A define list mentions all module objects that are to be accessible outside the module. A use list mentions all objects declared outside the module that are to be accessible inside. Identifiers in the define list are said to be exported, those in the use list are imported. Multiprogramming facilities are the processes, interface modules and signals which are added to the language called Sequential Modula. A process can not create other processes. Process creation is possible in the main program only. Modula supports the possibility of dynamic process generation, but it does not support the recycling of its store. Therefore, overall storage allocation mechanism of Modula is static. Synchronization operations are achieved by the use of signals. Signals can be sent, and a process can wait for a signal. Processes cooperate via common variables. An interface module, which is a kind of monitor, is a set of critical sections

where simultaneous execution by several process is excluded. The interface module allows more than one process to be in a critical region, provided that all but one are either waiting for a signal or sending a signal. The essential characteristic of Modula is the absence of interrupts. Modula is unusual in that it is designed to run on a bare machine without any operating system support.

Distributed Processes [42] is a language concept that is introduced for concurrent processes without common variables. These processes communicate and synchronize by means of procedure calls and guarded regions. A process on the language defines its own variables, common procedures and initial statements. It may call common procedures either within itself or within other processes. A process performs two kinds of operations, the initial statements and external requests made by other processes. The language is proposed for realtime applications controlled by microcomputer networks with distributed storage. There is no need for interrupts in a realtime program written in the proposed language. Fast response to external requests is achieved by dedicating a processor to each critical event in the environment. An attractive feature of the proposal is that it lets a process carry out computations between external calls of its procedures. Synchronization of individual processes is handled by means of guarded regions. As an illustration:

```
process   sem;  s : int
proc      wait; when s > Ø :   s:= s-1   end
proc      signal;   s:= s+1
s := Ø
```

The process sem is a semaphore implementation. It is initialized by the statement s:= Ø and wait/signal operations are defined by procedures. The when/end structure is a guarded region where the calling process waits until variable s is greater than zero. Processes are permanent in Distributed Processes language. Proposed mechanism for storage allocation is static. In the implementation of the language, parameter passing between two processes requires a single input operation

before the called procedure is executed and a single output operation when it terminates.

Communicating Sequential Processes [41] is a language proposal which has a brevity so that the primitive concepts are expressed with single character notation. In the language, guarded commands are adopted as sequential control structures. A simple i/o command is used for communication between processes. There is no automatic buffering in the i/o operations. Input commands may appear in guards. The language is implementable both in a machine which has a single main store and in a network of processors connected by i/o channels. A parallel command of the language specifies concurrent execution of its constituent processes. Communication occurs between two processes of a parallel command whenever an input command in one process specifies as its structure, the process name of other process, and an output command in the other process specifies as its destination, the process name of the first process, and the target variable of the input command matches the value denoted by the expression of the output command. The following statement is an illustration for process communication:

X :: *[c:character; west?c → east!c]

Process X copies characters from process west to process east.

The Ada programming language [43] was developed as the result of a procurement exercise by the U.S. Department of Defence. It is a powerful and elegant language with the features of data abstraction, exception handling, seperate compilation and concurrency. The data abstraction construct of the language is called a package which consists of two parts, the package specification and the package body. The package specification lists all objects which are accessible outside of the package. Generic definition facility is an ability of Ada language to parameterize units over appropriate data types. Exception handling feature provides that the control is transferred to an emergency action when a specific exception condition is raised. Seperate compilation feature permits the compilation of a program in distinct pieces. Ada allows concurrent tasks to be introduced into a program by using a

notation similar to that for packages. Intertask communication is handled by means of "randevous". Calls to transfer data are received by an accept statement with the called task. Nondeterminism is handled by using a select statement, each select alternative being preceeded by an optional guard. Since dynamic memory allocation and deallocation mechanism may be quite slow, Ada allows the maximum space to be allocated to a collection of dynamic objects such as tasks.

In Univac 1100 systems, the vendor supported languages with concurrency features are Plus [10,11], PL/1 [13] and Cobol [12]. Cobol is not worth discussing because it is inconvenient for system programming. But, in PL/1 multitask programming, users may use the following statements:

- call with task and/or event options
- clear
- lock
- post
- stop with or without task option
- wait
- unlock

Synchronization of the processes can be achieved by using the following built-in functions:

- completion
- status

Task, event and lock constants or variables are used on synchronization operations. A task constant represents a symbolic name which is dynamically associated with a task. It is initially inactive and becomes active when it is associated with a task and is inactive again when the task is terminated. An event constant represents a symbolic name of a dynamically associated task. It is inactive initially, becomes active when it is associated with a task, and is inactive again when the associated task is terminated. A lock constant represents a symbolic name of lock. Locks are used to protect a certain data area. Lock/unlock

statements are used to create a critical region.

A new task may be created by executing a call statement with task and event options. For example:

call sub-task task (t1) event (e1);

The wait statement is used to suspend the control of a task until an event associated with the wait statement has been completed.

wait (e1);

Programmers can alter the completion state of an event by using post and clear statements:

post	statement sets an inactive event constant or variable to complete
clear	statement sets an inactive event constant or variable to incomplete

The completion built-in function is used to know whether the state of an event is complete or incomplete. The built-in function status is used to change the status value of event variables, therefore these variables are used as communication signals among tasks. But, Univac PL/1 compiler contains a variety of bugs which may be solved in new releases.

The Plus compiler of Univac [11] was a restricted software for many years. It was used on system programming and compiler writing studies under the control of Sperry Univac. In recent years, the Plus 5R1 compiler was released worldwide.

Plus is a language which consists of language constructs similar to PL/1 and Pascal. The powerful feature of Plus is the ability of accessing facilities which can only be used in assembler programming. Plus provides a facility, called inline, for generating assembler code sequences. Since the inline facility of Plus is actually part of the compiler, it has access to the compiler's information tables to retrieve needed information. The inline facility has on and off directives to facilitate the conditional and/or iterative generation of code.

On the other hand, Plus allows programmers to direct the compilation by using compile-time statements, such as copy, include, resume and define. The copy statement provides a mechanism by which line images from other resources are incorporated into the compilation. The include and resume statements permit the conditional compilation of source code. The define statement allows the parameterization of programs.

Modularity in Plus programming is maintained by using module and term statements. The environment facility of Plus allows a program to save processed declarations that can be read into other compilations later.

Multitasking in Plus programming is possible by using inline facility. For that reason, programmers, who try to write multitask programs by using Plus, must have an extensive knowledge of Exec 8 and Univac 1100 assembler programming.

2.4 Application Area of Concurrent Software

Operating systems are the basic application fields of concurrent programming since concurrent programming grew out of problems associated with them. Timesharing, multiprogramming, distributed processing and similar sophisticated software systems can be realized after understanding concurrent programming concepts. Defects of operating systems are reduced to a minimum by using concurrent programming software and abstract data types. Concurrent programming will develop while it is used to increase availability and performance of parallel hardware facilities.

Concepts used on concurrent programming are very similar to concepts used on discrete event simulation. Data structures used in concurrent software may be used for scheduling and queuing events in simulation models. Concurrent software may be extended by adding special type priority lists and data structures to create a powerful simulation language. Simone is an example of this approach. Similarities between queuing network elements and concurrent language elements is stated by Sauer [54]. Various types of nodes on extended queuing models are

similar to semaphores and monitors in concurrent programming.

Concurrent programming is the only programming technique used on programming realtime systems which are the systems such as industrial plant control, military command control, air traffic control systems. Requirements of realtime systems are very special. A realtime program must respond to a variety of indeterministic requests from its environment. The programs cannot predict the order in which requests will occur. It absorbs and processes dozens of different asynchronous external signals and operator commands. Programs must respond to requests within certain time limits. Otherwise, input data to the program may be lost or output data of the program lose its significance. Concurrent software may reduce the programming effort and increase the reliability of programs which are applied to the control engineering field.

Time and space requirements of large scale mathematical problems may be reduced when the problems are solved in a multiprocessor media. Recently developed algorithms in the fields of sorting, polynomial evaluation and graph operations permits making a tradeoff between space, time and processors in a multiprocessor or a distributed system [55,56, 57,58,59].

Artificial intelligence subjects such as game playing and robotics are the application area of concurrent programming. Parallel algorithms for alpha-beta search or implementation of transportation tables in game trees improve the search speed. A discussion on parallel searching on game trees may be found in Marshlands' survey [60]. In another survey by Bonner [61], robot languages are classified and their extensibility, concurrency and modularity features are evaluated. A robot language would include the ability to operate different devices concurrently. Concurrent operations are performed either by wait/signal mechanism or parallel block execution. Wait/signal primitives are commonly used to synchronize processes in robot control programs. The parallel block execution method is preferred when concurrent processes are executed in different devices and they communicate with each other.

2.5 Description of CPS/1100

CPS/1100 was primarily designed to aid the writing and understanding of concurrent programs in various fields of computer science. The primary concern during the design and implementation phases was to produce a concurrent system suitable for writing model operating systems, real-time applications and discrete simulation.

CPS/1100 is designed to provide facilities to solve concurrent programming problems such as deadlock, mutual exclusion and nondeterminism. Special attention was devoted to facilitate the easy debugging of CPS/1100 programs. Two debugging aids are made available to users. Users may get a dump of process synchronization variables or may examine status of activities.

Processor dedication facility of CPS/1100 provides physical concurrency in program execution. Therefore, efficient parallel algorithms for mathematical and engineering problems can be programmed by using CPS/1100.

Structurally, CPS/1100 is an extension of the Pascal 8R1 compiler which was developed in Institute of Datalogy of University of Copenhagen. Pascal 8R1 compiler permits assembler code insertion into programs and seperate routine compilation. Syntactically, CPS/1100 and Pascal have the same structure. CPS/1100 has a prescanner to perform syntactical and semantical analyses of its commands and control directives. Prescanning is achieved in three phases. Prescanner programs were written by using a high level string processing language, Macro. At the end of the prescanning operation, a program, which is a mixture of Pascal and assembler codes, is created by CPS/1100. These assembler codes are used to call executive requests [62] for exception handling, processor dedication, activity creation, removal and control. Also, test-and-set type assembler instructions are used to implement and maintain critical regions. Afterwards, the Pascal 8R1 compiler generates an assembler program text instead of an object code stream. This assembler stream is then processed by the CPS/1100 postscanner which is also a Macro program. The postscanner recognizes the messages inserted during prescanning. It processes the

assembler code stream according to these messages. The final form of the program is a Univac assembler program which can only access the Exec8 and Pascal 8R1 libraries. This final form of the program is assembled and linked to produce an executable element. Block diagram of the CPS/1100 structure is given in Figure 2.3.

The basic restriction of CPS/1100 software is that procedure activation records are not allocated and deallocated dynamically. Therefore, CPS/1100 does not permit processing of multilevel routines. In other words, CPS/1100 allows only single level routines and its memory allocation mechanism is static.

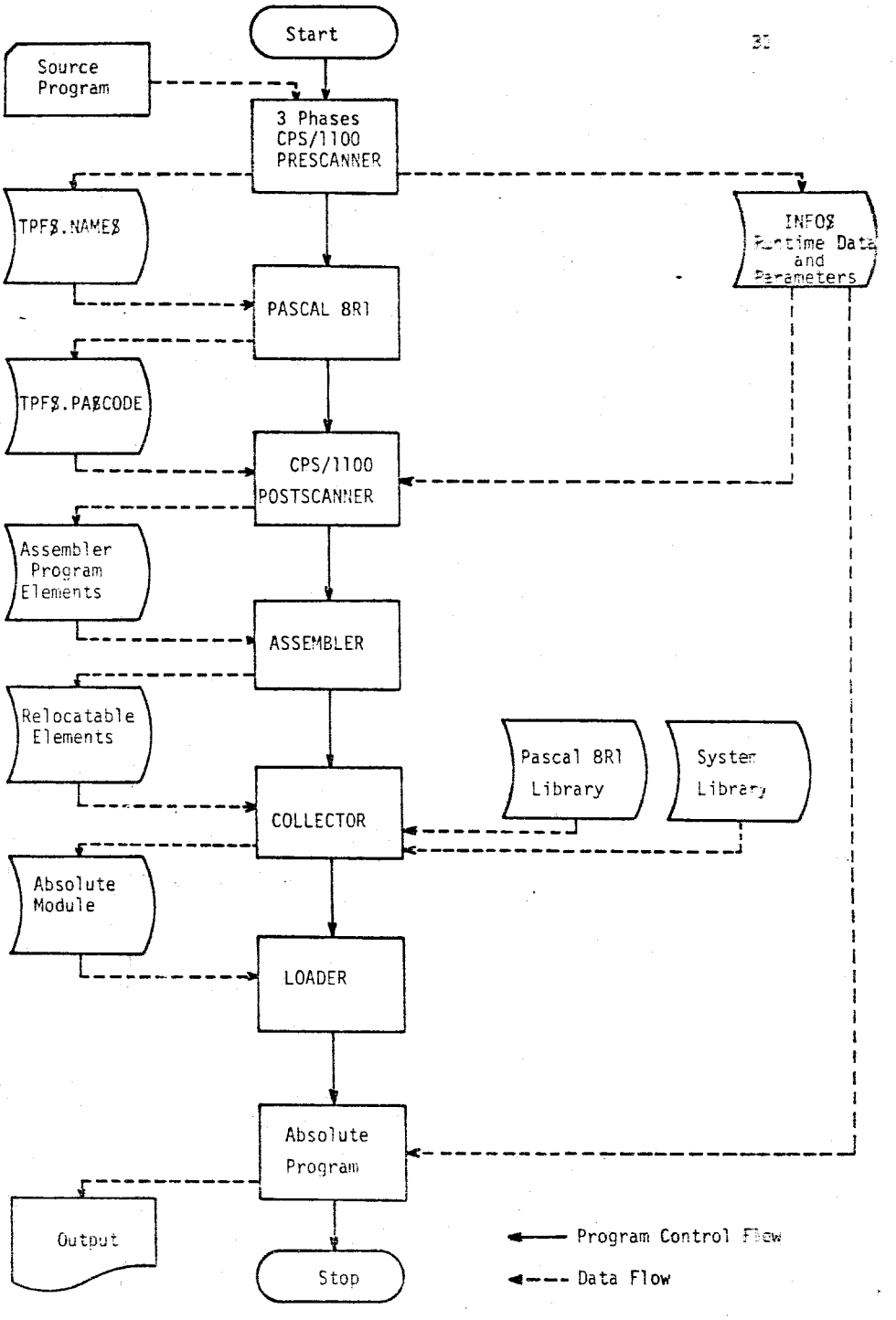


Figure 2.3 - Block Diagram of the CPS/1100 structure.

III. MULTITASKING ON UNIVAC 1100 SYSTEMS

Generally the name activity, which corresponds to the name process, is used to denote a program control flow in Univac terminology. The operating system of Univac 1100 machines, Exec8, provides services for creating multiple activities and for communication between activities. Several activities could simultaneously be in execution in programs. Activities created by Exec8 are identified in either of two ways: by an 'activity-id' or by an 'activity-name'. A program initially consists of a single activity. This is the initial activity of the program. Other activities can be created by using a fork$ request. Each child activity may have either the minor register set, which includes X8-X11, AØ-A5 and R1-R5 registers, or the major register set, which includes all user registers. Details of multitasking are given in this chapter.

3.1 Multiple Activity Programs and Activity Control

The operating system of Univac 1100 machines, called Exec8, provides services for creating, removing and controlling multiple activities. Activities may be identified by an activity-name, or by an activity-id or both. An activity-id is a number in the range of 1 to 35. An activity-name contains a maximum of three characters. An activity can be named by using the executive request name$. Activity names are used to activate or to interrupt the execution of tasks. Activity-ids are used to wait for the termination of other activities.

A program initially consists of a single activity called the initial activity. Other activities of a multitask program are created by using an executive request fork$. The entire program can be terminated by using the executive request abort$, while a single activity can be terminated by using exit$.

Activities can be controlled by await$, act$, dact$, twait$, int$ and aded$ requests. An activity may be delayed until the completion of other activities via the await$ request. This request can be used by an activity to suspend its execution until the completion of specific activities. The waiting activity and the activities being waited for are distinguished by their activity-ids. Act$ and dact$ requests may be used to activate and deactivate activities. Dact$ request suspends the activity that requests it. Act$ request causes the resumption of a named activity. An activity that issues an act$ request must have an activity name assigned through the use of a name$ request. Activities may interrupt each other by using the int$ request. Int$ request creates a contingency condition, which is an abnormal occurrance, in a indicated activity. Control of interrupted activity is directed to a predefined routine when an interactivity interrupt is handled via int$ request. A routine, called contingency routine, must be registered via all$ request by the interrupted activity. Another necessary condition to achieve an interactivity interrupt is that the interrupted activity name.

Test and set mechanism can be used to create and control critical regions. An activity may lock a critical region by using a test and set instruction. Another activity may reference the critical region by using a test and set instruction and if the region is locked, that activity enters a busy wait state (periodic checking) until the first activity unlocks the critical region.

Timed waiting is another technique used in synchronization operations. The execution of an activity can be delayed for a specified time interval by using the twait$ request.

Activities may have either a subset of user registers, called minor register set, or all of the user registers according to selected parameters during their creation.

Test-and-set queuing mechanism can be used to control interactions between activities. In this mechanism, an activity sets a test-and-set flag and then deactivates itself by clearing the test-and-set flag, until another activity sets the test-and-set flag and activates the first activity by clearing the test-and-set flag. Exec8 uses a queue for each test-and-set flag if a test-and-set queuing registration is

performed. The registration can be performed by calling the executive request tsqrg$.

Contingency handling mechanism of Exec8 is applicable to many exception conditions, other than interactivity interrupts, such as overflow/underflow, i/o errors. Exec8 stores information about interrupted activity into an information packet when a contingency condition is raised. At that moment, the interrupted activity has a high internal priority, called 'in contingency mode'. The activity leaves contingency mode when it calls an executive request. Error-address field of contingency packet, which contains the location counter when the activity is interrupted can be used to resume the execution of the activity.

3.2 Activity Creation, Removal and Naming

A fork$ request with a parameter word can be used to create a new activity. The s2 field, bits 24-29, of parameter word contains the activity-id which is unique and in the range of 1-35. If the s2 field is zero then the activity does not have any activity-id. The h2 field of the parameter word, corresponding to bits 0-17, is the address of first instruction to be executed by the new activity. The s3 field of parameter word, corresponds to bits 18-23, must be zero to indicate that all user registers are active. The parameter word must be loaded into AØ register before the executive request fork$ is called.

Following instructions are sufficient to create an activity.

```
        L   AØ, (Ø11, newactivity) . Load the parameter word
        ER  FORK$                  . Issue an executive
         -                           request to activate
         -                           the process indicated
         -                           by the parameter word
newactivity
         -
         -
```

The executive request exit$ should be used to remove an activity from the system.

The name$ request is used to assign a name to an activity. It converts an 18 bit, i.e. three characters, name to a one word activity name. The 18 bit user defined name must be unique. It must be loaded into the AØ register before the name$ request is called.

An activity is named and that name is stored at a specific location by the following codes:

```
L, U        AØ,'ABC'
ER          NAME$
S           AØ, activityname
```

3.3 Activation and Deactivation of a Named Activity

The executive request act$ activates an activity which is already named via a name$ request. It resumes the execution of the named activity after the activity deactivate itself by using a dact$ request. The name of the activity must be loaded into the AØ register before the executive request act$ is called. If the activated task is currently active it will not be deactivated after its next dact$ request.

In the following example, an activity is activated:

```
L           AØ, activityname
ER          ACT$
```

A named activity may deactivate itself by using dact$ request. Dact$ request prevents the execution of the activity until it is activated by another activity. If other activities have issued act$ request for an activity before it performs a dact$ request, deactivation does not occur and execution continues. If an activity remains deactivated after all activities have terminated, an await$/dact$ ambiguity error is reported by Exec8.

An activity deactivates itself through the following instruction:

```
ER          DACT$
```

3.4 Waiting for Activity Completion

The execution of an activity can be delayed until the completion of one or more activities by using the await$ request. Initial activity of a program can not call await$ request because it does not have an activity-id. A bit mask is used to indicate the activities being waited for. Bit Ø of the mast must always be zero. The activity-ids of the activities being waited for, must be used to indicate the bit positions which would be set to 1. The mask word must be loaded into AØ register just before calling of await$ request as illustrated below:

```
L       AØ,mask word
ER      AWAIT$
```

3.5 Contingency Registration and Interactivity Interrupt

The executive request iall$ can be used to register a contingency routine. A mask word is used to indicate the types of contingencies that may be handled by the contingency routine. Bit 34 of the mask word must be set to 1 to handle interactivity interrupt type contingency. H2 field (bits 0-17) of the mask work contains contingency routine address. The mask word must be loaded into AØ register before requesting iall$. The first two words of contingency routine is called the contingency packet. The contingency packet consists of information about contingency processing. The address, that is the location counter at the moment interrupt occurred, is stored in the H2 field of the first word of contingency packet. Interrupted activity can be resumed by transferring control to the successor of that address. The contingency packet is immediately followed by the codes of a contingency routine. An activity in a contingency routine is in contingency mode until it calls an executive request.

Another executive request, creg$, is used for contingency registration. Creg$ request allows the contingency packet to be seperated from the contingency routine. Further details on contingency registration are given in the Univac Executive System manuals [8,62].

The executive request int$ can be used to handle interactivity interrupt. An activity that may be interrupted must register contingency before it is interrupted. If an interrupted activity is already deactivated via an await$ or dact$, it is reactivated to handle the interrupt. If an interrupted activity has been deactivated via a test-and-set queuing request, it will be interrupted after activation is performed by another activity via test-and-set clear and activate request. The name of activity being interrupted is loaded into AØ register before int$ requested as illustrated below:

Interrupting Activity

```
        -
        L,U         AØ, name-of-the-interrupted-activity
        ER          INT$
        -
```

Interrupted activity:

```
        -
        L,U         AØ,activityname
        ER          NAME$                       . Activity naming
        L           AØ,(Ø2ØØØØØ,contingency-routine)
        ER          IALL$                       . Contingency registration
        -
        -
        -
        -
        -
        -
        ER          EXIT$
Contingency-routine
        RES         +2                          . Contingency packet
        -
        -
        -
        J           somewhere                   . Jumping
```

3.6 Test-and-Set Instruction and Test-and-Set Clearing

Test-and-set instruction (ts) is designed to cooperate asynchronous tasks via a common location for the tasks, called test-and-set cell. TS instruction checks bit 30 of test-and-set cell whether it is Ø or 1. If bit 30 of the cell is zero, the next instruction of the program is executed and this bit is set to 1. If bit 30 is set to 1, an interrupt occurs and the processor does not service this activity for a while. The activity receives control back and checks bit 30 of the cell again. A test-and-set cell can be created via a special assembler procedure t$cell. Bit 30 of a test-and-set cell can be reset to zero by using c$ts executive request. ts and c$ts pair can be used to create critical regions as illustrated below:

```
                -
cell            T$CELL                  . test-and-set cell creation
                -
                -
                TS      cell
                -                       . Critical region
                -
                C$TS    cell
```

3.7 Test-and-Set Queuing Registration and Deregistration, Test-and-Set Queuing and Activation

The executive request, test-and-set queuing registration, tsqrg$ is used to register automatic queuing of test-and-set conflicts within a program. On the contrary, test-and-set queuing deregistration request, tsqcl$, supresses queuing operations on test-and-set conflicts, but activities already on queues will be serviced by clear test-and-set and activate, c$tsa, requests.

The assembler procedure c$tsq clears a test-and-set cell and deactivates the requesting activity. The cell referenced by that request must be declared before. A test-and-set cell must be processed by a ts

instruction before it is referenced in a c$tsq request. Otherwise, the result of the c$tsq request may cause an ambiguity on the program execution.

The assembler procedure c$tsa clears a test-and-set cell and activates one activity, queued to the cell, which was deactivated by a c$tsq request. The cell must be set via a ts instruction before c$tsa request is used. c$tsa causes a search on a specific queue for an entry created by c$tsq request. If such an entry is found, it is activated and the test-and-set conflict is cleared.

The following example is a solution for a 'producer-consumer' problem by using c$tsq and c$tsa requests:

Activity A1, of program A, is passing information via a common data bank to activity B1 of program B. The following subroutines will provide the data protection and activity synchronization. CELL is in a common bank and it has test-and-set and queuing registered.

Within activity B1:

```
Lock data area (TS CELL)
Check for input
If input exists, remove it, clear (C$TS CELL), return
If no input, clear lock and deactivate (C$TSQ CELL)
```

Within activity A1:

```
Lock data area (TS CELL)
Deposit input for B1
Clear lock and activate (C$TSA CELL)
Return
```

3.8 Activity/Processor Dedication

The executive request aded$ dedicates a processor to a specific activity. A mask word should be used to indicate the processor on which the aded$ requesting activity is to be processed. The 2^n th bit indicates

processor n of a multiprocessor Univac 1100 system. The mask word must be loaded into the A0 register before aded$ is requested. At most one processor may be requested. A mask setting of zero, releases an activity. If the requested processor is down or nonexistent, the activity will be terminated in error.

Clearing mask and then calling aded$ request after an activity/processor dedication operation causes the return of the activity to normal processing mode in which activities may be serviced by any available processor.

IV. CPS/1100 KEYWORDS, STATEMENTS, STRUCTURE AND INMPLEMENTATION DETAILS

A set of keywords was developed to enhance parallel programming and process synchronization in CPS/1100. A complete list of keywords is given in Appendix C. CPS/1100 is structurally divided into three phases: prescanning, pascal compilation and assembler code modification. A series of Macro programs is used in the prescanning and assembler code modification phases.

In the design phase of CPS/1100, the syntax of the Pascal language was preferred as the syntax of CPS/1100 for the following reasons:

- CPS/1100 was an extension of Pascal; it should obey the syntactical rules of Pascal as much as possible.
- One of the design aims of CPS/1100 was to develop a concurrent language for average programmers. Therefore, it would be better that CPS/1100 has the same syntax of Pascal.

The open/close paranthesis characters are used as delimiters in some of CPS/1100 statements, while the semicolon character is used to denote a end-of-statement. Therefore, a close syntactical similarity can be observed between statements of CPS/1100 and statements of Pascal 8R1 and PL/1. For example, process and monitor declarative statements of CPS/1100 have the same syntax as the external routine declaration of Pascal 8R1. The lock/unlock statements of CPS/1100 are very similar to the lock/unlock statements of PL/1.

In this chapter of dissertation, detailed information about CPS/1100 statements, structure and implementation is given.

4.1 Declarations

4.1.1 Process and Monitor Declarations

A CPS/1100 program is composed of a main and several external procedures. External procedures are declared as either monitors or processes. Examples for process and monitor declarations are given below:

```
procedure forks (var fentry:labels; var philid:integer); monitor;
procedure phils (var pentry:philent); process;
```

Rules:

1. All process and monitor declarations must exist in the main program.
2. Only declarations of processes or monitors that will be called in a certain process are required within that process.
3. Monitor or process declarations must be placed before variable declarations in the main program or procedures.

4.1.2 Queue Type Declaration

Queue variable type is used only for condition variables of a CPS/1100 program. A queue variable can be used only for process synchronization purposes. An example for queue type declaration is given below.

```
var syncvar : queue;
```

Rule:

1. The maximum length of a queue variable is 12 characters.

4.1.3 Forward Declaration

Forward declaration placed after an argument in a start-up or fork statement prevents the transfer of the value or address of that specific argument to the procedure called. As an example:

fork with taskname (xx) procname (argument1, argument2 forward,...);

The forward keyword in the example prevents the transfer of the value or the address of the argument2 to the called procedure procname. This approach is similar to the 'optional parameter passing' mechanism on procedure calls.

4.1.4 i/o Initiation and i/o Termination Locks

Queue type variables are used to create a critical section around i/o statements in slavetasks. A lock command which uses i/o initiation lock is placed just before a read/write statement in a slavetask routine by CPS/1100. An unlock command which uses i/o termination lock is placed to the line that succeeds a read/write statement in a slavetask routine. These variables are common to model and slavetask routines. They may be used for synchronization purpose. Following statements are examples for the declarations of lock variables:

```
aaa : ioinitiation lock of queue;
bbb : iotermination lock of queue;
```

Rule:

1. Variables must be declared in the CPS/1100 main routine.

4.1.5 i/o Initiation and i/o Termination Flags

These variables are used in wait and signal statements if slavetasks perform input/output. CPS/1100 model tasks can control slavetasks by these flags when slavetasks perform i/o operations. These

variables are common to model and slave activities. The following statements are examples for the declaration of these flags.

```
aaa : ioinitation flag of queue;
bbb : iotermination flag of queue;
```

Rule:

1. Variables must be declared in the CPS/1100 main routine.

4.2 Keywords and Statements

4.2.1 Startup with Taskname and Startup Slavetask Statements

A startup with taskname statement creates a new activity with an activity-id associated with the taskname given. The calling activity enters a wait state until it is resumed by a release statement in the called procedure. In the meantime, the new activity provides for storage requirements of arguments, of local variables and of link data segment. It also sets a specific global variable associated with that procedure as the activation record pointer. The following statement creates an activity and transfers control to procedure gauss.

```
startup with taskname (task1) gauss (a,b,c);
```

Rules:

1. A taskname given to a specific activity must be unique. However the same taskname can be used for another activity if the programmer is sure that the previous activity has exited.
2. A startup statement must be used on the first call of any procedure and used only once.

A startup slavetask statement creates an activity with an activity name. Activity name can be a string up to three characters in length and has to be declared in the CPS/1100 control card of the slavetask.

Startup slavetask statement must be the first executable statement of the CPS/1100 main routine. The main activity enters a wait state, when a slavetask is started, until the name of the started slavetask is stored in a specific activity name field by the created activity. In the following statements 20 slavetasks are created.

```
i:= 1;
while i =< 20 do begin
                    startup slavetask (i); i:= i+1;
                end;
```

Rule:

1. All slavetasks must be started up in the CPS/1100 main routine before any activity is created.

4.2.2 Fork Statement

Fork statement creates a new activity with an activity-id associated with the taskname given. When the new activity enters into the called procedure, it sets a specific index register as the activation record pointer of the called procedure by obtaining the record address from a global variable which has been set by a startup statement. An example for the fork statement is given below:

```
fork with taskname (task09) gauss (a,b,c);
```

Rule:

1. The taskname given to a certain activity must be unique. However the same taskname can be used for another activity if the programmer is sure that the previous activity has exited.

4.2.3 Release Statement

Release statement causes the father activity, that is in a wait state after a startup statement, to resume its control again. Format of the release statement is given below:

release (<proc-id>);

where proc-id is the name of the procedure called in startup statement. For example, let the procedure gauss be called by a startup statement in the main routine and the control is suspended. New activity resumes the control of main activity by executing the following statement in procedure gauss:

release (gauss);

Rule:

1. Release statement must be used only once in a procedure.

4.2.4 Await Statement

This statement suspends the execution of an activity while specified activities exist in the system. The following statement suspends the execution of the calling activity while the activity named taskØ9 exists in the system.

await (taskØ9);

An activity may suspend its execution while more than one activity exists in the system with an await statement as shown below:

await (taskØ9,task21,abcd);

Rule:

1. Taskname(s) in an await statement must have been used in a startup, fork or cobegin statement before it is used in an await statement.

4.2.5 Wait and Signal Statements

Wait statement is used to suspend the execution of an activity and queue it to a test-and-set cell. An activity that executes a wait statement is deactivated and placed in a queue associated with the test-and-set cell. The following statement is an example for wait statement use:

```
wait (msg);
```

where msg is a queue type variable.

Signal statement is used to resume the execution of an activity previously placed in a test-and-set queue. It causes a search in the queue associated with the specified test-and-set cell and the first activity in the queue is reactivated. For example the following statement reactivates the activity that executed wait(msg) statement:

```
signal (msg);
```

Rule:

1. The condition variables referenced in wait and signal statements must have been declared as queue type variables in the main CPS/1100 routine.

4.2.6 Lock and Unlock Statements

Lock and unlock statements are used to create critical regions. An activity that executes a lock statement sets a test-and-set cell so that other activities, that access the cell, wait until that cell is cleared by an unlock statements. Unlock statement clears the specified test-and-set cell. In the following example, variable gate is a queue type variable.

```
lock(gate);
 <Critical Region>
unlock(gate);
```

Rule:

1. The condition variables referenced in lock and unlock statements must be declared as queue type variables in the main CPS/1100 routine.

4.2.7 Cobegin and Coend Statements

Cobegin/coend and associated await statements are used to simultaneously commence the execution of new activities which are started up in the program segment specified by cobegin/coend statements. Cobegin statement starts an activity with a given name and deactivates it. Coend statement causes reactivation of that activity and exits it from the system. Startup and fork statements between cobegin and coend statements create new activities. These new activities must be suspended via await statements on the called routines until the coend statement is executed. In the following example producer and consumer processes are created and then their controls are suspended by await statements. Execution of both processes are allowed by execution of coend statement in the main CPS/1100 routine.

```
*COMPILE   OPTIONS=ISRLM,ELTNAME=TPF$.MAIN
    program main;
                -
    var commence : queue;
                -
                -
    begin
       cobegin (commence);
                fork with taskname (task01) producer;
                fork with taskname (task02) consumer;
       coend;
                -
                -
                -
    end.
```

```
*COMPILE   OPTIONS=ISRLMV,ELTNAME=TPF$.PRODUCER
    program define (producer);
    procedure producer;
    begin
      await (commence);
              -
              -
              -
    end;

*COMPILE   OPTIONS=ISRLMV,ELTNAME=TPF$.CONSUMER
    program define (consumer);
    procedure consumer;
    begin
      await (commence);
              -
              -
              -
    end;
```

Rule:

1. Nested cobegin/coend usage is forbidden.

4.2.8 Clear Statement

It stores zero to a queue type variable. For example:

```
clear (flag);
```

statement stores zero to the queue type variable flag.

Rule:

1. The variable referenced in a clear statement must be declared as a queue type variable in the CPS/1100 main program.

4.2.9 Quit and Quit by Checking Statements

Quit statement causes an activity to exit from the system. But quit by checking causes an activity to exit from system if the referenced queue type variable has been cleared. The following statements are examples for unconditional and conditional quit statements:

```
quit;
quit by checking (flag);
```

Rule:

1. Queue type variable referenced in quit by checking statement must be declared in the main CPS/1100 routine.

4.2.10 Suspend and Wait Forever Statements

Suspend statement causes an activity to delay its execution for a specified time period. Wait-time period is in the range of 2-30000 miliseconds. Wait forever causes an activity to delay its execution for an undefinite time period. In the following statements execution of an activity is delayed by suspend and wait forever statements.

```
a:= 2500; suspend(a);    or    suspend (2500);
wait forever;
```

4.2.11 Activate and Deactivate Slavetask Statements

Activate statement resumes execution of a slavetask which has just started up or already deactivated by an external activity. Deactivate statement interrupts execution of a slavetask and suspends execution until it is reactivated externally. As an example:

```
i:= 7;
deactivate slavetask (i);
-
ℓ:= 7;
activate slavetask (ℓ);
```

Rule:

1. The variable referenced in an activate or deactivate slavetask statement must be an integer identifier.

4.2.12 Terminate Statement

This statement causes termination of all activities which are created by CPS/1100. Program execution may be ceased via a terminate statement.

4.2.13 Fetch Status of Slavetasks Statement

It can be checked whether a slavetask has exited from the CPS/1100 system or not by using the fetch status of slavetasks statement. If the activity in the specified slavetask routine has exited from the system, the corresponding element of a certain boolean array is set to true by that statement. Otherwise the element of the boolean array remains as false. In the following statement, status of slavetasks in the system are retrieved.

fetch status of slavetasks;

Rule:

1. User is responsible to declare a boolean array with the name of status in the routine in which the fetch statement is used. The size of that boolean array must be equal to the number of slavetasks in the CPS/1100 run.

4.2.14 Dedicate Processor and Original Mode Statements

Dedicate processor statement dedicates the specified processor to the requesting activity. Original mode statement causes the return to normal processing mode in which activities may be processed by any

available processor. In the following program segment processor1 is dedicated to an activity for a while:

```
-
-
dedicate processor(1);
-
-
-
original mode;
-
-
```

4.2.15 Cregion/Cend Statements

These statements are used to create a critical region where Pascal 8R1 library routines are called. A critical region is mondatory around library entry jumps because programs in the library are not re-entrant. More than one activity must not execute library program codes at a time, otherwise programs produce unpredictable results. In the following example, a string is printed in a cregion/cend critical region.

```
cregion;
   -
   -
   write('xxxxxxx');
cend;
```

4.2.16 Snoopy on and Snoopy off Statements

Snoopy on statement calls a utility program to trace assembler routines. Snoopy off statement turns off the trace operation. In the following statements a program segment is traced:

```
  -
  -
snoopy on;
<Portion of CPS/1100>
<program to be traced>
snoopy off;
  -
  -
```

Rule:

1. Only one activity at a time must be traced in a program.

4.2.17 Snapdump Statement

Snapdump statement causes a dumping of the queue type variables. The following statement is an example snapdump call:

```
snapdump (dump-id);
```

Rule:

1. Dump-id must be a name of maximum 6 character in length. It is used for identification purpose in the dump lists.

4.3 Implementation Details

4.3.1 Structure and Storage Allocation Mechanism of PASCAL 8R1

Pascal 8R1 compiler generates assembler instructions instead of machine code of the program being compiled. It stores the assembler program into a specific program file element, tpf$.pa$code. The assembler codes must be assembled by Univac 1100 assembler processor that creates a relocatable element. That element, therefore, must be linked with the Pascal 8R1 library which consists of routines for allocating and deallocating

storage for procedures, i/o handling facilities, communicating with other software processors and tracing facilities. The library also consists of routines for built-in mathematical functions.

External compilation is allowed in Pascal 8R1 software. Externally compiled routines must be collected to obtain the executable element. A sample program stream with an externally compiled procedure is given below:

```
@RUN,A  run-id, account-number, project-id
@BU*PASCAL.S,ISRLM
    program main;
    procedure extpas (var inp:integer); external;
    var a : integer;
    begin
        -
     extpas(a);
        -
        -
    end.
@ASM,UN    TPF$.PA$CODE,TPF$.MAIN
@BU*PASCAL.S,ISRLMV
    program define (extpas);
    procedure extpas (var abc:integer);
    var kk,ll:integer;
         -
         -
    begin
         -
         -
         -
    end;

@ASM,UN  TPF$.PA$CODE,TPF$.EXTER
@MAP,I     ,TPF$.MAIN
  IN    TPF$.MAIN
  LIB   BU*PASCAL.
  END
```

```
@XQT    TPF$.MAIN
     <data>
@FIN
```

The routine starter element (RS) of Pascal 8R1 library starts the execution of a program by allocating a run time stack. The size of the stack is dependent on the options used on the processor calling card. Program control is transferred to the user program codes after the processor calling options are checked by RS routine. The first executable code in the main program is:

```
LMJ     A1,PENT$
<3 words package>
```

Program control is transferred to pent$ entry of the RS routine of the library by lmj jump instruction. At this moment, index registers x9 and x10 contain the address of start$ which is the tag that refers to start address of the activation record of main routine. Locations between start$+136 and stack top are allocated to the variables declared in the main routine. The following storage map may be useful to demonstrate the storage allocation mechanism of Pascal 8R1 (Figure 4.1).

In the RS routine, the data area for the variables declared in the main routine is allocated and next available position in the stack is pointed as the stack top. Program control returns to the main program.

When an external procedure is called, the program control is transferred to the procedure. Then a jump to the pnet$ entry of RS routine is performed by the following instruction.

```
LMJ     A1,PENT$
<3 words package>
```

At this moment register A0 contains the address of the activation record for the incarnated procedure. Arguments of the procedure has been transferred to the locations in the activation record by the instructions created for procedure calls. The following map illustrates the activation record link fields (Figure 4.2).

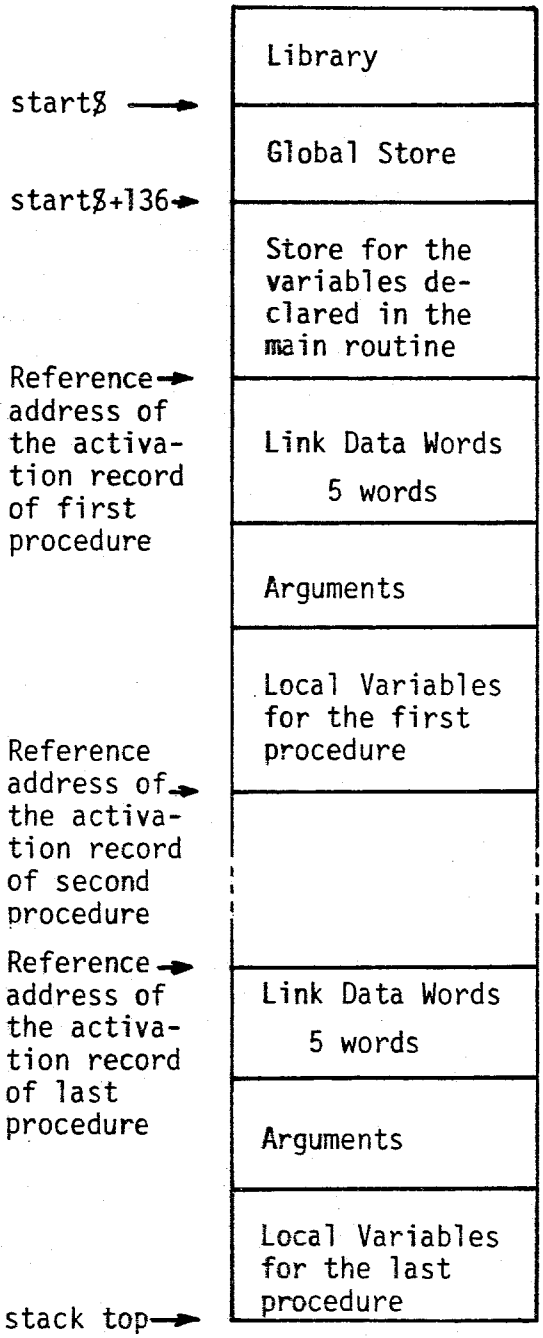


Figure 4.1 - Storage allocation map of Pascal 8R1

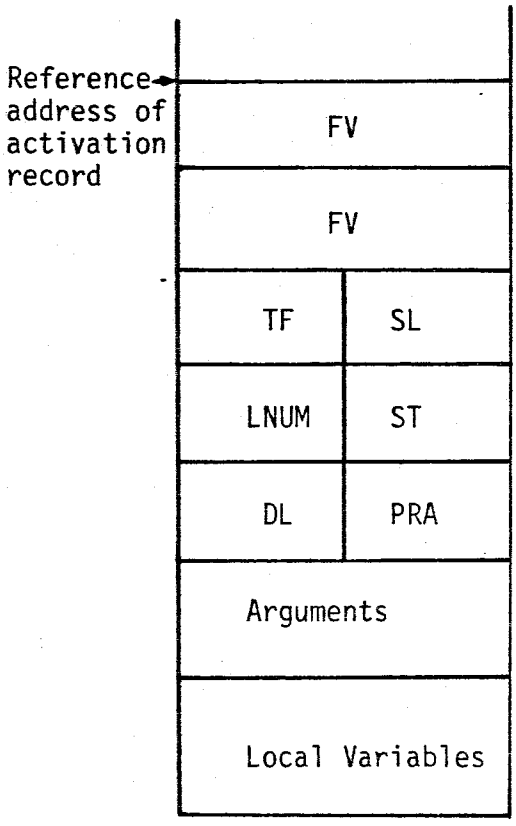


Figure 4.2 - Activation record map of Pascal 8R1

where,

FV : Function Return Value (2 words)

TF : Trace Flag

SL : Static Link

DL : Dynamic Link

LNUM: Line Number of Procedure Calling

ST : Stack Top

PRA : Procedure Return Address

The following tasks are performed when program control is transferred to the pent$ entry of RS routine:

1. TF, SL, LNUM, DL, PRA fields of the activation record of the called procedure are filled.
2. Index register x1Ø is set as the reference pointer of the activation record.
3. Reference address of the activation record is saved in a library global variable CX1Ø$.
4. Register AØ is set as stack top pointer.
5. The size required by procedure local variables is checked. If it is not enough, the stack is expanded.
6. Level of procedure calling, which is a library global information, is updated.
7. Function return value field is filled with nil.
8. Location devoted to the local variables is filled with nil.
9. Traceword is checked for tracing process.
10. Certain library global variables are updated.
11. Program control is returned to caller routine.

When an external procedure is called, the following tasks are performed to transfer values or addresses of the arguments:

1. Line number of the procedure calling statement is stored into the register R15.
2. Current stack top value is stored in register AØ. Afterwards, it is used as reference address of the activation record of the incarnated procedure.
3. Values or addresses of the arguments are stored into the locations that succeed the fifth word of the activation record.
4. Activation record address of the caller routine is loaded into register x9. This address is used as the static link value later.

5. Location counter of the caller routine is loaded into register x11 and program control is transferred to the called procedure.

The assembler code equivalents of the explained actions upon a procedure call is given below:

```
L,U     R15, <pascal program line number>
L,H2    AØ,3,x1Ø
L,U     ax, <address of argument1>
S       ax,5,AØ
-
-
L       ax, <address of argument i>
S       ax,n,AØ
-
-
L,U     x9, <address for static link>
LMJ     x11, <name of the called procedure>
```

where ax is an A or x register
n is an integer with the value of 4+i.

4.3.2 Modifications on Pascal 8R1 to Provide Parallel Processing

In sequential processing lmj instruction is used to jump to a procedure. In parallel processing er fork$ request must be used instead of lmj instruction:

In sequential processing

```
LMJ   x11, entryname
```

In parallel processing

```
L     aa,AØ
L     AØ,(ØØxxØ1,entryname)
ER    FORK$
L     AØ,aa
```

where aa is a register which is used to preserve content of AØ register. R15 register is used in implementation.

xx is the activity-id of the created activity.

In CPS/1100 programs, activation record of a procedure is allocated once and is not released until the program is finished. A flag is used to prevent reallocation of the activation record of a procedure. When a procedure is started up, the following instruction are executed.

```
1.  TS        <test-and-set cell for the called procedure>
2.  L,U        R15,  <pascal program line number>
3.  L,H2       AØ,3,x1Ø
     -
     -
    {Argument transfer}
     -
     -
4.  L,U        x9, <address for static link>
5.  L          R15,AØ
6.  L          AØ,(ØØxxØ1, name of the called procedure)
7.  ER         FORK$
8.  C$TSQ     <test-and-set cell for the called procedure>
9.  L          AØ, R15
```

Instructions in line 1 and in line 8 create a critical region and cause suspension of activity control until the created activity, by fork$ request, performs a signal operation on a CPS/1100 defined queue type variable. In line 2, statement number is stored in register R15 for tracing purpose. Activation record reference address of the called procedure is loaded into AØ register, in line 3. Argument transfer operation is performed by using this reference address. In line 4, the address that will be used as the static link in the called procedure is loaded into x9 register. In line 6, xx field is the activity-id of created activity and the adjacent Ø1 value denotes that the new activity uses the major registers set, i.e. all

the user accessible registers. Name of the procedure called is loaded into the H2 field, i.e. lower half, of the AØ register while ØØxxØ1 is loaded into the H1 field. R15 register is used as a temporary storage to preserve the content of AØ register between the lines 5 and 9. Executive request fork$, in line 7, creates an activity according to the specifications stated in register AØ and forks it to the procedure address which was stored in the H2 field of AØ register.

The newly created activity consists of a set of registers with the same contents of its creator activity after the creation operation. It processes the following instructions when it enters into the called procedure.

```
1.  L          AØ,R15
2.  TNZ        <flag>
3.  J          ENTER
4.  L          x1Ø, <address of global variable>
5.  J          PROCST
6. ENTER .
7.  LMJ        A1,PENT$
     <3 words package>
8.  SZ         <flag>
9.  S          x10, <address of global variable>
10. PROCST
```

R15 register has been used to preserve the contents of AØ register by the creator activity. In line 1, the content of AØ is recovered. Flag used in line 2 is a CPS/1100 defined location which is initially nonzero. This flag is used to control activation record allocation. If it is nonzero, activity control is transferred to the label enter. In line 7, control is transferred to the entrypoint pent$ of the RS routine of Pascal 8R1 library. When the activity control returns back to line 8, the activation record is allocated in memory. In line 8, the flag is set to zero. In line 9, content of x10 register, which is the reference address of the activation record, is stored into a CPS/1100 defined global variable.

When another activity is transferred to the procedure via a fork statement, it tests the flag, in line 2, and jumps to line 4. It retreives the reference address of the activation record from the global variable and it loads this into register x1Ø. Control passes on to the label procst in line 1Ø.

The activity that used startup statement is in wait state because of the associated c$tsq request. Control of that activity should be resumed by a release statement which is placed in an appropriate line in the called procedure. The appropriate line in the procedure may be the first executable statement in the procedure or the end of variable initialization section of the procedure. A release statement and the corresponding assembler codes are illustrated below:

```
release (<procedure name>);

TS        <test-and-set cell for the procedure>
C$TSA     <test-and-set cell for the procedure>
```

Fork statement is used to create an activity and to transfer new activity to a procedure which is already allocated in memory via a startup statement. Assembler code correspondants of a fork statement is given below:

```
L,U           R15, <pascal program line number>
   -
  {Argument transfer}
   -
L             R15,AØ
L             AØ,(ØØxxØ1, name of the called procedure)
ER            FORK$
L             AØ,R15
```

Slavetasks are lowest priority activities that may be used to simulate user jobs executing under an operating system. Parameter passing to a slavetask is not allowed. Slavetasks may only be started up, activated or deactivated by other activities. The following instructions correspond to the startup slavetask (i) statement:

```
1.  L           x10, globvar
2.  L,H2        reg1,3,x10
3.  L,U         x9, <address for static link>
```

where globvar is the address of the global variable that contains the reference address of the most recently allocated activation record, reg1 is a register in which the reference address of slavetask procedure that will be created is temporarily stored.

```
4.  L           reg2, <address of variable i>
5.  L           label 1
```

where reg2 is the register in which slavetask index i is stored, label 1 is the section where the slavetask index range check is performed and control is transferred to the corresponding section to prepare a register for activity creation.

```
6.  CØ$i
7.  L           AØ,(ØØØØØ1,SLAVETASK i)
8.  SZ          INTACTNAMEi
9.  L,U         reg3,INTACTNAMEi
10. J           label3
```

Codes in line 6 to 9 are repeated imax, that is the maximum number of slavetasks in the program, times. In line 6, AØ register is prepared for making a fork$ request. Slavetasks do not have activity-ids, for this reason the upper half of the AØ register is set to ØØØØØ1. Intactnamei is a CPS/1100 defined location in the common store of activities. Internal activity name of a slavetask is stored in the corresponding intactnamei word and the address of intactnamei is stored in a register. Label3 is the label of a section where fork$ executive request is used to create the slavetask.

```
11. label 1
12. TG,U        AØ,1
13. TG,U        AØ,imax+1
```

```
14.  J          label2
15.  ANU,U      AØ,1
16.  J          *$+1,A1
17.    +CØ$1
       +CØ$2
       -
       -
18.    +CØ$imax
19. label2
20.  LMJ        x11,PXCS$
```

In lines 12 to 14, the range of variable i, which is the content of AØ register at the moment, is checked. If it is out of range, control is transferred to the pxcs$ entry of the RS routine of Pascal 8R1 library and program is abort. In lines 14 to 18, control is transferred to label CØ$i.

```
21.  label3
22.     ER      FORK$
23.     TZ      ,*reg3
24.     J       $+4
25.     L,U     A1,1Ø
26.     ER      TWAIT$
27.     J       $-4
28.     L       x1Ø,globvar
```

In line 22 a new activity is created and transferred to the slavetaski procedure. Content of the address in reg3 register which is the intactnamei is tested for zero. If intactnamei is zero, it means activation record for the slavetaski procedure is not allocated and slavetaski is not named yet, control is suspended for 10 msec and then intactnamei is tested again. When intactnamei is found to be nonzero, x1Ø register is updated to contain the reference address of the most recent activation record.

The created activity that is transferred into the slavetask procedure executes the following instructions:

```
1.   L          AØ,regl
2.   LMJ        Al,PENT$
       <3 word  package>
3.   L          AØ,(Ø2ØØØØl,CONTNGi)
4.   ER         IALL$
5.   L          AØ,('<3 character activity name>')
6.   ER         NAME$
7.   ER         IDENT$
8.   S          AØ,INTACTNAMEi
9.   ER         DACT$
10.  ER         LEVEL$
```

In linel, reference address of activation record of the slavetask procedure, which is temporarily stored in the regl, is loaded into AØ register. Control is transferred into pent$ entry of RS routine to allocate the activation record. In line 3 and 4, activity is registered for interactivity interrupt. Contngi is the label where contingency packet and contingency routine is placed. Executive request iall$ registers the activity only for interactivity interrupt due to the mask value of Ø2ØØØØl. In line 5, a name which is 3 characters in length is loaded into the AØ register. An internal name for the activity is created by the Executive System in line 6. In lines 7 and 8, the system generated internal name is retreived by ident$ request into AØ register and it is stored in location intactnamei. In line 9, slave activity deactivates itself and it waits for an external reactivation. When this happens, it executes er level$ instruction to decrease the internal priority of the activity to the lowest level in the system.

A slavetask can be activated by another activity through the execution of an activate slavetask (i) statement. The following instructions are executed for activity i whenever an activate slavetask statement is requested.

```
L          AØ,INTACTNAMEi
ER         ACT$
```

A slavetask can be deactivated externally. This operation is performed by creating a contingency interrupt on the slave activity. The following instructions are executed when a deactivate slavetask (i) statement is processed by an activity.

```
L       AØ,INTACTNAMEi
ER      INT$
```

These statements cause an interrupt to the slavetaski. Control of the activity processing on the slavetaski procedure is transferred to the address labelled as contng i, where the following instructions are executed.

```
1.  CONTNGi
2.      RES     2
3.      S       AØ,SAVEAØi
4.      L,H2    AØ,CONTNGi
5.      A,U     AØ,1
6.      S       AØ,RTADDRi
7.      L       AØ,SAVEAØi
8.      ER      DACT$
9.      ER      LEVEL$
10.     J       *RTADDRi
```

The memory locations reserved in line 2 is the contingency packet that is filled when the contingency mode is raised. Content of AØ is saved into a memory location in line 3. In line 4, lower half of the first word of the contingency packet, which is the value of location counter when the interruption occurred, is loaded into the AØ register. Content of AØ is incremented by one, thus next instruction that will be executed by the activity is found. The address of the next instruction to be executed is stored in location rtaddr i in line 6. In line 7, the old content of AØ register is recovered. The activity leaves contingency mode and deactivates itself by executing dact$ request in line 8. When that activity is activated externally, it drops its priority via a level$ request. Control of the activity is then returned to the next instruction in the calling program.

Wait and signal primitives are implemented in CPS/1100 in the following way:

```
1.   cell1      T$CELL
2.   cell2      T$CELL
3.              ER       TSQRG$
                -
                -
4.              TS       cell1
5.              C$TSA    cell1
                -
                -
6.              TS       cell2
7.              C$TSQ    cell2
```

In lines 1 and 2 two locations cell1 and cell2 are declared as test-and-set cells via the system procedure t$cell. In line 3, test-and-set and queueing registration is performed. In lines 4 and 5 a signal operation is processed on cell1. In lines 6 and 7 a wait operation is processed on cell2.

Lock and unlock primitives are implemented in the following way:

```
8.              TS       cell
                {Critical Region}
9.              C$TSA    cell
```

Implementation details of other CPS/1100 statements can be found on Macro routines in Appendix D and assembler code listing for case one in Appendix E1.

4.3.3 Prescanner and Postscanner Routines of CPS/1100

The prescanner routines perform the syntactic and semantic analyses of a CPS/1100 program source. Primarily, these routines recognize and interpret the control directives encountered in a source program and

modify the source stream by inserting assembler and Pascal statements. On the other hand, the postscanner routine processes the assembler program generated by the Pascal compiler. Both the prescanner and the postscanner phases of CPS/1100 were implemented using Macro, which is described in Appendix A.

The prescanner is driven by three Macro programs named phaseØ, phase1 and phase2. PhaseØ of the prescanner performs the syntactic analysis of CPS/1100 control directives and statements. The input to this phase is the original CPS/1100 program text and the output is stored in a temporary file to be used in the other phases of prescanning.

Phase1 of the prescanner analyzes the parameters given to the slavetasks of a CPS/1100 program. During this phase an analysis of i/o operation flags is performed according to user declarations. The slavetasks are also determined during this phase. Flags, the number of slavetasks and the characteristics of slavetasks are written into a temporary file for use during phase2.

Prescanner phase2 inserts messages and assembler statements that correspond to CPS/1100 statements into its output stream. The output of this phase (which is passed onto the Pascal compiler) is stored in file element tpf$.name$. Messages and assembler instructions in the program text are ignored by the Pascal compiler in analysis phase. They are directly inserted into the assembler program produced by the Pascal compiler.

The postscanner of CPS/1100 modifies the assembler codes produced by the Pascal compiler according to the messages that were inserted into the source stream during phase2 of the prescanner.

Details of scanner programs are given in the succeeding sections of this chapter. Complete listings of those programs are given in Appendix D.

4.3.3.1 Description of Prescanner Phase0

In this macro program, procedure readln is used to read a line from the input stream and to tokenize the line into an array. If the first two characters in the line is recognized as the string /c, then this line is assumed to be a comment line and it is skipped. The procedure nexttoken is used to retrieve the next token in the input stream line. If all of the tokens of the line are processed, this line is written into the program file element scratch$.scratch1 and then the procedure readln is called again.

In the main body of program phase0, the program file element scratch$.scratch1 is opened. The first line of the input stream is read by using the procedure readln and the line is tokenized by using the procedure nexttoken. The variable tok is used to store the current token. The variable tok is compared with the first keywords of the CPS/1100 statements. If a match occurs, a routine which corresponds to the CPS/1100 statement is called. For example, the procedure proccps is called when the content of the variable tok is equal to the string *compile. In this case, succeeding tokens are analysed by matching with the fields of a CPS/1100 control directive by using the procedure proccps. An error message is displayed on the output stream when a syntax error is found in the input stream. In a similar way the other procedures in the program are used to analyse CPS/1100 statements in the input text. CPS/1100 statements and the corresponding procedures are listed below.

CPS/1100 Statement	Macro Routine
startup and fork	procstrtup
wait and wait forever	procwait
await	procawait
activate and deactivate	procactive
dedicate	procdedic
original mode	procorig
snoopy on and off	procsnoopy
quit and quit by checking	procquit
fetch status	procfetch

CPS/1100 Statement	Macro Routine
cobegin and signal and release and lock and unlock and suspend and clear	procother

4.3.3.2 Description of Prescanner Phase1

In this program, a set of macros is used to recognize the input/output locks and flags which provide synchronization between model and slavetasks of model operating systems implemented by using CPS/1100. A temporary file info$ is opened and the variables which are used to store the names of the input/output locks and flags are initialized with a null string.

Macro routine cpsslave is used to fetch the slavetask parameters, i.e. run parameters of the user jobs in a model study, and to store these parameters into the arrays which are declared with the names of user, progsize, priority, starttime. Number of user jobs in the model is counted by this Macro routine.

The Macro routine cps is used to convert the CPS/1100 control directives between model routines to a format that is very similar to the conventional Univac 1100 processor assignment.

The Macro routines ioinitlock, iotermlock, ioinitflag, ioterm are used to recognize the ioinitiation lock, iotermination lock, ioinitiation flag, iotermination flag respectively. The names of these locks and flags are stored in the corresponding variables.

When the end of text is recognized by the macro routine end-of-text, the number of user jobs and the names of locks and flags are written into the file info$. Afterwards, the parameters of the user jobs are written into the file info$ and then the file is closed.

4.3.3.3 Description of Prescanner Phase2

The assembler code correspondants of CPS/1100 statements and certain messages used in postscanning phase are produced by this program.

The first record of the file info$, where the number of slavetasks and i/o locks and flags has been stored, is read. The variables and control flags of the program are initialized.

The rest of the program is a collection of Macro routines which are triggered when the string series described in their picture definitions are found in the input text. Names and functions of these Macro routines are listed below:

Name(s) of macro(s)	Function
await	checks the arguments of await statements whether the activities corresponding to the arguments exist in the array activity-names. It produces assembler code correspondants of the await statement.
m1	initializes a series of variables when the keyword procedure has been encountered.
m2,m5	syntax macros, they are used in the picture definitions of some other Macro routines.
proc-dcl	recognizes process and monitor declarations, stores the name of procedures in an array.
var-dcl1, var-dcl2	recognize variable declarations. It stores queue type variables in an array.
m3	clears certain flags when a close paranthesis is encountered.
m4	recognizes the keyword var.
macbeg	produces codes to define the test-and-set cells and the fields to save A0, A1 registers. It also generates a set of codes for each slavetask to control their execution.
fork1, fork2	generates codes which corresponds to the fork statement of CPS/1100. Identifier in the taskname field is checked whether it is already defined in a startup statement or not. If it is not defined an error message is produced.
cobegin, coend	produce corresponding codes for cobegin and coend statements.
startup1, startup2	produce a message for postscanning phase. They produce codes that correspond to the startup statement.
wait, signal	produce codes for wait and signal statements.

Name(s) of macro(s)	Function
dedicate, normalmode	produce codes that correspond to dedicate processor and original mode statements.
program	generates a set of statements to define a slavetask routine.
progdef	recognizes the name of a model task routine, check whether this name is already declared or not. It sets certain control flags.
release	generates codes which correspond to the release statement.
lock, unlock	produce codes for lock and unlock statements.
suspend, suspend2	recognize suspend statements with two different formats. These routines generate codes corresponding to suspend statement.
cps2, cps, endoftext	produce a series text editing commands that erase the comment lines, produced by the Pascal 8R1 compiler.
snapdump, snoopyon, snoopyoff	produce codes which correspond to the snapdump, snoopy on, snoopy off statements.
clear, quitby, quit	produce codes corresponding to the clear quit by checking, quit statements.
slvstartup	generates a group of assembler instructions to create an activity which will be transferred to a specific slavetask routine during program execution.
activate, deactivate, terminate	produce assembler codes which correspond to the activate slavetask, deactivate slavetask and terminate statements of CPS/1100.
initiotermio	inserts a set of codes to the preceeding and succeeding lines of a write or writeln statement in a slavetask. Model task and slavetask are synchronized by the aid of these codes when a slavetask initiates and completes an i/o operation.
endpoint	inserts a set of assembler codes to the end of slavetask routines. These codes are used to suspend slavetask control for an undefined time period.
fetching	generates codes corresponding to the fetch status command.

Name(s) of macro(s)	Function
forkey	produces a message that will be used by the postscanner program.
waitforever	generates codes corresponding to the wait forever statement.
cregion, cend	produces codes which correspond to the cregion and cend statements.

4.3.3.4 Description of Postscanner

This program is composed of a set of Macro routines which modify the codes produced by the Pascal 8R1 compiler and insert assembler codes according to the messages produced during prescanner phase2. In the following list names and the functions of the macros are given.

Name(s) of macro(s)	Function
mØ	recognizes the location counter sign $(1) in the input text and sets a flag.
m1	updates the statement by which the run-time stack is allocated.
m2	inserts a group of codes to the preceeding lines of the pent$ entry in the input text. Jumping to the pent$ entry is controlled by these codes.
m3	fetchs the entry name of assembler routines.
m4, m5	recognize startup and fork messages produced by the prescanner phase2. They reset a group of control variables.
m6	deletes load modifier and jump (lmj) instruction and sets certain control flags.
m7	deletes load and load address (l and l,u) instructions which correspond to the arguments used together with a forward keyword in the CPS/1100 program text. It also updates some control variables.
m8	deletes store (s) instructions which correspond to the arguments used together with a forward keyword.
m9	modifies the assembler lines by which the activation record address of routines are loaded into the AØ register.

Name(s) of macro(s)	Function
ml1	updates certain control variables when a delete argument message is recognized.
ml2	updates a control variable when a slave-task entry message is recognized.
formac, dsmac, dlmac	modify codes corresponding to the for statement of Pascal. They are basically used to store the values of loop counters into a predefined table.
storeR13	loads the value 1 into R13 register and stores that value to the address when the s R15,<address> instruction is recognized.
suskey	updates a control variable when a suspend keyword message is recognized.
suskey2	generates codes to load the suspension period into A1 register.
R15ignore	deletes L R15,address statements
cregion, cregionoff	update a control variable.

4.4 Comparison of CPS/1100 Statements with Other Concurrent Languages

A group of statements of CPS/1100 is functionally similar to the statements of other concurrent languages. Comparison of the CPS/1100 statements and the statements of other concurrent languages is given below in a tabular form:

Keyword of Statement	Explanations
monitor/process	exist in Concurrent Pascal, Pascal-plus, Simone, Modula and Ada, but in different formats. The format used in CPS/1100 is just like the format of external routine declaration of Pascal 8R1. Functionally these declarations are used to define scope rules as in Concurrent Pascal.
queue	same name is used in Concurrent Pascal for the same type of variables. Condition variables of Simone and Pascal-plus have the same function.

Keyword or Statement	Explanations
forward	optional parameter passing is performed by using different entry points of procedures in Concurrent Pascal, Simone, Pascal-Plus and Ada.
startup	init statement of Concurrent Pascal is functionally equivalent to this keyword of CPS/1100. In most of the concurrent programming languages dispatcher like facilities start up the execution of new processes.
fork	same type of statements exist in CSP/k and in Simone.
wait, signal	exist almost in every concurrent language with different formats.
lock, unlock	functionally same commands used in PL/1. Exist almost in every concurrent language with different formats.
cobegin, coend	exist in CSP/k.
quit	exist in Simone, Pascal-plus and in CSP/k, but conditional quit does not exist.
suspend, terminate	exist in Simone and Pascal-plus.

The other CPS/1100 statements such as deactivate/activate slavetasks, dedicate processor, original mode, snoopy on/off do not exist in other concurrent languages, as these statements were developed by taking advantage of the facilities available under the Exec8 operating system.

V. CASE STUDIES

5.1 Case Study One: Producer-Consumer Problem

5.1.1 Problem Statement [16]

A buffer is shared by two processes so that one of them sends a message to the buffer while the other receives the message from the buffer. Operation of both processes are independent of each other.

Define basic data structures and write CPS/1100 procedures to re - present the events described above.

5.1.2 Method of Solution

Let the two processes stated in the problem be called the card reader and printer processes respectively. Operations and the system components can be represented by the following figure.

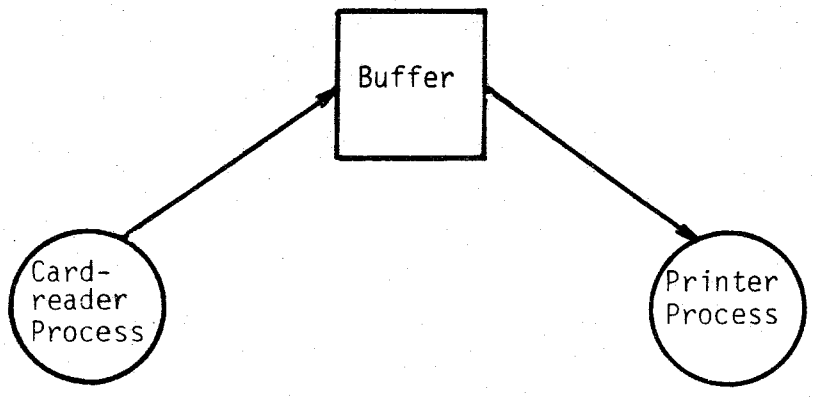


Figure 5.1 - Schematic description of producer-consumer problem.

Card reader and printer processes may be represented by the following data structure in the program implementation.

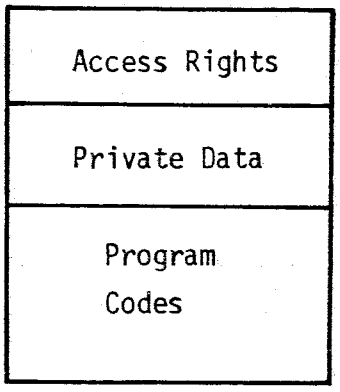


Figure 5.2 - Representation of a Process.

The access rights are conceptual equivalents of the arrows on the Figure 5.1. The private data for card reader and printer processes are the message sent and the message received. Program codes perform the sending and receiving of messages. The following CPS/1100 routine is the implementation of the above data structure for the card reader process:

```
program define (cardproc);
type labels = (receive, send, init);
/c
/c       Access Rights
/c
procedure buffer (var entry: labels;var inp:integer; var out:integer);monitor;
/c
/c       Private Data
/c
procedure cardproc;
var entry    : labels;
    i,inp,out: integer;
/c
/c       Program Codes
/c
```

```
begin
        release (cardproc);
        await (starter);
        i:=1;
        while true do
            begin
                inp:= i*1;
                lock (lockv);
                entry:= send;
                fork with taskname (c1) buffer (entry,inp,out forward);
                await(c1);
                i:=i+1;
        end;
end;
```

Buffer in the system can be represented by a monitor type data structure. Shared data section of the monitor is a location where the sent and received messages are stored temporarily. The following figure illustrates the structure of a monitor data type:

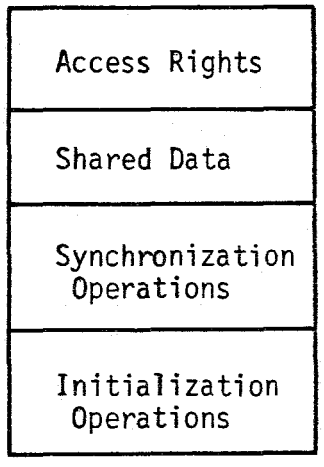


Figure 5.3 - Representation of a monitor.

CPS/1100 routine for the buffer is given below:

```
program define (buffer);
type labels = (receive, send, init);
procedure buffer (var entry: labels; var inp: integer; var out:integer);
/c
/c       Shared Data
/c
var    full    : boolean;
       contents: integer;
/c
/c       Synchronization Operations
/c
begin
       case entry of
         receive:
             begin
                unlock (lockv);
                lock (receiver);
                if not full then wait (receiver);
                            else unlock (receiver);
                out:= contents;
                full:= false;
                lock (sender);
                signal (sender);
                quit;
             end;
         send:
             begin
                unlock (lockv);
                lock (sender);
                if full then wait (sender);
                        else unlock (sender);
                contents:= inp   ;
                full    := true  ;
                lock (receiver);
```

```
            quit;
          end;
/c
/c     Initialization Operations
/c
          init;
            begin;
                 full:= false;
                 release (buffer);
                 wait forever;
            end;
          end;
        end;
```

The shared variable full defines whether the buffer is full or not. The other shared variable contents is used to store the information sent and received by the processes. Queue type variables sender and receiver are used in synchronization operations.

An activity created in the main routine is transferred to init label of the buffer procedure. This activity sets the boolean full to false and deactivates itself via a wait forever statement. An activity created by the card reader process is transferred to the label send of the procedure buffer. Control of that activity is suspended if the boolean variable full is true. If full is false or the activity is woken up via a signal (sender) statement, the information sent by the card reader process is stored into the variable contents. Boolean full is set to true and if there is an activity suspended by wait (receiver) statement it is activated by executing a signal (receiver) statement. The activity created by the card reader process leaves system. This allows the execution of the card reader process if it is suspended by an await statement. An activity created by printer process is transferred to the label receive of the procedure buffer. Control of that activity is suspended if the boolean variable full is false. If full is true or the suspended activity is activated via a signal (receiver) statement, the information stored in the variable contents is transferred to the printer process. The boolean

variable full is set to false and if there is an activity suspended by wait (sender) statement, it is activated via a signal statement. The activity created by the printer process leaves system and allows the execution of the activity suspended by an await statement in the printer process routine.

Operations performed while transferring information to the monitor and transferring the control of the created activity into a specified label in the procedure buffer must be indivisible. Indivisibility is created by critical regions that start before fork statements in the card reader and printer processes and end after receive and send labels in the monitor buffer.

The main routine of the program is not worth to discuss, since it only creates activities for card reader and printer processes. Complete CPS/1100 and corresponding assembler program listings for this case study are given in Appendix E1.

5.2 Case Study Two: Dining Philosophers

5.2.1 Problem Statement [3]

Five philosophers sit around a table. Each philosopher alternates between thinking and eating. In front of each philosopher there is a plate with spaghetti. When a philosopher wishes to eat, he picks up two forks next to his plate. There are, however, only five forks on the table. So a philosopher can only eat when none at his neighbours are eating.

Assume that all philosophers are thinking in the initial state and spaghetti plates are continually replenished. Define thinking and eating periods of philosophers. Write a deadlock free program to represent events described above.

5.2.2 Method of Solution

The following figure is the table described in the problem.

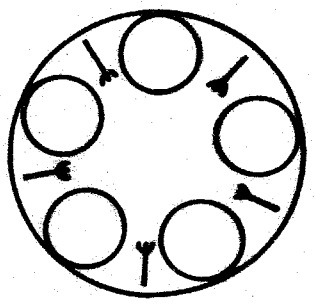


Figure 5.4 - Forks on the table.

Philosophers are simulated by phils procedure and the forks which are resources are represented by the forks monitor. An activity for each philosopher is created and transferred to the specific labels in the procedure phils. Those activities are suspended via await statements until the coend statement is executed in the main routine. A queue type variable is declared for waiting/signaling operations of each philosopher. Following codes describe the main routine of the program:

```
program main;
/c
/c      Access Rights
/c
procedure forks (<argument declarations>); monitor;
procedure phils (<argument declarations>); process;
/c
/c      Variable Declarations
/c
begin
        startup with taskname (FØØ) forks (<arguments>);
        startup with taskname (PØØ) phils (<arguments>);
        cobegin (starter);
/c
/c      Forking to philosopher Ø
/c
        pentry := philØ;
        fork with taskname (PØ) phils(pentry);
```

```
/c
/c      Forking to philosopher 1
/c
        pentry := phil1 ;
        fork with taskname (P1)phils(pentry);
        -
        -
        -
/c
/c      Forking to philosopher4
/c
        pentry := phil4 ;
        fork with taskname (P4) phils (pentry);
    coend;
    wait forever;
end.
```

Philosophers live in a thinking and eating loop. An activity that simulates the actions of a philosopher is suspended for a certain period of time, i.e., thinking period. At the end of that period the philosopher attacks to get his forks which are the shared resources with his neighbours. Entry to monitor forks is defined in a critical region. Only one philosopher at a time may pick up or put down his forks. An activity is created to simulate each pickup or putdown operation of each philosopher. When a fork is requested by a philosopher, the requesting philosopher is entered into a wait state until one of his neighbour philosophers wakes him up. Process phils is given below:

```
program define (phils);
type philent = (phil 0, phil1 , phil2 , phil3 , phil4 , pinit);
type labels = (pickup, putdown, finit);
procedure phils (var pentry: philent; var i: integer);
/c
/c      Access Rights
/c
procedure forks (var fentry: labels; var i: integer); monitor;
```

```
/c
/c     Variable Declarations
/c
begin
       case pentry of
         phil0:
              begin
                   await (starter);
                   phid0 := 0;
                   while true
                     do begin
/c
/c                         Thinking time is 3 time units
                           suspend (3);
/c
/c                         Pickup Operation
                           lock (entrylock);
                           lock (philq0);
                           fentry := pickup;
                           fork with taskname (F0) forks(fentry,phid0);
                           wait (philq0);
                           await (F0);
/c
/c                         Eating time is 8 time units
                           suspend (8);
/c
/c                         Putdown Operation
                           lock (entrylock);
                           fentry := putdown;
                           fork with taskname (F0) forks (fentry,phid0);
                           await (F0);
                     end;
              end;
                   -
                   -
                   -
```

```
phil4:
     begin
          await (starter);
          phid4 := 4;
          while true
           do begin
              -
              -
              -
              -
              end;
     end;
 pinit:
     begin
          release (phils);
          wait forever;
     end;
  end;
end;
```

When a philosopher attacks to get his forks, he may receive them if both forks are available. The activity that simulates a pickup operation decrements the variables that represent the number of forks available for the neighbouring philosophers. It resumes the control of the activity that simulates the requesting philosopher via a signal statement. The activity then unlocks the monitor entry and leaves system. If both forks are not available when they are requested, an element of the boolean array, that indicates whether the requesting philosopher in wait state or not, is set to true. In this case, the activity representing the pickup operation leaves the system.

Philosophers try to put their forks down via an activity that simulates a putdown operation. This activity increments the variables that represent the number of forks available for neighbouring philosophers. It checks whether neighbouring philosophers are in wait state and both of their forks are available. When a neighbour philosopher is found

as waiting for forks and there are two available forks for him, a pickup operation is applied for that philosopher. After this, the activity that simulates the putdown operation exits the system and the requesting philosopher thinks for a while again.

Listing of monitor forks is given below. Complete listing of CPS/1100 program for case study two can be found in Appendix E2.

```
program define (forks);
type labels = (pickup, putdown, init);
procedure forks (var fentry: labels; var i:integer);
var     frk      : array [0..4] of 0..2;
        waiting  : array [0..4] of boolean;
begin
   case fentry of
       pickup:
         begin
              case i of
                ∅: lock (philq∅);
                   -
                   -
                4: lock (philq4);
              end;
              if frk [I] <> 2
                then  begin  waiting [i]:= true;
                             case i of
                               ∅: unlock (philq∅);
                                  -
                                  -
                               4: unlock (philq1);
                           end;
                           unlock (entrylock);
                           quit;
                      end;
                 else begin
```

```
                                waiting [i]:= false;
                                frk[(i+4)mod5]:=frk[(i+4)mod5]-1;
                                frk[(i+1)mod5]:=frk[(i+4)mod5]-1;
                                case i of
                                  Ø: signal (philqØ);
                                      -
                                      -
                                  4: signal (philq4);
                                end;
                                unlock (entrylock);
                                quit;
                            end;
    putdown:
       begin
        frk[(i+4)mod5]:=frk[(i+4) mod5]+1;
        frk[(i+1)mod5]:=frk[(i+1) mod5]+1;
        if (frk[(i+4) mod5] = 2) and
           (waiting [(i+4) mod5])
           then begin
                waiting [(i+4) mod5]:= false;
                frk[(i+3) mod5]:= frk[(i+3) mod5]-1;
                frk[i]:= frk[i]-1;
                case (i+4) mod5 of
                  Ø: signal (philqØ);
                      -
                      -
                  4: signal (philq1);
                end;
          if (frk[(i+1) mod5]= 2) and
             (waiting [(i+1) mod 5])
             then begin
/c                 Pickup forks for philosopher (i+1) mod 5
/c                 and wake him up
/c              end;
        quit;
```

```
        end;
    init:
        begin
          for i:= Ø to 4 do begin
                                frk [i] := 2;
                                waiting [i] := false;
                              end;
          release (forks);
          wait forever;
        end;
    end;
end;
```

5.3 Case Study Three: Quicksort with Processor Dedication

5.3.1 Problem Statement

Quicksort [17] is an efficient sorting algorithm. Its performance may be improved by exploiting parallelism. Any sorting algorithm may be modified for a dual processor system in the following way:

1. Divide the array to be sorted into two halves
2. Sort the two halves simultaneously
3. Merge two halves.

The first arrangement operation of the quicksort algorithm is used to divide the array into two subarrays. Those subarrays can be sorted concurrently in two different processors of a dual processor system. Merging operation is not essential for quicksort algorithm.

Modify the quicksort algorithm for a dual processor system and write its program.

5.3.2 Modified Quicksort Algorithm

Let x be the array to be sorted and n be the number of elements in the array. Choose a pivot from a specific position within that array such as the first element of array. Rearrange the array x and place the pivot element into a position j such that, each of the elements in position 1 to j-1 is less than or equal to the pivot element and each of the elements in position j+1 to n is greater than or equal to the pivot element. Sort the subarrays, which corresponds to the elements 1 to j-1 and j+1 to n of array x, by dedicating a processor to each of them.

5.3.3 Program Description

Recursion on the quicksort algorithm must be eliminated by using a stack since CPS/1100 does not permit recursive procedure calls. This stack is used to store pointers for lower and upper bounds during rearrangement operations.

Order of comparisons in sequential quicksort algorithm is $n \ln_2 n$ on average. It is decreased to $(n \ln_2 n + (n/2)\ln_2(n/2))/2$ in the modified quicksort algorithm. Efficiency of the modified algorithm depends on how well the pivot is chosen. But the order of comparison in the modified algorithm on worst case is equal to the average case of sequential algorithm.

In the CPS/1100 program for this case study, three process, divide-two, quick1, quick2 are declared in the main routine. The unsorted array x is read. Processes are started up by the main activity and the address of array x and the size of it is transferred to the process dividetwo as arguments. Control of the main activity is suspended until the sorting operation is completed. The main routine is illustrated with comments in the following program outline.

```
program main;
/c
/c      Access Rights
/c
```

```
procedure dividetwo (<argument declarations>); process;
procedure quick1 (<argument declarations>); process;
procedure quick2 (<argument declarations>); process;
/c
/c     Variable Declarations
/c
begin
/c
/c     Read Array x
/c
     startup with taskname (TØØ) dividetwo (<arguments>);
     startup with taskname (TØ1) quick1 (<arguments>);
     startup with taskname (TØ2) quick2 (<arguments>);
/c
/c     Wait until sorting completion
/c
     quit;
end;
```

Dividetwo process chooses the first element of array x as the pivot element. It rearranges the array x and places the pivot into a position j, so that the pivot element divides the array into two subarrays according to the values of the elements. Dividetwo process creates two activities and transfers their control to the quick1 and quick2 routines. It suspends its execution until quick1 and quick2 processes both complete their duties. Two different routines, quick1 and quick2 are used to sort two subarrays, although these routines are the same of each other, since the Pascal 8R1 compiler does not produce reenterant codes. The dividetwo routine is explained with comments in the following program outline.

```
program define (dividetwo);
procedure dividetwo (<argument declarations>);
/c
/c     Access Rights
/c
```

```
procedure quick1 (<argument declarations>); process;
procedure quick2 (<argument declarations>); process;
/c
/c     Variable Declarations
/c
begin
    release (dividetwo);
/c
/c     Choose a pivot element, arrange array x
/c
/c     and divide it into subarrays
/c
    fork with taskname (TØØ) quick1 (<arguments>);
    fork with taskname (TØ7) quick2 (<arguments>);
    await (TØ6, TØ7);
/c
/c     Print the sorted array x
/c
/c
    quit;
end;
```

Quick1 process dedicates processor Ø while quick2 process dedicates processor 1 for their execution. Quick1 sorts one of the subarrays by successive rearrangements. Quick2 performs the same task on the other subarray. Both of the activities exit the system after they finish sorting. The following statements explain quick2 process:

```
program define (quick2);
procedure quick2 (<argument declarations>);
begin
   case entry of
   q2sort:
       begin
         dedicate processor (1);
```

```
/c      Sort one of the subarrays
/c
        quit;
     end;
   q2init:
        begin
          release (quick2);
/c        Initialization operations
/c
        end;
  end;
end;
```

Complete program listing for this case study is given in Appendix E3. Dedicate processor statements are not used in the program listed in Appendix E3.1. Sorting is performed by two processes on a single processor. In Appendix E3.2, only the program segments, where processors are dedicated, and the obtained results are given. In this case, due to the absence of a second processor in the machine that the program was run on, one of the sorting activities is aborted with error type Ø4 and error code Ø77. For this reason one subarray was sorted.

5.4 Case Study Four: Gaussian Elimination with Processor Dedication

5.4.1 Problem Statement [18]

Gauss elimination method, which is well known, is used to solve linear equation systems. This method can be improved for dual processor systemsand thus execution time may be decreased.

5.4.2 Gaussian Elimination Algorithm for Dual Processor Systems

Operations of the gaussian elimination method may be divided into two parts, the reduction operation on the pivot row and the reduction

operation of the rows that succeed the pivot row. The second operation can be handled by two similar activities within different processors. Sequential gaussian elimination algorithm may be modified in the following manner:

1. Create an activity and dedicate the second processor to it. Suspend that activity.
2. Select the pivot row, i, starting from first row.
3. Reduce the pivot row so that the diagonal element is equal to 1. If the pivot row is the last row, stop elimination.
4. Wakeup the second activity.

Tasks performed by first activity:

5. Select row k as i+1, i+3, i+5 and reduce these rows such that the element k, i is equal to zero.
6. If the last row is reached check whether the second activity has finished its duty. If the second activity has not finish its duty, enter a wait state otherwise jump to step 3 incrementing i by one.

Tasks performed by second activity:

7. Wait until the first activity sends a signal for waking up.
8. Select row ℓ as i+2, i+4, i+6,... and reduce these rows such that the element ℓ,i is equal to zero.
9. If the last row is reached, register that the duty of second activity is complete and send a signal to wake up the first activity.
10. Jump to step 7.

5.4.3 Program Description

The main routine reads the input matrix which has n rows and n+1 columns. Last column of the matrix consists of the right hand sides of the equalities. Main activity initializes the process gauss. Two reduction activities are created. Control of the main activity is suspended until elimination is finished. First reduction activity wakes up the main activity when it finishes its duty. Then, the main activity calculates the unknown variables by using the reduced matrix. Main routine is explained by comments in the following program outline.

```
program main;
const   n = 20; npl = 21;
type entries = (entry1, entry2, init);
     arrtype = array [1..n, 1..npl] of real;
procedure gauss (entry: entries; var A: arrtype); process;
var  A    : arrtype;
     i,j,k: integer;
            -
            -
begin
/c
/c  Read the input matrix A
/c
   startup with taskname (gØ) gauss (init, A forward);
       -
       -
   fork with taskname (g1) gauss (entry1, A);
       -
       -
   fork with taskname (g2) gauss (entry2, A);
       -
       -
   wait(waitwd);
```

```
/c
/c      Calculate the unknown variables
/c
end.
```

There are three entries in the routine gauss: init, entry1 and entry2. The activity, which is transferred to entry init initializes the boolean variable permission as false. Boolean variable permission shows whether the second reduction activity is in a wait state or not. The first reduction activity, which is named g1, is transferred to label entry1. It starts to reduce the pivot row i while the second activity is transferred to the label entry2. Activity g1 sets the boolean variable permission to true in a critical region. It reduces the rows i+1, i+3, i+5, etc. At this time, the second reduction activity g2 checks the variable permission in a critical region. It either enters a wait state or leaves the critical region depending on the value of the boolean permission. If permission is true or the second activity, g2, is woken up then activity g2 starts to reduce the rows i+2, i+4, i+6 and so on. Activity g2 sets the boolean permission to false and checks the value of pivot row index i. If the pivot row is the last row of the matrix, activity g2 exits the system otherwise it checks boolean permission for further reduction operations. When activity g1 finishes a reduction pass it checks boolean permission to see whether activity g2 has finished its duty or not. If activity g2 has finished its reduction pass then activity g1 increments the row index i by 1 otherwise enters a wait state. When activity g1 reduces the last row of the matrix, it exits the system. Following program outline explains the routine gauss.

```
program define (gauss);
const  n = 20; npl = 21;
type entries = (entry1, entry2, init);
     arrtype = array [1..n, 1..npl] of real;
procedure gauss (entry: entries; var A: arrtype);
var  i,j,k,l,m  : integer;
     permission : boolean;
     p,q,r      : real   ;
```

```
begin
   case entry of
        entry1:
          begin
            dedicate processor (Ø);
            for i:= 1 to n
                do begin
/c
/c                    Reduce pivot row i
/c
                  if i = n then
                     begin lock (waitwd);
                           signal (waitwd);
                           quit;
                     end;
                  lock (act2);
                  permission:= true;
                  signal (act2);
                  k:= k+1;
                  while k ≤ n
                     do begin
/c
/c                        Reduce row k
/c
                        k:= k+2;
                        end;
                  lock (act1);
                  if permission then wait (act1)
                                else unlock (act1);
                end;
          end;
        entry2:
          begin
              dedicate processor (1);
              -
              while true
```

```
                do begin
                     lock (act2);
                     if not permission then wait (act2);
                                       else unlock (act2);
                     ℓ:= i+2;
                     while ℓ ≤ n
                        do begin
/c
/c                                Reduce row ℓ
/c
                                   ℓ:= ℓ+2;
                              end;
                     lock (act1);
                     permission:= false;
                     signal (act1);
                     if i ≥ (n-1) then quit;
                   end;
                 init:
                   begin
                     permission:= true;
                     -
                     -
                     quit;
                   end;
        end;
end;
```

The program listing can be found in Appendix E4.1. Dedicate processor statements are not used on the listed program. Equations are solved in a single processor system and the results are printed. In Appendix E4.2, only the program segments,where processors are dedicated to distinct reduction activities, are given. In that case program is aborted with error type Ø4 and error code Ø77 which corresponds to the error message processor requested on aded$ call was unavailable at the time of the er aded$, or was downed by the system operator.

5.5 Case Study Five: A Model Operating System

5.5.1 Problem Statement

Assume that a timesharing and multiprogramming operating system can manage only pascal programs. Memory requirements, priorities and start-times of the user jobs are given on the job control cards as parameters. The system has the following properties:

1. A line frequency clock generates regular clock interrupts in every predefined time interval.
2. User programs may be time shared according to different scheduling strategies.
3. The system maintains three seperate queues of user programs.

One is the ready queue of all programs in memory that are capable of immediately utilizing the CPU. The second queue is the blocked queue of all programs that can not compete for the CPU because they are on secondary storage. All members of blocked queue can proceed directly to the ready queue when loaded into main memory. The third queue is the i/o queue of all programs that are waiting for i/o processing.

4. Once every predefined time duration, if the blocked queue is not empty, the oldest job in the ready queue is swapped out of main memory. A job in the blocked queue that is selected according to a priority rule is loaded into the ready queue.

Write a CPS/1100 program for this model operating system.

5.5.2 Model

CPU and i/o unit are the servers and ready, blocked and i/o queues are the three queues in the system. This model is schematically described by the following figure.

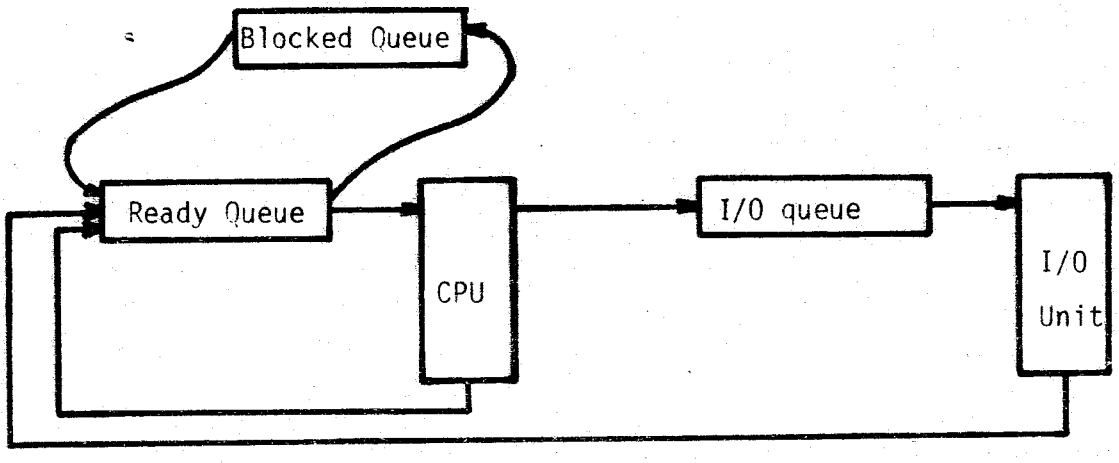


Figure 5.4 - Representation of the model operating system.

Actions in the system are listed below:

1. A job processing in CPU is interrupted and is moved to the end of ready queue at every regular clock interrupt. At these intervals, the ready queue is rearranged according to a specific scheduling rule. First job in the ready queue is moved to the CPU for processing.

2. A job deactivates itself while informing the operating system that it has started an i/o operation. At this instant, the requesting job is transferred to the i/o unit queue. The first job in the ready queue is fetched and it is moved to the CPU for processing. The i/o queue is handled on a first come first served basis. The first job in the i/o queue gets the i/o unit first.

3. A job reactivates itself while informing the operating system that it has finished its i/o operation. This job is transferred to the end of ready queue. Ready queue is rearranged according to a specified scheduling rule. If i/o processing queue is not empty, the first job in the i/o queue is transferred to the i/o unit.

4. Oldest job in the ready queue is swapped to the end of the blocked queue at every predefined time period. The blocked

queue is rearranged according to a scheduling rule. A number of jobs are transferred to the end of the ready queue so that unused memory in the system is reduced to a minimum. The ready queue is also rearranged during this operation.

5.5.3 Program Description

Processes arrange and model operating system (mos) are declared in the main CPS/1100 routine. Slavetasks, which simulate user jobs in the model, are started up. Processes arrange and mos are also initiated. An activity, that simulates the system clock, is created and transferred to the clockstart label of the mos routine. Another activity that simulates regular clock interrupts, is created and directed to the regularint label of the routine mos. The activity that simulates the actions performed when an i/o operation is started in a user job is created and directed to the label ioinitiate. The activity that simulates actions when an i/o operation is completed in a user job is created and transferred to the label ioterminate in the mos routine. Outline of the main routine is given below:

```
program main;
/c
/c       Type declarations
/c
procedure mos (<argument declarations>); process;
procedure arrange (<argument declarations>); process;
/c
/c       Variable declarations
/c
begin
    i:=1;while i ≤ <number-of-slavetasks>
                do begin
                       startup slavetask  (i);
                       i:= i+1;
                   end;
```

```
startup with taskname (AØØ) arrange (<arguments>);
startup with taskname (TØØ) mos (<arguments>);
-
-
mosentry:= clockstart;
fork with taskname (tØ1) mos (mosentry);
-
-
mosentry:= regularint;
fork with taskname (tØ2) mos (mosentry);
-
-
mosentry:= ioinitiate;
fork with taskname (tØ3) mos (mosentry);
-
-
mosentry:= ioterminate;
fork with taskname (tØ4) mos (mosentry);
-
-
end.
```

The program segment under the label clockstart simulates the system clock. Execution of this segment is in an endless loop in that segment. Control of the clock activity, that represents the time slice used in the model, is suspended for a while. The clock is then updated and a signal operation on the queue variable clockintrpt is performed. This program segment is listed below:

```
clockstart;
    begin
      -
      -
      while true do begin
```

```
        suspend (50);
        lock (clocklock);
        clock: = clock + 50;
        unlock (clocklock);
        if clock  >= 30 000 then terminate;
        lock (clockintrpt);
        signal (clockintrpt);
    end;
```

Actions performed after each regular clock interrupt are programmed in the regularint segment of the mos routine. An activity in that segment waits for a clock interrupt. It is woken up when a signal operation is performed on the queue type variable clockintrpt. This activity checks whether the CPU is idle and the ready queue is empty. If both conditions occur, then the activity enters a wait state by using the queue type variable emptyrq. Otherwise it may start a swapping or a CPU timesharing operation in the system.

The activity in the regularint segment checks the following conditions for swap operation:

1. Blocked queue is not empty
2. Swappable memory space, which is the portion of memory used by the jobs waiting for CPU, is equal to or greater than the memory requirement of the first job of the blocked queue.
3. The predefined time interval between two swap operation is consumed.

The activity, whether it performs a swap operation or not, checks the time for a CPU sharing operation. If the difference between clock value and the time, at which last CPU switching is performed, is equal to or greater than the predefined time interval for timesharing then a CPU switching operation is performed. Afterwards, the activity being in an endless loop enters a wait state until a signal operation is performed on the queue type variable clockintrpt. The following program outline shows the actions performed after each regular clock interrupt:

```
regularint:
    -
    -
    while true
         do begin
            lock (clockintrpt);
            wait (clockintrpt);
            if (rqtail = rqhead) and
               (controltable.ccu = Ø)
                   then begin
                             lock (emptyrq);
                             wait (emptyrq);
                        end;
               lock (masterlock);
               lock (clocklock);
               if (bqhead<>bqtail) and
                  (memreq[bqlist[bqhead]] <= memswapable) and
                  ((clock - lastswap) >= 5ØØ)
                  then begin
                        lastswap:= clock;
/c
/c                       Swap operation
                        end;
               if ((clock - timedecrement) >= 5Ø) or (timedecrement=Ø)
                  then begin
                        timedecrement:= clock;
/c
/c                      CPU switching operation
                       end;
               end;
```

CPU switching is performed in the following manner:

If any job is already occupying the CPU that job gets deactivated. Then, the status of all user jobs are checked in order to determine

whether the current CPU user already exists in the system. The deactivated job is placed at the end of the ready queue. The current clock value is registered for the purpose of searching the oldest job in the ready queue. Jobs in the ready queue are rearranged by creating an activity and forking it to the arrange routine. After the arrangement operation, the variable that represents swappable memory space is updated and the CPU is registered as idle. The first job in the memory queue is transferred to CPU. Pointers of ready queue and the variable that represents swappable memory space are updated. The new job in CPU is activated. The program segment that performs CPU switching is given below:

```
if (rqtail<>rqhead)
    then begin
        if (ccu<>Ø) and ((quantum [ccu] mod quantmax) = Ø)
            then begin
                deactivate slavetask (ccu);
                fetch status of slavetasks;
                if status [ccu]
                  then begin
                        rqlist [rqtail]:= ccu;
                        rqwait [rqlist[rqtail]]:= clock;
                        rqtail:= (rqtail+1) mod 2Ø;
                        lock (arrangelock);
                        arrangentry:= arrglist;
                        lock (arrflag);
                        fork with taskname (AØ2)
                          arrange (arrangentry,rqlist,rqhead,
                                                rqtail,quantum);
                        wait  (arrflag);
                        await (AØ2);
                        unlock (arrangelock);
                    end;
                memswapable:= memswapable+memreq[ccu];
                ccu:= Ø;
```

```
                    if rqtail = rqhead then cpuidle := clock;
                end;
            end;
        if (rqtail<>rqhead) and (ccu = 0)
            then begin
                    ccu:= rqlist [rqhead];
                    rqlist [rqhead]:= 0;
                    rqhead:= (rqhead+1) mod 20;
                    memswapable:= memswapable - memreq [ccu];
                    activate slavetask (ccu);
                end;
```

Swapping operation is performed in the following manner:

If ready queue is not empty the oldest job in the queue is removed to the end of the blocked queue. Variables corresponding to unused memory and swappable memory space are updated. The blocked queue is rearranged. Ready queue is reorganized by shifting some elements to successive positions to recover the gap created by the oldest job. These operations are repeated until the memory requirement of the first job of the blocked queue is satisfied. Program outline for this segment is given below:

```
while (rqtail<>rqhead) and
      (memreq [bqlist [bqhead]]>= memunused)
    do begin
/c
/c        Find the oldest job j
/c
          memunused:= memunused + memreq [rqlist[j]];
          memswapable:= memswapable - memreq[rqlist[j]];
          bqlist[bqtail]:= rqlist[j];
          bqtail:= (bqtail + 1) mod 20;
/c
/c        Rearrange blocked queue and ready queue
/c
       end;
```

If unused space in memory is equal to or greater than the memory requirement of the first job in the blocked queue, this job is appended to the end of the ready queue. The current clock value is registered as the time of joining to ready queue. Ready queue tail pointer is updated and the ready queue is rearranged. Variables denoting the unused memory and the swappable portion of memory are also updated. Block queue head pointer is changed. Those operations are repeated successively until either the blocked queue is empty or memory request of the first job in the blocked queue is greater than the unused space in memory. Following program outline describes these actions:

```
while (memreq[bqlist[bqhead]]<= memunused) and
      (bqhead<>bqtail)
   do begin
      rqlist[rqtail]:= bqlist[bqhead];
      rqwait[rqlist[rqtail]]:= clock;
      rqtail:= (rqtail+1) mod 20;
/c
/c    Arrange ready queue
/c
      memunused:= memunused - memreq[bqlist[bqhead]];
      memswapable:= memswapable+memreq[bqlist[bqhead]];
      bqlist bqhead := 0;
      bqhead:= (bqhead+1) mod 20;
     end;
```

When a user job begins an i/o operation, it performs a signal operation on the queue type variable that is defined as i/o initiation flag in the main CPS/1100 routine. The user job then deactivates itself. At this moment, the activity that is already suspended in ioinitiate segment of mos routine is woken up by a signal operation. This activity places the user job at the end of the i/o queue. It transfers the first job in ready queue to CPU for processing and updates the head pointer of the ready queue. If the ready queue is empty, the CPU is registered as idle. Meanwhile, if the i/o unit is empty,

the first job in the i/o queue is placed into the i/o unit and head pointer of i/o queue is updated. The user job in the i/o unit is activated for i/o operation. The following program segment describes the actions outlined above.

```
ioinitiate:
    -
    -
    while true
      do begin
         wait (ioinit);
         lock (ioinit);
         -
         -
         dioqlist [dioqtail]:= ccu;
         dioqtail:= (dioqtail+1) mod 20;
         if rqhead<>rqtail
         then  begin
                 ccu:= rqlist [rqhead];
                 rqlist[rqhead]:= 0;
                 rqhead:= (rqhead+1) mod 20;
                 activate slavetask (ccu);
               end
         else begin
                ccu:= 0;
                cpuidle:= clock;
              end;
          if cioj = 0 then
            begin
              cioj:= dioqlist [dioqhead];
              dioqlist [dioqhead]:= 0;
              dioqhead:= (dioqhead+1) mod 20;
              activate slavetask (cioj);
            end;
       end;
```

When a user job in the i/o unit completes its i/o operation, it performs a signal operation on the queue type variable that is defined as i/o termination flag in the main CPS/1100 routine. This user job deactivates itself. Consequently, the activity that is woken up by a signal operation inserts the user job at the end of the ready queue. It rearranges the ready queue and updates the variable that keeps track of the swappable memory space. Then, a signal operation is performed on the queue type variable emptyrq to state that the ready queue is not empty. If i/o queue is empty, the i/o unit is registered as idle, otherwise the first job in i/o queue is removed to the i/o unit and the head pointer of i/o queue is updated. The job in possession of the i/o unit is activated. Program outline for the described actions is given below:

```
ioterminate:
    -
    -
while true do
   begin
    wait (ioterm);
    lock (ioterm);
    -
    -
    rqlist[rqtail]:= cioj;
    rqwait[rqlist[rqtail]]:= clock;
    rqtail:= (rqtail+1) mod 2Ø;
/c
/c  Arrange ready queue
/c
    -
    lock (emptyrq);
    signal (emptyrq);
    -
    -
    memswapable:= memswapable + memreq[cioj];
```

```
    if dioqhead = dioqtail then cioj = ∅
                           else begin
/c
/c                           Remove the job into i/o unit
/c                           and activate it.  Update i/o queue
/c                           head pointer
/c
/c
                                end;
    -
    -
  end;
```

The activity which is created and transferred to the label mosinit of mos routine, initializes local variables and arrays of the routine mos. It reads memory requirements, priorities and start-times of user jobs from a file named infotable. This information is originally extracted from CPS/1100 control directives of the user jobs. Characteristic parameters of these jobs are registered in the arrays starttime, memreq and priority. Jobs are arranged according to their start-times, and their priorities if required. A group of jobs are transferred into the ready queue until the memory is full. The remaining jobs are filled into the blocked queue. The following program outline describes actions on initialization of routine mos.

```
mosinit:
    begin
/c
/c       Variables and arrays are initialized
/c
         reset (infotable);
         readln (infotable);
         for i:= 1 to <number of slavetasks>
               do begin
                    read (infotable,memreq[i],priority[i],starttime[i]);
                  end;
```

```
/c
/c      Sort jobs according to their starttimes and sort them
/c
/c      according to their priorities, if required.
/c
/c      Fill ready and then blocked queue
/c
        -
        -
    end;
```

User jobs in this model study are single level Pascal programs. Characteristics such as size, priority of a user job are given on its control directive. A sample user program with its control card is given below:

```
*compile options=isrlmv,eltname=tpf$.user3,user=uc,priority=5,starttime=0000
    program main;
    var a,b,j: integer; c:real;
    begin
        b:=3;
      while true
        do begin
            for j:=1 to 999999
              do begin
                  a:=b; c:= 5.23*18.2*0.03/(3.8*8.8*0.44);
                  if (j mod 444) = 0
                    then begin
                          writeln (a,c);
                         end;
                   b:= a;
                end;
          end;
    end;
```

The complete program listing for this case study is given in Appendix E5. Minimum response time strategy is applied for CPU switching in the model. Quantum size is selected as five. In this case study 18 user jobs were managed by the model operating system. Diagnosis for switching and swapping operations and the queue dumps are given on the output.

VI. DISCUSSION

In the present work, a concurrent language has been designed, implemented and tested. Its main virtues are:

- Flexibility
- Processor dedication capability
- Program trace capability
- Easy usage.

More details are available in a section of Chapter two, "Description of CPS/1100".

The present chapter is mainly devoted to discuss the use of CPS/1100, extensibility and portability of CPS/1100, comparison of CPS/1100 with other concurrent languages, and recommendations for future research.

6.1 The Use of CPS/1100

CPS/1100 is a powerful language with distinguishing characteristics from the other concurrent languages. These characteristics make CPS/1100 a favourable language in operating system modelling and concurrent programming studies for average programmers. The attractive features of the language are stated below:

A. Flexibility of the Language:

CPS/1100 is modifiable and extensible because of its special structure. The structure of CPS/1100 permits any modification on the syntax and the semantics of the language. Therefore, capabilities of

the language can be improved by modifying scanner routines of CPS/1100. Thus, new languages could be developed for specific applications. An average programmer may easily modify the language, because a high level string manipulation language has been chosen for implementing the scanner routines.

B. Processor Dedication Capability:

This capability makes CPS/1100 a powerful language, since real parallelism on program control flow can be obtained with this feature. Thus, programmers can make a trade-off between space, time and processors while they analyze their problems.

C. Program Trace Capability:

Program tracing capability of CPS/1100 is very useful for concurrent program debugging, since errors in concurrent programs are not reproducible and may occur time to time. Errors in CPS/1100 programs can be fixed by using the program trace capability.

D. Easy Usage of the Language:

CPS/1100 syntax is similar to the syntax of the Pascal language. Therefore, any programmer who knows Pascal programming can write programs in CPS/1100.

These distinguishing features of CPS/1100 are discussed, by comparing it with other concurrent languages, in the succeeding sections of this chapter.

6.2 Extensibility and Portability of CPS/1100

CPS/1100 uses EXEC8 facilities to create, remove and control activities. Those features of EXEC8 that are not normally available to users have not been employed. However, it is possible to extend CPS/1100 by making privileged EXEC8 instructions available to it in a straightforward manner by simply adding new prescanner and postscanner routines.

Fortran routines can not be called in the present form of CPS/1100. This restriction stems from restrictions in the Pascal 8R1 library, and may be overcome by simply modifying this library. Such a change will make CPS/1100 available for a wide range of numerical applications.

It is possible to extend CPS/1100 and make it a powerful realtime language by adding new statements and console communication features into it.

The lack of portability in CPS/1100 arises from the fact that Macro and Pascal 8R1 are software written specifically for Univac 1100 series. This characteristic is quite natural for any piece of software which heavily interacts with the operating system.

6.3 Comparison of CPS/1100 with Other Concurrent Languages

The design philosophy of CPS/1100 is different from that in Distributed Processes, Communicating Sequential Processes, Modula, Pascal-plus and Ada. The concurrency and synchronization constructs of CPS/1100 are high level statements having low level correspondents in EXEC8. The objective of CPS/1100 study was to raise and embed the multitasking features of EXEC8 into a high level programming system. However, the design of other concurrent languages were dictated by the programming needs. Extensive studies were performed by software designers to satisfy the needs of professional software developing studies for embedded computer systems, in the Ada project. The design philosophy of Modula was to build up a language that has powerful data abstraction features and that runs without support of an operating system. The objective of Distributed Processes and Communicating Sequential Processes was to define programming languages for distributed memory systems. Therefore, the essential difference between CPS/1100 and the other concurrent software is that, CPS/1100 has concurrency features which are raised from EXEC8, the supporting software, while the constructs of other languages were designed according to needs.

Extensibility of CPS/1100 is its most powerful aspect compared to the other software such as Modula. Pascal-plus, Ada and Concurrent

Pascal. Any modification or improvement on these concurrent languages necessitates extensive work on both design and implementation phases. But, extensions on CPS/1100 are rather simple. CPS/1100 is a software that can be reshaped rather easily.

Automatic program debugging and tracing is a bottleneck for concurrent programming software. Tracing facilities of EXEC8 are raised and embedded into CPS/1100. This is the advantage of CPS/1100 when compared with the other languages such as Modula and Concurrent Pascal.

CPS/1100 and Modula are two extreme cases due to their structures among the concurrent languages. CPS/1100 is fully supported by an abstract machine which is the combination of Univac 1100 hardware and its operating system EXEC8. In contrast, Modula runs on a bare machine.

Externally compilation of CPS/1100 routines is achieved by CPS/1100 control directives. Externally compilation aspect of CPS/1100 nearly resembles the modular structures of other languages such as Ada's packages and Modula's modules.

The common characteristic of CPS/1100, Concurrent Pascal, Modula and Distributed Processes is that all these languages have a static memory allocation mechanism. Dynamic memory allocation of concurrent objects in those languages is ignored because of the effect of memory reorganizations on the overall efficiency of the programs.

The similarity between CPS/1100 and Concurrent Pascal is consistance of access right declarations. In both software, a process can not call another process or monitor without declaring it in a particular section of the program.

CPS/1100 and Plus, both being Univac software for system programming, have similar data structures. Concurrency features of EXEC8 are accessible in both software. But, users are responsible from almost every thing about creation and controlling of activities in Plus programming. Some parts of Plus programs must be coded in Univac 1100 assembler to work on multitasking mode. For that reason, Plus users must know Univac 1100 assembler programming. In contrast, the way of creating and controlling activities in CPS/1100 is well defined. An average programmer who knows Pascal programming may use CPS/1100.

As a result, CPS/1100 has a distinguishing structure and it fills a gap in the available Univac 1100 software.

6.4 Recommendations for Future Research

The following extensions on CPS/1100 are recommended:

1. Accessing the realtime facilities of EXEC8:

   CPS/1100 may be furnished with realtime facilities, such as rt$ and nrt$ requests, to execute activities in realtime mode. In realtime mode, activities respond externally generated input stimuli within a finite and speciable delay. Thus CPS/1100 can be applied to the programming of engineering control problems. For example robotics or industrial process units may be connected to a Univac 1100 system and can be controlled by CPS/1100 programs.

2. Accessing EXEC8 private data area and routines:

   CPS/1100 may be extended so that it becomes a system programming language. It can make use of the console communication and i/o handling requests of Exec8, with simple modifications. It may access all hardware facilities of the machine and private area of Exec8 in the memory if protection on the executive system is suppressed. Protection on Exec8 area can be removed by a simple system generation operation. Then, new statements which correspond to the privilage set of Univac 1100 assembler instructions may be inserted to CPS/1100. Also, new statements to manipulate Exec8 internal tables or routines can be developed.

3. Allowing dynamic storage allocation to CPS/1100 routines:

   Although, implementation of dynamic storage allocation mechanism in CPS/1100 is not so easy, such an extension permits the building up of large scale operating system models via CPS/1100.

4. Creating a CPS/1100 library:

   Such a library may consist of a set of Pascal and assembler routines which correspond to basic data structures such as queue lists and stacks. Graphic processing and plotting routines may be added to the library. This library would be helpful for better model implementations, program abstraction and coding.

5. Accessing Fortran program libraries:

   This feature can be added by modifying the Fortran interface routine in the Pascal 8R1 library. As a result of this extension, a wide range of numerical and scientific application can be programmed in CPS/1100 with spending less effort.

6. Reentrant code creation:

   Pascal 8R1 multipass compiler does not create reentrant program codes. If new releases of this compiler produce reentrant codes, then it may be possible to execute more than one activity on the same program codes. This will provide a powerful feature to CPS/1100 whereby a single routine may be used for a set of processes or monitors. As an example, a single routine may be used to simulate a set of user jobs in a model study.

7. Having generic units:

   Data types and routines in CPS/1100 programs may be parameterized by producing their copies, if CPS/1100 has generic producing capability. That capability may be obtained by redesigning and recoding the prescanner routines. Such an improvement would increase the abstraction power of CPS/1100.

Compile time checking is the best way of preventing time dependent errors in multiactivity programs. Therefore, CPS/1100 may be furnished via compile time check routines. Algorithms to detect possible deadlocks in the program may be implemented in those routines.

The present form of CPS/1100 uses a common memory for interprocess communication. New keywords may be added to CPS/1100 to provide process communication with only i/o operations. With this kind of extensions, CPS/1100 would be suitable for programming in distributed computer organizations.

VII. CONCLUSION

In this work, design and implementation details of a concurrent programming language, which is structurally distinguished from the other concurrent languages, has been described. The merits of CPS/1100 were demonstrated by programming five typical concurrent programming problems with this language.

In case study one, a monitor type data structure was implemented by using the wait/signal and lock/unlock commands of CPS/1100. The wait/signal pair is used for process synchronization while the lock/unlock commands were used to provide mutually exclusive access to the monitor.

In case study two, a resource allocation problem was solved. The essential difference between concurrent and sequential programming techniques, that is the programmer's ability of thinking in a parallel manner, was demonstrated by this case study.

In case study three, it was showed that some sequential algorithms can easily be adopted for concurrent programming. It was proved by this case study that elegant algorithms can be written by modifying already existing sort, search algorithms and by gaining the control on processors in multiprocessor environments. This case study was an example for using the processor dedication command of CPS/1100.

In case study four, it was illustrated that the processor dedication facility can be used to develop efficient and improved algorithms in widely used mathematical and engineering applications, especially in matrix operations.

In case study five, the suitability of CPS/1100 as a teaching aid and its modelling aspects were displayed. A model of a timesharing-multiprogramming operating system was implemented. Real Pascal programs

were used as user programs in the model. In this case study, it was emphasized that a hierarchical programming system can be implemented by using slavetasks and model tasks of CPS/1100. Activate slavetask deactivate slavetask and fetch status commands were demonstrated in the model study. The contingency registration and handling scheme was used to synchronize slavetasks and model tasks. On the other hand, wait/signal, lock/unlock commands were effectively used to synchronize processes. The case study was a non-trivial concurrent programming example.

In this dissertation, it has been suggested and demonstrated that the prescanning/compilation/postscanning structure is an elegant and convenient way of developing flexible concurrent software. In order to produce an easily modifiable concurrent language, a high level language was chosen for implementing the scanner. Set, token and picture constructs of Macro language were extremely suitable for scanner implementation. Modifications of CPS/1100 syntax and code generation, which were essential during the implementation phase, were performed easily by adding new routines or by updating existing routines of the scanner programs. As an example, the fetch status statement was not considered during the design phase, but it was easily added to the CPS/1100 command repertoire. Also, address assignment capability of the suspend command was easily implemented by simply adding a new macro routine into the prescanner program.

It is quite apparent that the processor dedication facility of CPS/1100, which can be considered as the most distinguishing characteristic from other concurrent languages, provides better control and physical parallelism on program execution flow. Thus, efficient algorithms were developed in the third and forth case studies by using processor dedication command.

Trace capabilities of CPS/1100 was used to debug programs step by step. The snapdump command of CPS/1100 was used to get dumps of common data area where process synchronization variables were stored. The benefits of debug facilities were experienced during program developments for case studies.

In summary, CPS/1100 was designed and implemented as a concurrent programming language with a flexible structure. The language was enriched with processor dedication and program trace capabilities. It has been proved by the case studies that the design aims were achieved in the implementation of CPS/1100.

APPENDICES

APPENDIX A. MACRO PROGRAMMING LANGUAGE

Macro is a language which provides powerful and structured text transformation facilities suitable for extending and translating programming languages under Univac 1100 executive system. Macro language may be used in any of the following areas:

1. Language extension, e.g. preprocessor for PL/1
2. Language translation, e.g. Algol to PL/1 translation
3. Text generation, e.g. text searching and report generation
4. Text editing, e.g. systematic editing of texts
5. Data validation, e.g. format as value range checks.

Macro system consists two seperate program modules. A compilation module, which converts Macro programs into an internal format, and a processor module, which performs actual text transformation. Macro program can be compiled and used without the need for a collection.

A program, known as macro, of the Macro language has two logical parts, a picture and a body. Picture is a specification of the form of the string that the macro will recognize. The body is a series of statements that are executed to generate an output text from input text.

Control cards for Macro compilation and processing are given below: Further information about Macro language can be found on Macro Reference Manual [14].

```
@UNIVAC*MACRO.MDC      file . source, file.omn
@UNIVAC*MACRO.MDP      file . text, file.omn, file.out
```

where	file.source	contains Macro program
	file.omn	contains omnibus element after compilation
	file.text	contains input text
	file.out	contains output text produced after processing.

APPENDIX B. CPS/1100 CONTROL CARDS

Control cards for a sample CPS/1100 is given below. Blanks between fields are allowed. Each control card must be given in one line. Comment lines are identified by /c character in columns 1 and 2.

```
@CPS.S,S      ,CPS.S/Ø,
*COMPILE OPTIONS=.ISRLM, ELTNAME=TPF$.xxx

    Main routine

*COMPILE OPTIONS= ISRLMV, ELTNAME= TPF$.yyy

    Process or monitor routine

*COMPILE OPTIONS= ISRLMV,ELTNAME=TPF$.zzz, USER=uuu, SIZE=nnn,
        PRIORITY=k, STARTTIME=hhmm

    Slavetask, if any

@CPS.S,N        SCRATCH$.SCRATCH1, CPS.S/1, SCRATCH$.SCRATCH2
@CPS.S,N        SCRATCH$.SCRATCH2, CPS.S/2,
@CPS.X
```

A CPS/1100 program may consists of a main and several process, monitor and slavetask routines. Options of Pascal 8R1 calls are valid on *COMPILE directives of CPS/1100. V option is mondatory for all routines except the main routine. Element names stated as xxx, yyy, zzz may be a string that is maximum 12 characters in length. User name uuu is a string maximum 3 alphanumeric characters in length.

nnn in SIZE field on slavetask *COMPILE directive must be an acceptable integer number. In PRIRORITY field must be a single digit integer number and hhmm in STARTTIME field must be a four digit number.

First @CPS.S card is used to call first phase of prescanner, CPS.S/Ø. The other two @CPS.S cards are used to call the other two phase of prescanner which are CPS.S/1 and CPS.S/2. @CPS.X card maintains Pascal compilation, postscanning, linking and execution of the program.

APPENDIX C. CPS/1100 STATEMENTS AND KEYWORDS

Statement or keyword	Function
monitor and process	Used for scope rule definitions
queue	type declaration; used to declare process synchronization variables
forward	used for optional parameter transfer
ioinitiation lock, iotermination lock	used to create a critical region around i/o statements in slavetask routines
ioinitiation flag, iotermination flag	used to provide synchronization between model and slave task when an i/o operation in a slavetask is initiated and completed
startup with taskname	creates a new activity with an activity-id associated with the taskname given, allocates the activation record of the procedure to which the control of new activity is transfered, suspends control of the parent activity until the new activity executes a release statement
startup slavetask	creates a new activity with an activity-name associated with the slavetask, allocates the activation record of the slavetask procedure
fork with taskname	creates a new activity with an activity-id associated with the taskname given, transfers the control of this activity to a procedure which is already called by a startup statement
release	resumes the control of the parent activity of the requesting activity that the parent activity has entered in a wait state by performing a startup statement

Statement or keyword	Function
await	suspends the control of an activity while the specified activities in the statement exist in the system
wait	suspends the control of an activity by using the test-and-set and queuing mechanism
signal	resumes the control of an activity, which is already in wait state, by using the test-and-set and queuing mechanism
lock	sets a specific bit of a test-and-set cell if the bit is not set or suspends the control of an activity for a specific time interval if the bit is set
unlock	clears the specific bit of a test-and-set cell if the bit is set
cobegin	creates a specific activity and suspends its control
coend	removes the activity which is created by a cobegin statement
quit	removes an activity from the system
quit by checking	conditionally quit operation
suspend	suspends the control of an activity for a defined time period
clear	stores zero to a queue type variable
wait forever	suspends the control of an activity for an undefined time period
deactivate slavetask	suspends the control of a slavetask
activate slavetask	resumes the control of a slavetask which has been suspended by a deactivate slavetask statement
terminate	ceases the execution of whole activities

Statement or keywords	Function
fetch status of slavetasks	checks whether a slavetask has exited from the system or not. Status of slavetasks are stored into a specific boolean array
dedicate processor	dedicates a specific processor to an activity
original mode	returns back the system into normal processing mode
cregion	executes a ts instruction on a pre-defined test-and-set cell
cend	clears the test-and-set cell which is set by a cregion statement
snoopy on	calls the snoopy trace utility
snoopy off	turns off the trace operation
snapdump	dumps the contents of the queue type variables.

APPENDIX D - LISTINGS OF MACRO PROGRAMS

D.1 - Prescanner Phase0

D.2 - Prescanner Phase1

D.3 - Prescanner Phase2

D.4 - Postscanner

D.1 - PRESCANNER PHASEØ

```
@CPS:C,SR   CPS.MACRO0,CPS:S/0
MACRO COMPILER LEVEL 7R1 07/27/83 06:06:27
   100          1
   110          2
   120          3     //  ************************************************************  //
   130          4     //  *                                                          *  //
   140          5     //  *                                                          *  //
   150          6     //  *           CPS/1100        P R E S C A N N E R            *  //
   160          7     //  *                                                          *  //
   170          8     //  *                      PHASE  0                            *  //
   180          9     //  *                                                          *  //
   190         10     //  *                                                          *  //
   200         11     //  *         CPS/1100  STATEMENTS   ARE    SYNTACTICALLY     *  //
   210         12     //  *         ANALYSED IN THIS PHASE.INPUT STREAM OF THIS      *  //
   220         13     //  *         PHASE IS A CPS/1100 PROGRAM.  OUTPUT STREAM      *  //
   230         14     //  *         IS PLACED INTO  THE ELEMENT 'SCRATCH1' OF A      *  //
   240         15     //  *         TEMPORARY FILE 'SCRATCHS'.                       *  //
   250         16     //  *                                                          *  //
   260         17     //  *                                                          *  //
   270         18     //  ************************************************************  //
   280         19
   290         20
   300         21
   310         22     DEBUG ON;
   320         23     SET ALPHA <'A' .. 'Z' >;
   330         24     SET ID_CHAR  <'A' .. 'Z'\'0' .. '9'\'_'\'$'\'#'\':'\'/'>;
   340         25     SET DIGIT  <'0' .. '9'>;
   350         26
   360         27
   370         28
   380         29     TOKEN  OP<'('>;
   390         30     TOKEN  CP<')'>;
   400         31     TOKEN  MCPS<'*COMPILE'>;
   410         32     TOKEN  ID < ALPHA(ID_CHAR) ...> ;
   420         33     TOKEN  BLANK IGNORE <' ' ..> ;
   430         34     TOKEN  NUM<DIGIT(DIGIT) ..>;
   440         35     TOKEN  EOTX<S'EOF'>;
   450         36     TOKEN  COM<','>;
   460         37     TOKEN  SZ<'SIZE='>;
   470         38     TOKEN  OPT<'OPTIONS='>;
   480         39     TOKEN  PR<'PRIORITY='>;
   490         40     TOKEN  ELTN<'ELTNAME='>;
   500         41     TOKEN  STT<'STARTTIME='>;
   510         42     TOKEN  COMMENT<'/C'>;
   520         43
   530         44
   540         45     A=S'NUL';
   550         46     I=0;
   560         47     TOK=S'NUL';
   570         48     DECLARE R(*);
   580         49     ERR=' ** ERROR ** SYNTAX ERROR  ';
```

```
590          50     PROCEDURE READLN;
600    1     51       ST: I=0;
610    1     52            READ A;
620    1     53           IF LENGTH(A) EQ 0
630    1     54             THEN BEGIN
640    1     55                    CLOSE WRITE INTO 'SCRATCH$:SCRATCH1';
650    2     56                    STOP;
660    2     57                  END;
670    1     58           IF  A[1,2]  EQC '/C' THEN  GO TO ST;
680    1     59           TOKENIZE A INTO R;
690    1     60     END;
700          61
710          62
720          63     PROCEDURE NEXTTOKEN;
730    1     64       ST: I = I+1;
740    1     65           IF  I  GT SIZE(R)
750    1     66            THEN BEGIN
760    1     67                    WRITE   A  INTO 'SCRATCH$,SCRATCH1' ;
770    2     68                    ALL REA LN;
780    2     69                   I=1;
790    2     70                 END;
800    1     71           IF TRIM(R(I)) EQC ' ' THEN GO TO ST;
810    1     72           TOK = TRIM(R(I));
820    1     73     END;
830          74
840          75
850          76
860          77     PROCEDURE  PROCCPS;
870    1     78      IF TOK EQC '*COMPILE' THEN
880    1     79       BEGIN
890    1     80        CALL NEXTTOKEN; T=TOK; CALL NEXTTOKEN; T = T&TOK;
900    2     81        IF T   EQC 'OPTIONS=' THEN
910    2     82         BEGIN
920    2     83          CALL NEXTTOKEN;CALL NEXTTOKEN;
930    3     84          IF TOK EQC ',' THEN
940    3     85           BEGIN
950    3     86            CALL NEXTTOKEN;T = TOK;CALL NEXTTOKEN;T=T&TOK;
960    4     87            IF     EQC 'ELT AME=' T EN
970    4     88            BEGIN
980    4     89             CALL NEXTTOKEN;
990    5     90             TTT= TOK[1,5];
1000   5     91             IF ( TTT   EQC 'TPFS$') AND
1010   5     92                ( TOK   NEC 'TPFS$NAMES')
1020   5     93              T EN BEGIN
1030   5     94                    CALL NEXTTOKEN;
1040   6     95                    IF TOK NEC ','
1050   6     96                     THEN RETURN;
1060   6     97                     ELSE BEGIN
1070   6     98                           CALL NEXTTOKEN; T=TOK;CALL NEXTTOKEN; T = T&TOK;
1080   7     99                           IF T   EQC 'USER=' THEN
1090   7    100                            BEGIN
```

```
1100   7    101                          CALL NEXTTOKEN; CALL NEXTTOKEN;
1110   8    102                          IF TOK EQC ',' THEN
1120   8    103                           BEGIN
1130   8    104                             CALL NEXTTOKEN; T=TOK;CALL NEXTTOKEN; T = T&TOK;
1140   9    105                             IF T   EQC 'SIZE=' THEN
1150   9    106                              BEGIN
1160   9    107                               CALL NEXTTOKEN; CALL NEXTTOKEN;
1170  10    108                               IF TOK EQC ',' THEN
1180  10    109                                BEGIN
1190  10    110                                 CALL NEXTTOKEN; T=TOK;
1200  11    111                                 CALL NEXTTOKEN; T = T&TOK;
1210  11    112                                 IF  T   EQC 'PRIORITY=' THEN
1220  11    113                                  BEGIN
1230  11    114                                   CALL NEXTTOKEN; CALL NEXTTOKEN;
1240  12    115                                   IF TOK EQC ',' THEN
1250  12    116                                    BEGIN
1260  12    117                                     CALL NEXTTOKEN;T=TOK;
1270  13    118                                     CALL NEXTTOKEN;T=T&TOK;
1280  13    119                                     IF T   EQC 'STARTTIME=' THEN
1290  13    120                                      BEGIN
1300  13    121                                       CALL NEXTTOKEN;
1310  14    122                                       CALL NEXTTOKEN;
1320  14    123                                       RETURN;
1330  14    124                                      END;
1340  13    125                                    END;
1350  12    126                                  END;
1360  11    127                                END;
1370  10    128                               END;
1380   9    129                            END;
1390   8    130                         END;
1400   7    131                       END;
1410   6    132                 END;
1420   5    133            END;
1430   4    134          END;
1440   3    135        END;
1450   2    136      END;
1460   1    137     WRITE' ** ERROR ** SYNTAX ERROR ON CPS/1100 CONTROL CARD ' ;
1470   1    138   END;
1480        139
1490        140
1500        141
1510        142   PROCEDURE  PROCSTRTUP;
1520   1    143     CALL NEXTTOKEN;
1530   1    144     IF TOK EQC 'WITH'
1540   1    145       THEN BEGIN
1550   1    146             CALL NEXTTOKEN;
1560   2    147             IF TOK EQC 'TASKNAME'
1570   2    148              THEN BEGIN
1580   2    149                    CALL NEXTTOKEN;
1590   3    150                    IF TOK EQC '('
1600   3    151                     THEN BEGIN
```

```
1610   3     152                          CALL NEXTTOKEN; CALL NEXTTOKEN;
1620   4     153                          IF TOK EQC ')'
1630   4     154                            THEN BEGIN
1640   4     155                                   CALL NEXTTOKEN;
1650   5     156                                   RETURN;
1660   5     157                                 END;
1670   4     158                        END;
1680   3     159                  END;
1690   2     160            END;
1700   1     161       ELSE IF TOK EQC 'SLAVETASK'
1710   1     162              THEN BEGIN
1720   1     163                    CALL NEXTTOKEN;
1730   2     164                    IF TOK EQC '('
1740   2     165                     THEN BEGIN
1750   2     166                          CALL NEXTTOKEN; CALL NEXTTOKEN;
1760   3     167                          IF TOK EQC ')'
1770   3     168                            THEN BEGIN
1780   3     169                                   CALL NEXTTOKEN;
1790   4     170                                   RETURN;
1800   4     171                                 END;
1810   3     172                        END;
1920   2     173                  END;
1830   1     174      WRITE ' ** ERROR ** SYNTAX ERROR ON FORK/STARTUP STATEMENT ';
1840   1     175   END;
1850         176
1860         177
1870         178
1880         179   PROCEDURE PROCAWAIT;
1890   1     180      CALL NEXTTOKEN;
1900   1     181      IF TOK EQC '('
1910   1     182        THEN BEGIN
1920   1     183               CALL NEXTTOKEN; CALL NEXTTOKEN;
1930   2     184               LOOP: IF TOK EQC ')'
1940   2     185                       THEN BEGIN CALL NEXTTOKEN;  RETURN; END;
1950   2     186                       ELSE IF TOK EQC ','
1960   2     187                          THEN BEGIN
1970   2     188                                 CALL NEXTTOKEN; CALL NEXTTOKEN;
1980   3     189                                 GO TO LOOP;
1990   3     190                               END;
2000   2     191             END;
2010   1     192       WRITE ' ** ERROR ** SYNTAX ERROR ON AWAIT STATEMENT  ';
2020   1     193   END;
2030         194
2040         195
2050         196
2060         197
2070         198   PROCEDURE PROCOTHER;
2080   1     199      LASTTOK = TOK;
2090   1     200      CALL NEXTTOKEN;
2100   1     201      IF (LASTTOK EQC 'LOCK') AND (TOK EQC 'OF') THEN RETURN;
2110   1     202      IF TOK EQC '('
```

```
2120   1     203          THEN BEGIN
2130   1     204               CALL NEXTTOKEN; CALL NEXTTOKEN;
2140   2     205               IF TOK EQC ')'
2150   2     206                  THEN BEGIN
2160   2     207                         CALL NEXTTOKEN;
2170   3     208                         RETURN;
2180   3     209                       END;
2190   2     210               END;
2200   1     211       WRITE ERR;
2210   1     212    END;
2220         213
2230         214
2240         215
2250         216    PROCEDURE PROCWAIT;
2260   1     217       CALL NEXTTOKEN;
2270   1     218       IF TOK EQC 'FOREVER'
2280   1     219         THEN BEGIN CALL NEXTTOKEN; RETURN; END;
2290   1     220         ELSE BEGIN
2300   1     221         IF TOK EQC '('
2310   2     222           THEN BEGIN
2320   2     223                CALL NEXTTOKEN; CALL NEXTTOKEN;
2330   3     224                IF TOK EQC ')'
2340   3     225                  THEN BEGIN
2350   3     226                         CALL NEXTTOKEN;
2360   4     227                         RETURN;
2370   4     228                       END;
2380   3     229                END;
2390   2     230              END;
2400   1     231        WRITE ERR;
2410   1     232    END;
2420         233
2430         234
2440         235
2450         236    PROCEDURE PROCFETCH;
2460   1     237       CALL NEXTTOKEN;
2470   1     238       IF TOK EQC '%TATUS'
2480   1     239         THEN BEGIN
2490   1     240                CALL NEXTTOKEN;
2500   2     241                IF TOK EQC 'OF'
2510   2     242                   THEN BEGIN
2520   2     243                          CALL NEXTTOKEN;
2530   3     244                          IF TOK EQC 'SLAVETASKS'
2540   3     245                            THEN BEGIN
2550   3     246                                   CALL NEXTTOKEN;
2560   4     247                                   RETURN;
2570   4     248                                 END;
2580   3     249                          RETURN;
2590   3     250                        END;
2600   2     251              END;
2610   1     252       WRITE  ERR;
2620   1     253    END;
```

```
2630          254     PROCEDURE PROCACTIVE;
2640    1     255       CALL NEXTTOKEN;
2650    1     256       IF TOK EQC 'SLAVETASK'
2660    1     257         THEN BEGIN
2670    1     258                CALL NEXTTOKEN;
2680    2     259                IF TOK EQC '('
2690    2     260                   THEN BEGIN
2700    2     261                          CALL NEXTTOKEN; CALL NEXTTOKEN;
2710    3     262                          IF TOK EQC ')'
2720    3     263                            THEN BEGIN CALL NEXTTOKEN; RETURN; END;
2730    3     264                        END;
2740    2     265              END;
2750    1     266       WRITE ERR;
2760    1     267     END;
2770          268
2780          269
2790          270     PROCEDURE PROCDEDIC;
2800    1     271        CALL NEXTTOKEN;
2810    1     272        IF TOK EQC 'PROCESSOR'
2820    1     273          THEN BEGIN
2830    1     274                 CALL NEXTTOKEN;
2840    2     275                 IF TOK EQC '('
2850    2     276                    THEN BEGIN
2860    2     277                           CALL NEXTTOKEN; CALL NEXTTOKEN;
2870    3     278                           IF TOK EQC ')'
2880    3     279                             THEN BEGIN CALL NEXTTOKEN; RETURN; END;
2890    3     280                         END;
2900    2     281                 END;
2910    1     282        WRITE ERR;
2920    1     283     END;
2930          284
2940          285
2950          286     PROCEDURE PROCQUIT;
2960    1     287       CALL NEXTTOKEN;
2970    1     288       IF TOK EQC 'BY'
2980    1     289         THEN BEGIN
2990    1     290                CALL NEXTTOKEN;
3000    2     291                IF TOK EQC 'CHECKING'
3010    2     292                   THEN BEGIN
3020    2     293                          CALL NEXTTOKEN;
3030    3     294                          IF TOK EQC '('
3040    3     295                            THEN BEGIN
3050    3     296                                   CALL NEXTTOKEN; CALL NEXTTOKEN;
3060    4     297                                   IF TOK EQC ')'
3070    4     298                                     THEN BEGIN CALL NEXTTOKEN; RETURN; END;
3080    4     299                                   END;
3090    3     300                        END;
3100    2     301              END;
3110    1     302         ELSE RETURN;
3120    1     303       WRITE ERR;
3130    1     304     END;
```

```
3140          305     PROCEDURE PROCSNOOPY;
3150    1     306        CALL NEXTTOKEN;
3160    1     307        IF ( TOK  EQC 'ON' ) OR
3170    1     308           ( TOK  EQC 'OFF')
3180    1     309           THEN BEGIN CALL NEXTTOKEN; RETURN;  END;
3190    1     310        WRITE ERR;
3200    1     311     END;
3210          312
3220          313
3230          314
3240          315     PROCEDURE PROCORIG;
3250    1     316        CALL NEXTTOKEN;
3260    1     317        IF TOK  EQC 'MODE'
3270    1     318           THEN BEGIN CALL NEXTTOKEN; RETURN;  END;
3280    1     319        WRITE ERR;
3290    1     320     END;
3300          321
3310          322
3320          323
3330          324     OPEN WRITE INTO 'SCRATCH$.SCRATCH1';
3340          325     CALL READLN;
3350          326     CALL NEXTTOKEN;
3360          327     WHILE TOK NEC S'EOF'
3370          328      DO BEGIN
3380          329        START:
3390    1     330         IF TOK EQC '*COMPILE'
3400    1     331          THEN BEGIN CALL PROCCPS;GO TO START; END;
3410    1     332          ELSE IF (TOK EQC 'STARTUP') OR (TOK EQC 'FORK')
3420    1     333                THEN BEGIN CALL PROCSTRTUP; GO TO START; END;
3430    1     334                ELSE IF TOK EQC 'WAIT'
3440    1     335                      THEN BEGIN  CALL PROCWAIT; GO TO START; END;
3450    1     336                      ELSE IF TOK EQC 'AWAIT'
3460    1     337                            THEN BEGIN CALL PROCAWAIT;GO TO START; END;
3470    1     338                            ELSE IF (TOK EQC 'ACTIVATE') OR
3480    1     339                                    (TOK EQC 'DEACTIVATE')
3490    1     340                                  THEN BEGIN CALL PROCACTIVE;GO TO START; END;
3500    1     341                                  ELSE IF TOK EQC 'DEDICATE'
3510    1     342                                        THEN BEGIN CALL PROCDEDIC;GO TO START; END;
3520    1     343                                        ELSE IF TOK EQC 'ORIGINAL'
3530    1     344                                              THEN BEGIN CALL PROCORIG;GO TO START; END;
3540    1     345                                              ELSE IF TOK EQC 'SNOOPY'
3550    1     346                                                    THEN BEGIN CALL PROCSNOOPY;GO TO START; END;
3560    1     347                                                    ELSE IF TOK EQC 'QUIT'
3570    1     348                                                          THEN BEGIN CALL PROCQUIT;GO TO START; END;
3580    1     349                                                          ELSE IF TOK EQC 'FETCH'
3590    1     350                                                                THEN BEGIN CALL PROCFETCH;GO TO START;END;
3600    1     351                                                                ELSE IF (TOK EQC 'COBEGIN') OR
3610    1     352                                                                        (TOK EQC 'SIGNAL' ) OR
3620    1     353                                                                        (TOK EQC 'RELEASE') OR
3630    1     354                                                                        (TOK EQC 'LOCK'   ) OR
3640    1     355                                                                        (TOK EQC 'UNLOCK' ) OR
```

```
  3650    1      356
  3660    1      357
  3670    1      358
  3680    1      359
  3690    1      360
  3700    2      361
  3710    2      362
  3720    1      363
  3730    1      364           END;
  3740           365      CLOSE WRITE INTO 'SCRACTH$.SCRATCH1';
  3750           366      STOP;
END MDC 0 ERRORS 0 WARNINGS 0 REMARKS
```

```
   (TOK EQC 'SUSPEND') OR
   (TOK EQC 'SNAPDUMP') OR
   (TOK EQC 'CLEAR'   )
 THEN BEGIN
        CALL PROCOTHER;
        GO TO STRT;
      END;
 ELSE CALL NEXTTOKEN;
```

D.2 - PRESCANNER PHASE1

```
@CPS/C,SR   CPS/MACRO1,CPS/S/1
MACRO COMPILER LEVEL 7R1 07/27/83 06:25:25
   100          1
   110          2
   120          3      //  ************************************************************  //
   130          4      //  *                                                          *  //
   140          5      //  *                                                          *  //
   150          6      //  *            CPS/1100     P R E S C A N N E R              *  //
   160          7      //  *                                                          *  //
   170          8      //  *                          PHASE    1                      *  //
   180          9      //  *                                                          *  //
   190         10      //  *     THIS  PROGRAM  RECOGNIZES  THE PARAMETERS, SUCH      *  //
   200         11      //  *     AS PRIORITY AND PROGRAM SIZE, OF A USER PROGRAM      *  //
   210         12      //  *     IN A MODEL OPERATING  SYSTEM  IMPLEMENTED   VIA      *  //
   220         13      //  *     CPS/1100,  IT  ALSO  RECOGNIZES  INPUT / OUTPUT      *  //
   230         14      //  *     FLAGS  WHICH  ARE  USED  TO  RESUME   EXECUTION     *  //
   240         15      //  *     CERTAIN SUSPENDED CPS/1100 MODEL ROUTINES. USER      *  //
   250         16      //  *     PROGRAM  PARAMETERS AND INPUT/OUTPUT FLAGS  ARE      *  //
   260         17      //  *     WRITTEN  INTO A FILE "INFO$",  OUTPUT STREAM IS      *  //
   270         18      //  *     PLACED INTO THE ELEMENT "SCRATCH2" OF "SCRATCH$"     *  //
   280         19      //  *     FILE.                                                *  //
   290         20      //  *                                                          *  //
   300         21      //  *                                                          *  //
   310         22      //  ************************************************************  //
   320         23
   330         24
   340         25
   350         26      DEBUG ON;
   360         27      SET  ALPHA <'A' ,. 'Z' >;
   370         28      SET  ID_CHAR  <'A' .. 'Z'\'0' ,. '9'\'_'\',','\'$'>;
   380         29      SET  DIGIT  <'0' .. '9'>;
   390         30
   400         31
   410         32
   420         33      TOKEN  OP<'('>;
   430         34      TOKEN  MCPS<'*COMPILE'>;
   440         35      TOKEN  CP<')'>;
   450         36      TOKEN  ID < ALPHA(ID_CHAR) .,.> ;
   460         37      TOKEN  BLANK IGNORE <' ' .,.>;
   470         38      TOKEN  NUM<DIGIT(DIGIT) ,.,>;
   480         39      TOKEN  EOTX<S'EOF'>;
   490         40      TOKEN  COM<','>;
   500         41
   510         42
   520         43
   530         44
   540         45       DECLARE  USER(*);
   550         46       DECLARE  PROGSIZE(*);
   560         47       DECLARE  PRIORITY(*);
   570         48       DECLARE  STARTTIME(*);
   580         49
```

```
590          50      NT = 0;
600          51      IOINITLOCK = S'NUL';
610          52      IOTERMLOCK = S'NUL';
620          53      IOINITFLAG = S'NUL';
630          54      IOTERMFLAG = S'NUL';
640          55      OPEN  WRITE INTO 'INFOS';
650          56
660          57
670          58
680          59      MACRO CPSSLAVE TRIGGER PROTECT
690    1     60         < MCPS  'OPTIONS' '=' W1:<ID>  ',' 'ELTNAME' '=' W2:<ID> ',' 'USER' '=' W3:<ID> ',' 'SIZE' '='
700    1     61              W4:<NUM> ',' 'PRIORITY' '=' W5:<NUM> ',' 'STARTTIME' '=' W6:<NUM>>;
710    1     62            NT = NT+1;
720    1     63            USER(NT)=TRIM(W3);
730    1     64            PROGSIZE(NT)=TRIM(W4);
740    1     65            PRIORITY(NT)=TRIM(W5);
750    1     66            STARTTIME(NT)=TRIM(W6);
760    1     67            ANSWER S'DELB'&'@CPS,'& W1 & '    '& W2 &',USER='& USER(NT);
770    1     68      END;
780          69
790          70
800          71
810          72      MACRO CPSROUTINE TRIGGER PROTECT
820    1     73         < MCPS  'OPTIONS' '=' W1:<ID>  ',' 'ELTNAME' '=' W2:<ID> >;
830    1     74            ANSWER S'DELB'&'@CPS,'& W1 & '    '& W2 ;
840    1     75      END;
850          76
860          77
870          78
880          79       MACRO IOINITLCK  TRIGGER PROTECT
890    1     80           < W1:<ID> ':' 'IOINITIATION' 'LOCK' 'OF' 'QUEUE' ';'>;
900    1     81              IOINITLOCK = TRIM(W1);
910    1     82              ANSWER '   '& W1 & ':' & 'QUEUE' & ';' ;
920    1     83       END;
930          84
940          85
950          86
960          87
970          88       MACRO IOTERMLCK  TRIGGER PROTECT
980    1     89           < W1:<ID> ':' 'IOTERMINATION' 'LOCK' 'OF' 'QUEUE' ';'>;
990    1     90              IOTERMLOCK = TRIM(W1);
1000   1     91              ANSWER '   '& W1 & ':' & 'QUEUE' & ';' ;
1010   1     92       END;
1030         93
1040         94
1050         95
1060         96       MACRO IOINITFLG    TRIGGER PROTECT
1070   1     97           < W1:<ID> ':' 'IOINITIATION' 'FLAG' 'OF' 'QUEUE' ';'>;
1080   1     98              IOINITFLAG = TRIM(W1);
1090   1     99              ANSWER '   '& W1 & ':' & 'QUEUE' & ';' ;
1100   1    100       END;
```

```
1140          101       MACRO IOTERM TRIGGER PROTECT
1150    1     102           < W1:<ID> ':' 'IOTERMINATION' 'FLAG' 'OF' 'QUEUE' ';'>;
1160    1     103              IOTERMFLAG = TRIM(W1);
1170    1     104              ANSWER '    '& W1 & ':' & 'QUEUE' & ';' ;
1180    1     105       END;
1190          106
1200          107
1210          108
1220          109       MACRO ENDOFTEXT TRIGGER PROTECT< EOTX >;
1230    1     110          A = NTE' '&IOINITLOCK&' '&IOTERMLOCK&' '&IOINITFLAG&' '&IOTERMFLAG;
1240    1     111          WRITE A INTO 'INFO$.';
1250    1     112          I = 1;
1260    1     113          WHILE  I LE NT DO BEGIN
1270    1     114                              A = PROGSIZE(I) & ' ' &  PRIORITY(I) & ' ' &
1280    2     115                                  ' ' & STARTTIME(I);
1290    2     116                              WRITE A INTO 'INFO$.';
1300    2     117                              I = I + 1 ;
1310    2     118                             END;
1320    1     119          CLOSE WRITE INTO 'INFO$.';
1330    1     120       END;
END MDC 0 ERRORS 0 WARNINGS 0 REMARKS
```

D.3 - PRESCANNER PHASE2

```
@CPS:C,SR   CPS.MACRO2,CPS:S/2
MACRO COMPILER LEVEL 7R1 07/27/83 06:27:18
   100          1     //  ************************************************************  //
   110          2     //  *                                                          *  //
   120          3     //  *                                                          *  //
   130          4     //  *              CPS/370      P R E S C A N N E R            *  //
   140          5     //  *                                                          *  //
   150          6     //  *                           PHASE   2                      *  //
   160          7     //  *                                                          *  //
   170          8     //  *     ASSEMBLER CODES AND MESSAGES FOR POSTSCAN PHASE      *  //
   180          9     //  *     ARE INSERTED TO THE PROGRAM TEXT IN THIS PHASE.      *  //
   190         10     //  *     INPUT STREAM RETRIEVED FROM "SCRATCH$:SCRATCH2"      *  //
   200         11     //  *     IS COMPARED  WITH PICTURES  DECLARED  IN  MACRO      *  //
   210         12     //  *     ROUTINES.IF A MATCH IS FOUND A SET OF ASSEMBLER      *  //
   220         13     //  *     LER CODES OR MESSAGES  ARE PRODUCED. THE  CODES      *  //
   230         14     //  *     OR MESSAGES ARE INSERTED INTO THE OUTPUT STREAM      *  //
   240         15     //  *     THAT IS PLACED INTO "NAME$" ELEMENT  OF  "TPF$"      *  //
   250         16     //  *     FILE.                                                *  //
   260         17     //  *                                                          *  //
   270         18     //  *                                                          *  //
   280         19     //  ************************************************************  //
   290         20
   300         21
   310         22
   320         23     DEBUG   ON;
   330         24     EXPAND  ANS = ANSWER ;
   340         25     EXPAND  TRIG = TRIGGER ;
   350         26     EXPAND  PROT = PROTECT   ;
   360         27     EXPAND  ZZ   = S'EOL'    ;
   370         28     EXPAND  QQ   = S'DELB'    ;
   380         29
   390         30
   400         31
   410         32     SET  ALPHA <'A' .: 'Z' >;
   420         33     SET  ID_CHAR <'A' .: 'Z'\'0' :. '9'\'_'\':'\'$'>;
   430         34     SET  DIGIT <'0' .: '9'>;
   440         35
   450         36
   460         37
   470         38     TOKEN  SL<ZZ>;
   480         39     TOKEN  TP<':.'>;
   490         40     TOKEN  OP<'('>;
   500         41     TOKEN  NLL < S'NUL'>;
   510         42     TOKEN  MCPS<'@CPS,'>;
   520         43     TOKEN  CP<')'>;
   530         44     TOKEN  ID < ALPHA(ID_CHAR) :.:> ;
   540         46     TOKEN  BLANK IGNORE <' ' :.:' >;
   550         46     TOKEN  FORK<'FORK'>;
   560         47     TOKEN  TS<'T$CELL'>;
   570         48     TOKEN  RS<'RES   '>;
   580         49     TOKEN  NUM<DIGIT(DIGIT) .:.>;
```

```
590          50     TOKEN  EOTX<S'EOF');
600          51     TOKEN  EQSIGN<':=');
610          52
620          53
630          54
640          55     ERROR01   = ZZ6' ** ERROR **  UNDECLARED PROCEDURE IN LINE '  ;
650          56     ERROR02   = ZZ6' ** ERROR **  UNDECLARED QUEUE TYPE VARIABLE IN LINE ';
660          57     WARNING01 = ZZ6' ** WARNING **  CHECK THE ACTIVITY NAME(S) IN LINE';
670          58
680          59
690          60
700          61     PROG_ID ='MAIN';
710          62     PROC_FLAG = 0;
720          63     VAR_FLAG = 0;
730          64     BEGIN_FLAG=0;
740          65     COBEGIN_FLAG=S'NUL';
750          66     COBEGIN_COUNT=0;
760          67     MAINPROG_FLAG=1;
770          68     SACN=0;
780          69     CPS_COUNT =0;
790          70     SLVTASKNAME = S'NUL' ;
800          71     SLVTASKCNT = 0;
810          72     DECLARE R(*);
820          73
830          74
840          75
850          76     OPEN  READ FROM 'INFOS';
860          77     READ A  FROM 'INFOS';
870          78     TOKENIZE A  INTO  R;
880          79     NT=TRIM(R(1));
890          80     IOINITLOCK = TRIM(R(3));
900          81     IOTERMLOCK = TRIM(R(5));
910          82     IOINITFLAG = TRIM(R(7));
920          83     IOTERMFLAG = TRIM(R(9));
930          84
940          85
950          86
960          87     DECLARE  QUEUES(**);
970          88     DECLARE  VARIABLES(**);
980          89     DECLARE  PROCS(**);
990          90     DECLARE  ACTID(**);
1000         91     DECLARE  ELTNAME(*);
1010         92
1020         93
1030         94
1040         95     PROCS('MAIN')='MAIN';
1050         96     ACN=0 ;
1060         97
1070         98
1080         99
1090        100
```

```
1100          101     MACRO AWAIT TRIG PROT<'AWAIT'(SL)OP(SL) W1:<<ID(',')>*,*>(SL) W2:< CP(SL)(';')>>;
1110    1     102       IF TRIM(W2)[*,1] EQC ';' THEN WEND ='END;'; ELSE WEND='END';
1120    1     103       ACNAMES=TRIM(W1);
1130    1     104       NM = 0;
1140    1     105       I =2 ; NAME = ACNAMES[1,1];
1150    1     106       WHILE  I  LE LENGTH(ACNAMES)
1160    1     107           DO BEGIN
1170    1     108                IF (ACNAMES[I,1] EQC ',' ) OR
1180    2     109                   ( I EQ LENGTH(ACNAMES) )
1190    2     110                  THEN BEGIN
1200    2     111                         IF( I EQ LENGTH(ACNAMES) ) AND
1210    3     112                           ( ACNAMES[I,1] NEC ',' )
1220    3     113                            THEN NAME=NAME&ACNAMES[I,1];
1230    3     114                         IF VOID(ACTID,TRIM(NAME))
1240    3     115                           THEN BEGIN
1250    3     116                                  WRITE ZZ& WARNING01 & LINE ;
1260    4     117                                  ACN=ACN+1;
1270    4     118                                  ACTID(NAME)=ACN;
1280    4     119                                END;
1290    3     120                         M=ACTID(TRIM(NAME));
1300    3     121                         J=1;  N=1;
1310    3     122                         WHILE  J LE M
1320    3     123                           DO BEGIN
1330    3     124                                N=N*2;
1340    4     125                                J=J+1;
1350    4     126                              END;
1360    3     127                         NM=NM+N;
1370    3     128                         IF I LT LENGTH(ACNAMES)
1380    3     129                           THEN BEGIN
1390    3     130                                  I=I+1;
1400    4     131                                  NAME= ACNAMES[I,1];
1410    4     132                                END;
1420    3     133                       END;
1430    2     134                  ELSE IF ACNAMES[I,1] NEC ' ' THEN NAME=NAME&ACNAMES[I,1];
1440    2     135                I=I+1;
1450    2     136              END;
1460    1     137       ANS 00&  '  BEGIN                                  '&ZZ;
1470    1     138       ANS 00&'$CODE       L       R15,A0                 '&ZZ;
1480    1     139       ANS 00&'$CODE       LA      A0,('& NM &')'&ZZ;
1490    1     140       ANS 00&'$CODE       ER      AWAIT$ '&ZZ;
1500    1     141       ANS 00&'$CODE       L       A0,R15                 '& ZZ;
1510    1     142       ANS 00&    WEND                                    & ZZ;
1520    1     143     END;
1530          144
1540          145
1550          146
1560          147     MACRO M1 TRIG <M:<'PROCEDURE'>>;
1570    1     148       PROC_FLAG=1;
1580    1     149       BEGIN_FLAG=0;
1590    1     150       RETURN   M;
1600    1     151     END;
```

```
1610          152     MACRO M2 TRIG PROT <M:<OP>>;
1620    1     153       IF PROC_FLAG EQ 1
1630    1     154         THEN VAR_FLAG = 1;
1640    1     155         ELSE VAR_FLAG = 0;
1650    1     156       RETURN   M;
1660    1     157     END;
1670          158
1680          159
1690          160
1700          161     MACRO M5  <M:<<('VAR') (SL) ID (SL) ':' (SL)ID (SL)(';')> .?.>>;
1710    1     162       ANS M;
1720    1     163     END;
1730          164
1740          165
1750          166
1760          167     MACRO PROC_DCL TRIG
1770    1     168       <PROCNAME:<ID>(SL)ARGS:<(OP(SL)M5(SL)CP)(SL)';' > <'MONITOR'\'PROCESS'> ';'>;
1780    1     169         PROCS(TRIM(PROCNAME))=TRIM(PROCNAME);
1790    1     170         ANS  PROCNAME & ARGS & 'EXTERNAL ;' ;
1800    1     171     END;
1810          172
1920          173
1930          174
1940          175     MACRO VAR_DCL1 TRIG PROT <<('VAR')(SL) NAME:<<ID (',') ?.?> (SL)':'(SL)TYPE:<ID> (SL)';'> ;
1950    1     176       IF VAR_FLAG EQ 1       THEN FAIL;
1960    1     177       IF MAINPROG_FLAG EQ 0 THEN FAIL;
1970    1     178       J = 1; W= ' ';NAME=TRIM(NAME)&',' ;
1980    1     179       LOOP:
1990    1     180            IF TRIM(NAME)[J,1] NEC ','
2000    1     181              THEN W = W & TRIM(NAME)[J,1] ;
2010    1     182              ELSE BEGIN
2020    1     183                     IF TRIM(TYPE) EQC 'QUEUE'
2030    2     184                       THEN  QUEUES(TRIM(W))='INTEGER';
2040    2     185                       ELSE  VARIABLES(TRIM(W))=TRIM(TYPE);
2050    2     186                     W = ' ';
2060    2     187                   END;
2070    1     188            J = J+1;
2080    1     189            IF TRIM(W) EQC 'VAR'        THEN W = ' ';
2090    1     190            IF J LE LENGTH(TRIM(NAME)) THEN GO TO LOOP;
2100    1     191     END;
2110          192
2020          193
2030          194
2040          195     MACRO VAR_DCL2 TRIG PROT
2050    1     196        <('VAR')(SL)NAME:<<ID (',')>?.?>(SL)':'(SL)TYPE:<<'ARRAY'(SL)'['<<<NUM \ ID>(TO)<NUM \ ID>(',')>>.?.>
2060    1     197                                                (SL) ']' (SL)'OF'(SL) ID >  (SL) ';'> ;
2070    1     198       IF  VAR_FLAG EQ 1      THEN FAIL;
2080    1     199       IF MAINPROG_FLAG EQ 0 THEN FAIL;
2090    1     200       J = 1; W= ' ';NAME=TRIM(NAME)&',' ;
2100    1     201       LOOP:
2110    1     202            IF TRIM(NAME)[J,1] NEC ','
```

```
2120  1     203              THEN W = W & TRIM(NAME)[J,1] ;
2130  1     204              ELSE BEGIN
2140  1     205                     IF TRIM(TYPE) EQC 'QUEUE'
2150  2     206                       THEN  QUEUES(TRIM(W))='INTEGER';
2160  2     207                       ELSE  VARIABLES(TRIM(W))=TRIM(TYPE);
2170  2     208                     W = ' ';
2180  2     209                   END;
2190  1     210            J = J+1;
2200  1     211            IF TRIM(W) EQC 'VAR'       THEN W = ' ';
2210  1     212            IF J LE LENGTH(TRIM(NAME)) THEN GO TO LOOP;
2220  1     213     END;
2230        214
2240        215
2250        216
2260        217     MACRO M3 TRIG PROT <M:<CP>>;
2270  1     218       IF PROC_FLAG EQ 1
2280  1     219         THEN BEGIN
2290  1     220                PROC_FLAG = 0 ;
2300  2     221                VAR_FLAG = 0  ;
2310  2     222              END;
2320  1     223       RETURN M;
2330  1     224     END;
2340        225
2350        226
2360        227
2370        228     MACRO M4 TRIG PROT <'VAR'>;
2380  1     229        IF(VAR_FLAG EQ 1) OR (MAINPROG_FLAG EQ 0)THEN RETURN 'VAR' ;
2390  1     230     END;
2400        231
2410        232
2420        233
2430        234     MACRO MACBEG   TRIG PROT< 'BEGIN'(SL) (';')>;
2440  1     235        BEGIN_FLAG = BEGIN_FLAG +1;
2450  1     236        IF BEGIN_FLAG NE 1 THEN FAIL;
2460  1     237        IF MAINPROG_FLAG EQ 1
2470  1     238         THEN BEGIN
2480  1     239               N=3*SIZE(PROCS)+SIZE(QUEUES)+4+900+900 ;
2490  2     240               NN = NT * 3+ N ;
2500  2     241               ANS 'VAR GLOBALS : ARRAY [,1 :, '&NN &'3) OF INTEGER ;'&ZZ;
2510  2     242               IF SIZE(VARIABLES) NE 0
2520  2     243                 THEN BEGIN
2530  2     244                       NAME = FIRST(VARIABLES);
2540  3     245                       LNAME = LAST(VARIABLES);
2550  3     246                       WHILE NAME NEC LNAME
2560  3     247                          DO BEGIN
2570  3     248                               ANS '      '&NAME&' : '& VARIABLES(NAME) &' ;'& ZZ ;
2580  4     249                               NAME = NEXT(VARIABLES,NAME);
2590  4     250                             END;
2600  3     251                       ANS '      '& LNAME &' : '& VARIABLES(LNAME) &' ;'& ZZ ;
2610  3     252                       ANS QQ&'$CODE RSCELL*      T$CELL'&ZZ;
2620  3     253                       ANS QQ&'$CODE CBGNST*      T$CELL'&ZZ;
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```
2530   3     254                ANS QQ&'$CODE SYSTEMHOLD*  T$CELL'&ZZ;
2640   3     255                J=1;N=SIZE(QUEUES);
2650   3     256                NAME= FIRST(QUEUES);
2660   3     257                WHILE J LE N
2670   3     258                  DO BEGIN
2680   3     259                       ANS QQ&'$CODE '&NAME&'*'&'                    '[1,13=LENGTH(NAME)]
2690   4     260                                                                            &'T$CELL'&ZZ;
2700   4     261                       J=J+1;  NAME=NEXT(QUEUES,NAME);
2710   4     262                     END;
2720   3     263                J=1;N=SIZE(PROCS);
2730   3     264                NAME= FIRST(PROCS);
2740   3     265                WHILE J LE N
2750   3     266                  DO BEGIN
2760   3     267                       ANS QQ&'$CODE T$'&NAME&'*'&'                  '[1,13=LENGTH(NAME)]
2770   4     268                                                                            &'T$CELL'&ZZ;
2780   4     269                       J=J+1;  NAME=NEXT(PROCS,NAME);
2790   4     270                     END;
2800   3     271                J=1;N=SIZE(PROCS);
2810   3     272                NAME= FIRST(PROCS);
2820   3     273                WHILE J LE N
2830   3     274                    DO BEGIN
2840   3     275                       ANS QQ&'$CODE XS$'&NAME&'*'&'                 '[1,13=LENGTH(NAME)]&'RES     1'&ZZ;
2850   4     276                       J=J+1;  NAME=NEXT(PROCS,NAME);
2860   4     277                      END;
2870   3     278                ANS QQ&'$CODE CBGNAME*         RES      1'&ZZ;
2880   3     279                K=1;
2890   3     280                WHILE K LE NT
2900   3     281                  DO BEGIN
2910   3     282                       ANS QQ&' $CODE INTACTNAME'&K&'*     RES     1'&ZZ ;
2920   4     283                       ANS QQ&' $CODE SAVEAD'&K&'*     RES     1'&ZZ ;
2930   4     284                       ANS QQ&' $CODE RTADDR'&K&'*     RES     1'&ZZ ;
2940   4     285                       K=K+1 ;
2950   4     286                     END ;
2960   3     287                J=1;N=SIZE(PROCS);
2970   3     288                NAME= FIRST(PROCS);
2980   3     289                WHILE J LE N
2990   3     290                  DO BEGIN
3000   3     291                       ANS QQ&'$CODE F$'&NAME&'*'&'                  '[1,13=LENGTH(NAME)]& 'RES     1'&ZZ;
3010   4     292                       J=J+1;  NAME=NEXT(PROCS,NAME);
3020   4     293                     END;
3030   3     294                N=3*SIZE(PROCS) + SIZE(QUEUES) +4+900+900;
3040   3     295                NN = NT * 3 + N;
3050   3     296                ANS QQ&'$CODE SVRGAD*    RES     900    '& ZZ;
3060   3     297                ANS QQ&'$CODE SVRGAT*    RES     900    '& ZZ;
3070   3     298                ANS QQ&'$CODE        RES         '&  'SIZES=136='&NN& ZZ&QQ&'$CODE $(1)'&ZZ;
3080   3     299                K=4;
3090   3     300                WHILE K LE NT
3100   3     301                  DO BEGIN
3110   3     302                       ANS  QQ&'$CODE CONTNG'&K&'*      RES       2      '&ZZ ;
3120   4     303                       ANS  '$CODE     S          AU,SAVEAD'&  K   & ZZ ;
3130   4     304                       ANS  '$CODE     L,H2       AU,CONTNG'&  K   & ZZ ;
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```
3140  4  305                    ANS  '$CODE    A,U      A0,1          '& ZZ ;
3150  4  306                    ANS  '$CODE    S        A0,RTADDR'&   K   & ZZ ;
3160  4  307                    ANS  '$CODE    L        A0,SAVEA0'&   K   & ZZ ;
3170  4  308                    ANS  '$CODE    ER       DACT$     '& ZZ ;
3180  4  309                    ANS  '$CODE    ER       LEVEL$    '& ZZ ;
3190  4  310                    ANS  '$CODE    J        *RTADDR'& K   & ZZ ;
3200  4  311                    K=K+1;
3210  4  312                  END;
3220  3  313                ANS ZZ&'$CODE COBEGIN* '&ZZ;
3230  3  314                ANS '$CODE    L          A0,(''CBG'')'&ZZ;
3240  3  315                ANS '$CODE    ER         NAME$     '&ZZ;
3250  3  316                ANS '$CODE    S          A0,CBGNAME'&ZZ;
3260  3  317                ANS ZZ&'$CODE    TS         CBGNST    '&ZZ;
3270  3  318                ANS ZZ&'$CODE    C$TSA      CBGNST    '&ZZ;
3280  3  319                ANS '$CODE    ER         DACT$     '&ZZ;
3290  3  320                ANS '$CODE    ER         EXIT$     '&ZZ;
3300  3  321                ANS '  BEGIN'&ZZ;
3310  3  322                ANS '     BEGIN'&ZZ;
3320  3  323                ANS '$CODE     S       X10,XS$'&PROG_ID&ZZ;
3330  3  324                N=SIZE(PROCS) + SIZE(QUEUES) +3;
3340  3  325                ANS QQ&'$CODE  '&'     L,U     A0,057'&ZZ;
3350  3  326                ANS QQ&'$CODE '&'I DO '&N&' , SZ    RSCELL-1+I'&ZZ;
3360  3  327                ANS QQ&'$CODE '&'I DO '&N&' , S,S2 A0,RSCELL-1+I'&ZZ;
3370  3  328                ANS QQ&'$CODE '&'      ER      TSORG$'&ZZ;
3380  3  329                ANS QQ&'$CODE '&'      L,U     R13,0 '&ZZ;
3390  3  330                ANS QQ&'  END;'&ZZ;
3400  3  331                MAINPROG_FLAG=0;
3410  3  332              END;
3420  2  333        END;
3430  1  334  ELSE IF SLVTASKNAME EQC S'NUL'
3440  1  335          THEN BEGIN
3450  1  336                 ANS QQ&'BEGIN'&ZZ;
3460  2  337                 ANS QQ&'   BEGIN'&ZZ;
3470  2  338                 ANS '$CODE     SZ       F$'&PROG_ID&ZZ;
3480  2  339                 ANS '$CODE     S        X10,XS$'&PROG_ID&ZZ;
3490  2  340                 ANS '$CODE PROCST              '&ZZ;
3500  2  341                 ANS QQ&'  END;'&ZZ;
3510  2  342               END;
3520  1  343          ELSE BEGIN
3530  1  344                 ANS QQ&'BEGIN'&ZZ;
3540  2  345                 ANS QQ&'   BEGIN'&ZZ;
3550  2  346                 ANS '$CODE    L     A0,(02000001,CONTNG'&SLVTASKCNT&')'&ZZ;
3560  2  347                 ANS '$CODE     ER       IALL$     '  & ZZ;
3570  2  348                 ANS '$CODE     L        A0,('' &SLVTASKNAME&'')';
3580  2  349                 ANS ZZ&'$CODE     ER       NAME$' &  ZZ;
3590  2  350                 ANS '$CODE     SZ       A0    ' &   ZZ;
3600  2  351                 ANS '$CODE     ER       IDENT$ '&   ZZ;
3610  2  352                 ANS '$CODE     TZ       A0     '&   ZZ;
3620  2  353                 ANS '$CODE     J        $+4    '&   ZZ;
3530  2  354                 ANS '$CODE     L,U      A1,100 '&   ZZ;
3640  2  355                 ANS '$CODE     ER       TWAIT$ '&   ZZ;
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3650  2   356                       ANS '$CODE    J       $5    '& ZZ;
3660  2   357                       ANS '$CODE    S    A0,INTACTNAME'&SLVTASKCNT&ZZ;
3670  2   358                       ANS '$CODE    ER      DACT$    '  & ZZ;
3680  2   359                       ANS '$CODE    ER      LEVEL$   '  & ZZ;
3690  2   360                       ANS QQ&'  END;'&ZZ;
3700  2   361                    END;
3710  1   362     END;
3720      363
3730      364
3740      365
3750      366
3760      367
3770      368
3780      369
3790      370     MACRO FORK1 TRIG
3800  1   371     <'FORK'(SL)'WITH'(SL)'TASKNAME'(SL)OP(SL)W2:<ID>(SL)CP(SL)PROCNAME:<ID>W3:<(SL)W1:<OP\CP\',\ID\';'>.,>>;
3810  1   372      DECLARE W(*);
3820  1   373      IF SIZE(W1) EQ 1 THEN IF TRIM(W1(1)) EQC ';' THEN FAIL;
3830  1   374      IF TRIM(W1(1)) EQC 'ELSE' THEN FAIL;
3840  1   375      ANS QQ&'$CODE     FORK    '&PROCNAME&'   '&ZZ;
3850  1   376      IF COBEGIN_FLAG NEC S'NUL' THEN  COBEGIN_COUNT = COBEGIN_COUNT + 1;
3860  1   377      IF VOID(ACTID,TRIM(W2)) THEN BEGIN
3870  1   378                                     ACN=ACN+1;
3880  2   379                                     ACTID(TRIM(W2))=ACN;
3890  2   380                                  END;
3900  1   381      IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERRORD1&LINE;
3910  1   382      J=1; K=0; L=0; NN=SIZE(W1);
3920  1   383      WHILE J LE NN
3930  1   384        DO BEGIN
3940  1   385             IF (TRIM(W1(J)) EQC '(') OR
3950  2   386                (TRIM(W1(J)) EQC ',')
3960  2   387              THEN BEGIN
3970  2   388                     K=K+1;
3980  3   389                     W(K)=TRIM(W1(J));
3990  3   390                   END;
4000  2   391              ELSE IF TRIM(W1(J)) EQC ')'
4010  2   392                    THEN BEGIN
4020  2   393                           K=K+1; W(K)=TRIM(W1(J));
4030  3   394                           N=SIZE(W);
4040  3   395                           K=1;
4050  3   396                           ANS PROCNAME;
4060  3   397                           WHILE K LE N DO BEGIN
4070  3   398                                             ANS W(K);
4080  4   399                                             K=K+1;
4090  4   400                                           END;
4100  3   401                           OAID=ACTID(TRIM(W2));
4110  3   402                           AID=(OAID/8)*10+(OAID-(OAID/8)*8);
4120  3   403                           IF TRIM(W3)C*,1) EQC ';' THEN ANS  ';'&ZZ;
4130  3   404                           ANS '$CODE'&'   L,U   R15,'& OAID & ZZ ;
4140  3   405                           ANS '$CODE'&'   S     R15,0,A0    '& ZZ ;
4150  3   406                           ANS '$CODE'&'   L     R15,A0      '& ZZ ;
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4160   3     407                        IF AID LE 7
4170   3     408                         THEN
4180   3     409                           ANS '$CODE'&'    L  A0,(000'&AID&'01,' &TRIM(PROCNAME)&')'&ZZ;
4190   3     410                         ELSE
4200   3     411                           ANS '$CODE'&'    L  A0,(00'&AID&'01,'&TRIM(PROCNAME)&')'&ZZ;
4210   3     412                          ANS '$CODE'&'   ER    FORK$'&ZZ;
4220   3     413                          ANS '$CODE'&'    L    A0,R15     '& ZZ;
4230   3     414                          RETURN;
4240   3     415                      END;
4250   2     416                ELSE
4260   2     417                 IF(TRIM(W1(J)) EQC 'FORWARD') OR
4270   2     418                   (TRIM(W1(J)) EQC 'FORW')
4280   2     419                  THEN ANS QQ&'$CODE   DELETE ARGUMENT '&L&'   '&ZZ;
4290   2     420                  ELSE BEGIN
4300   2     421                         L=L+1;
4310   3     422                         K=K+1;
4320   3     423                         W(K)=TRIM(W1(J));
4330   3     424                       END;
4340   2     425           J=J+1;
4350   2     426         END;
4360   1     427    END;
4370         428
4380         429
4390         430
4400         431     MACRO FORK2    TRIG PROT
4410   1     432        <'FORK' (SL) 'WITH' (SL) 'TASKNAME'(SL)OP (SL) W2:<ID> (SL)CP  (SL)  W3:<PROCNAME:<ID>  (';') >  >;
4420   1     433        ANS QQ&'$CODE     FORK   '&PROCNAME&'  '&ZZ;
4430   1     434        IF COBEGIN_FLAG NEC S'NUL' THEN  COBEGIN_COUNT = COBEGIN_COUNT + 1;
4440   1     435        IF VOID(ACTID,TRIM(W2)) THEN BEGIN
4450   1     436                                       ACN=ACN+1;
4460   2     437                                       ACTID(TRIM(W2))=ACN;
4470   2     438                                     END;
4480   1     439        IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERROR01&LINE;
4490   1     440        ANS PROCNAME;
4500   1     441        OAID=ACTID(TRIM(W2));
4510   1     442        AID=(OAID/8)*10+(OAID-(OAID/8)*8);
4520   1     443        IF TRIM(W3)[*,1] EQC ':' THEN ANS  ':'&ZZ;
4530   1     444        ANS '$CODE'&'   L,U   R15,'& OAID & ZZ ;
4540   1     445        ANS '$CODE'&'   S     R15,0,A0    '& ZZ ;
4550   1     446        ANS '$CODE'&'   L     R15,A0      '& ZZ ;
4560   1     447        IF AID LE 7
4570   1     448          THEN ANS '$CODE'&'   L  A0,(000'&AID&'01,' &TRIM(PROCNAME)&')'&ZZ;
4580   1     449          ELSE ANS '$CODE'&'   L  A0,(00'&AID&'01,'&TRIM(PROCNAME)&')'&ZZ;
4590   1     450        ANS '$CODE'&'   ER    FORK$'&ZZ;
4600   1     451        ANS '$CODE'&'    L    A0,R15     '& ZZ;
4610   1     452        RETURN;
4620   1     453     END;
4630         454
4640         455
4650         456
4660         457
```

```
4670          458     MACRO COBEGIN TRIG PROT<'COBEGIN'(SL)OP(SL)W1:<ID>(SL) W2:<CP (SL)(';')>>;
4680    1     459       IF TRIM(W2)[*,1] EQC ';' THEN WEND ='END;' ;ELSE WEND = 'END' ;
4690    1     460       IF COBEGIN_COUNT EQ 0 THEN
4700    1     461                                BEGIN
4710    1     462                                   ACN = ACN +1;
4720    2     463                                   SACN =(ACN/8)*10+(ACN-(ACN/8)*8);
4730    2     464                                   COBEGIN_COUNT  = COBEGIN_COUNT + 1;
4740    2     465                                END;
4750    1     466       ACTID(TRIM(W1)) = ACN;
4760    1     467       ANS ZZ & '  BEGIN     ' & ZZ;
4770    1     468       ANS ZZ&'$CODE      L       R15,A0          '&ZZ;
4780    1     469       IF SACN LE 7
4790    1     470         THEN  ANS '$CODE      L      A0,(000'&SACN&'01,COBEGIN)'&ZZ;
4800    1     471         ELSE  ANS '$CODE      L      A0,(00'&SACN&'01,COBEGIN)'&ZZ;
4810    1     472       ANS '$CODE      ER     FORK$           '&ZZ;
4820    1     473       ANS ZZ&'$CODE      L       A0,R15          '&ZZ;
4830    1     474       ANS '$CODE      TS      CBGNST          '&ZZ;
4840    1     475       ANS '$CODE      C$TSQ   CBGNST          '&ZZ;
4850    1     476       ANS  WEND & ZZ;
4860    1     477     END;
4870          478
4880          479
4890          480
4900          481     MACRO COEND  TRIG PROT<W1:<'COEND' (SL) (';')> >;
4910    1     482        IF TRIM(W1)[*,1] EQC ';' THEN WEND = 'END;'; ELSE WEND='END' ;
4920    1     483        COBEGIN_COUNT = 0;
4930    1     484        ANS ZZ & '  BEGIN     ' & ZZ ;
4940    1     485        ANS ZZ&'$CODE      L     R15,A0            '&ZZ;
4950    1     486        ANS '$CODE      L       A0,CBGNAME'&ZZ;
4960    1     487        ANS '$CODE      ER      ACT$        '&ZZ;
4970    1     488        ANS '$CODE        L     A0,R15      '&ZZ;
4980    1     489        ANS  WEND & ZZ ;
4990    1     490     END;
5000          491
5010          492
5020          493
5030          494     MACRO STARTUP1 TRIG
5040    1     495       <'STARTUP' (SL) 'WITH' (SL) 'TASKNAME'(SL)OP (SL) W2:<ID> (SL)CP  (SL)  PROCNAME:<ID>
5050    1     496                                   W3:<(SL) W1:<OP\CP\','\ID\':'> ...> >;
5060    1     497        IF SIZE(W1) EQ 1 THEN IF TRIM(W1(1)) EQC ';' THEN FAIL;
5070    1     498        IF TRIM(W1(1)) EQC 'ELSE' THEN FAIL;
5080    1     499        DECLARE W(*);
5090    1     500        ANS 00&'$CODE        STARTUP '&PROCNAME&'    '&ZZ;
5100    1     501        IF COBEGIN_FLAG NEC S'NUL' THEN COBEGIN_COUNT = COBEGIN_COUNT + 1;
5110    1     502        IF VOID(ACTID,TRIM(W2)) THEN BEGIN
5120    1     503                                        ACN=ACN+1;
5130    2     504                                        ACTID(TRIM(W2))=ACN;
5140    2     505                                     END;
5150    1     506        IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERROR0&LINE;
5160    1     507        J=1; K=0; L=0; NN=SIZE(W1);
5170    1     508        WHILE J LE NN
```

```
5180   1     509          DO BEGIN
5190   1     510              IF (TRIM(W1(J)) EQC '(') OR
5200   2     511                 (TRIM(W1(J)) EQC ',')
5210   2     512                 THEN BEGIN
5220   2     513                        K=K+1;
5230   3     514                        W(K)=TRIM(W1(J));
5240   3     515                      END;
5250   2     516                 ELSE IF TRIM(W1(J)) EQC ')'
5260   2     517                        THEN BEGIN
5270   2     518                             K=K+1; W(K)=TRIM(W1(J));
5280   3     519                             N=SIZE(W);
5290   3     520                             K=1;
5300   3     521                             ANS '$CODE'&'   L     X10,CX10$'&ZZ;
5310   3     522                             ANS PROCNAME;
5320   3     523                             WHILE K LE N DO BEGIN
5330   3     524                                               ANS W(K);
5340   4     525                                               K=K+1;
5350   4     526                                             END;
5360   3     527                             OAID=ACTID(TRIM(W2));
5370   3     528                             AID=(OAID/8)*10+(OAID-(OAID/8)*8);
5380   3     529                             IF TRIM(W3)C*,1] EQC ';' THEN  ANS  ';'&ZZ;
5390   3     530                             ANS '$CODE'&'   L,U     R15,'& OAID     &ZZ;
5400   3     531                             ANS '$CODE'&'   S       R15,0,A0       '&ZZ;
5410   3     532                             ANS '$CODE'&'   L       R15,A0 ' & ZZ ;
5420   3     533                             ANS '$CODE'&'   TS   T$'&TRIM(PROCNAME)&ZZ;
5430   3     534                             IF AID LE 7
5440   3     535                                THEN ANS '$CODE'&'   L  A0,(U00'&AID&'01,'   &TRIM(PROCNAME)&')'&ZZ;
5450   3     536                                ELSE ANS '$CODE'&'   L  A0,(U0'&AID&'01,'  &TRIM(PROCNAME)&')'&ZZ;
5460   3     537                             ANS '$CODE'&'   ER    FORK$'&ZZ;
5470   3     538                             ANS '$CODE'&' C$TSQ  T$'&TRIM(PROCNAME)&ZZ;
5480   3     539                             ANS '$CODE'&'   L     A0,R15          '&ZZ;
5490   3     540                             RETURN;
5500   3     541                           END;
5510   2     542                      ELSE
5520   2     543                        IF(TRIM(W1(J)) EQC 'FORWARD') OR
5530   2     544                          (TRIM(W1(J)) EQC 'FORW')
5540   2     545                           THEN ANS QQ&'$CODE   DELETE ARGUMENT '&L&'   '&ZZ;
5550   2     546                           ELSE BEGIN
5560   2     547                                  L=L+1;
5570   3     548                                  K=K+1;
5580   3     549                                  W(K)=TRIM(W1(J));
5590   3     550                                END;
5600   2     551             J=J+1;
5610   2     552           END;
5620   1     553     END;
5630         554
5640         555
5650         556
5660         557
5670         558
5680         559
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5690          560     MACRO STARTUP2 TRIG PROT
5700    1     561        <'STARTUP'(SL)'WITH'(SL)'TASKNAME'(SL)OP(SL)W2:<ID> (SL)CP (SL) W3:<PROCNAME:<ID>  (';') >  >;
5710    1     562        ANS QQ&'$CODE        STARTUP '&PROCNAME&'    '&ZZ;
5720    1     563        IF COBEGIN_FLAG NEC S'NUL' THEN COBEGIN_COUNT = COBEGIN_COUNT + 1;
5730    1     564        IF VOID(ACTID,TRIM(W2)) THEN BEGIN
5740    1     565                                       ACN=ACN+1;
5750    2     566                                       ACTID(TRIM(W2))=ACN;
5760    2     567                                    END;
5770    1     568        IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERROR01&LINE;
5780    1     569        ANS '$CODE'&'    L      X10,CX10$'&ZZ;
5790    1     570        ANS PROCNAME;
5800    1     571        IF TRIM(W3)C*,1] EQC ';' THEN ANS ';' & ZZ;
5810    1     572        OAID=ACTID(TRIM(W2));
5820    1     573        AID=(OAID/8)*10+(OAID-(OAID/8)*8);
5830    1     574        ANS '$CODE'&'    L,U      R15,'& OAID      &ZZ;
5840    1     575        ANS '$CODE'&'    S        R15,0,AU        '&ZZ;
5850    1     576        ANS '$CODE'&'    L        R15,AU ' & ZZ ;
5860    1     577        ANS '$CODE'&'    TS    T$'&TRIM(PROCNAME)&ZZ;
5870    1     578        IF AID LE 7 THEN
5880    1     579                     ANS '$CODE'&'    L  AD,(000'&AID&'01,'    &TRIM(PROCNAME)&')'&ZZ;
5890    1     580                  ELSE
5900    1     581                     ANS '$CODE'&'    L  AD,(00'&AID&'01,'   &TRIM(PROCNAME)&')'&ZZ;
5910    1     582        ANS '$CODE'&'    ER     FORK$'&ZZ;
5920    1     583        ANS '$CODE'&'   C$TSQ   T$'&TRIM(PROCNAME)&ZZ;
5930    1     584        ANS '$CODE'&'    L      AD,R15           '&ZZ;
5940    1     585        RETURN;
5950    1     586     END;
5960          587
5970          588
5980          589
5990          590     MACRO  WAIT TRIG PROT< 'WAIT'(SL)OP(SL) W1:<ID> (SL) W2:<CP(SL)(';')>>;
6000    1     591        IF TRIM(W2)C*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END' ;
6010    1     592        IF VOID(QUEUES,TRIM(W1)) THEN WRITE ERROR02&LINE;
6020    1     593        ANS ZZ&'BEGIN'&ZZ;
6030    1     594        ANS '$CODE       C$TSQ     '& W1 &ZZ;
6040    1     595        ANS WEND    &ZZ;
6050    1     596     END;
6060          597
6070          598
6080          599
6090          600     MACRO SIGNAL TRIG PROT<'SIGNAL'(SL)OP(SL) W1:<ID>(SL)W2:<CP(SL)(';')>>;
6100    1     601        IF TRIM(W2)C*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END' ;
6110    1     602        IF VOID(QUEUES,TRIM(W1)) THEN WRITE ERROR02&LINE;
6120    1     603        ANS ZZ&'BEGIN'&ZZ;
6130    1     604        ANS '$CODE       C$TSA     '& W1 &ZZ;
6140    1     605        ANS WEND    &ZZ;
6150    1     606     END;
6160          607
6170          608
6180          609
6190          610
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6200          611     MACRO DEDICATE TRIGGER PROTECT <'DEDICATE'(SL)'PROCESSOR'(SL)OP(SL)W1:<NUM>(SL)W2:<CP(SL)(';')>>;
6210    1     612        IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;' ; ELSE WEND='END';
6220    1     613        IF W1 EQ 0 THEN   W2 = 1 ;
6230    1     614        IF W1 EQ 1 THEN   W2 = 2 ;
6240    1     615        IF W1 EQ 2 THEN   W2 = 4 ;
6250    1     616        IF W1 EQ 3 THEN   W2 = 8 ;
6260    1     617        ANS  ZZ & '   BEGIN ' & ZZ ;
6270    1     618        ANS QQ&' $CODE    L       R15,A0 '&S'EOL';
6280    1     619        ANS QQ&' $CODE    L,U     A0,'&W2& S'EOL';
6290    1     620        ANS QQ&' $CODE    ER      ADED$ '& S'EOL';
6300    1     621        ANS QQ&' $CODE    L       A0,R15 '& S'EOL';
6310    1     622        ANS  ZZ & WEND & ZZ;
6320    1     623     END;
6330          624
6340          625
6350          626
6360          627
6370          628     MACRO NORMALMODE TRIGGER PROTECT <'ORIGINAL'(SL) W1:<'MODE'(SL)(';')>>;
6380    1     629        IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;' ; ELSE WEND='END';
6390    1     630        ANS  ZZ & '   BEGIN ' & ZZ ;
6400    1     631        ANS QQ&' $CODE    L       R15,A0 '&S'EOL';
6410    1     632        ANS QQ&' $CODE    L,U     A0,0'  & S'EOL';
6420    1     633        ANS QQ&' $CODE    ER      ADED$ '& S'EOL';
6430    1     634        ANS QQ&' $CODE    L       A0,R15 '& S'EOL';
6440    1     635        ANS  ZZ & WEND & ZZ;
6450    1     636     END;
6460          637
6470          638
6480          639
6490          640     MACRO PROGRAM TRIG PROT
6500    1     641       < 'PROGRAM' (SL) PROCNAME:<ID>(SL)W:<( OP(SL)<ID / ','>(SL)CP)(SL)';'>>;
6510    1     642       IF TRIM(PROCNAME) EQC  'DEFINE'   THEN FAIL;
6520    1     643       BEGIN_FLAG=0;
6530    1     644       IF SLVTASKNAME NEC S'NUL'
6540    1     645         THEN BEGIN
6550    1     646                ANS QQ&'   PROGRAM DEFINE(SLAVETASK'&SLVTASKCNT&');'&ZZ;
6560    2     647                ANS QQ&'   PROCEDURE   SLAVETASK'&SLVTASKCNT&';'&ZZ;
6570    2     648                ANS QQ&'   $CODE     SLAVETASK  ENTRY        '&ZZ;
6580    2     649              END;
6590    1     650         ELSE BEGIN
6600    1     651                IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERROR01&LINE;
6610    2     652                PROG_ID=TRIM(PROCNAME);
6620    2     653                RETURN 'PROGRAM'&PROCNAME & W;
6630    2     654              END;
6640    1     655     END;
6650          656
6660          657
6670          658
6680          659
6690          660
6700          661
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6710         662     MACRO PROGDEF  TRIG PROT<'PROGRAM'(SL)'DEFINE'(SL)W:<(SL)OP(SL)PROCNAME:<ID>(SL)CP(SL)';'>>;
6720    1    663        IF VOID(PROCS,TRIM(PROCNAME)) THEN WRITE ERROR01&LINE;
6730    1    664        BEGIN_FLAG=0;
6740    1    665        PROG_ID=TRIM(PROCNAME);
6750    1    666        RETURN  'PROGRAM'&'  DEFINE'&  W;
6760    1    667     END;
6770         668
6780         669
6790         670
6800         671     MACRO RELEASE TRIG PROT<'RELEASE'(SL)OP(SL)W1:<ID>(SL)W3:<CP(SL)(';')>>;
6810    1    672         IF TRIM(W3)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
6820    1    673         IF VOID(PROCS,TRIM(W1)) THEN WRITE ERROR01&LINE;
6830    1    674         ANS ZZ&'BEGIN'&ZZ;
6840    1    675         ANS '$CODE       TS        TS'&TRIM(W1)&ZZ;
6850    1    676         ANS '$CODE       C$TSA     TS'&TRIM(W1)&ZZ;
6860    1    677         ANS WEND   &ZZ;
6870    1    678     END;
6880         679
6890         680
6900         681
6910         682     MACRO LOCK TRIG PROT<'LOCK'(SL) OP(SL) W1:<ID>(SL)W3:<CP(SL)(';')>>;
6920    1    683        IF TRIM(W3)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
6930    1    684        ANS  ZZ & 'BEGIN' & ZZ;
6940    1    685        ANS  '$CODE       TS     ' & W1 & ZZ;
6950    1    686        ANS  WEND      & ZZ;
6960    1    687     END;
6970         688
6980         689
6990         690
7000         691     MACRO UNLOCK TRIG PROT<'UNLOCK'(SL)OP(SL) W1:<ID>(SL)W3:<CP(SL)(';')>>;
7010    1    692        IF TRIM(W3)[*,1] EQC ';' THEN WEND='END;'; ELSE WEND='END';
7020    1    693        ANS  ZZ & 'BEGIN' & ZZ;
7030    1    694        ANS  '$CODE       C$TS     ' & W1 & ZZ;
7040    1    695        ANS  WEND      & ZZ;
7050    1    696     END;
7060         697
7070         698
7080         699
7090         700     MACRO SUSPEND TRIG PROT<'SUSPEND'(SL)OP(SL)W1:<NUM>(SL)W3:<CP(SL)(';')>>;
7100    1    701        IF TRIM(W3)[*,1] EQC ';' THEN WEND='END;'; ELSE WEND='END';
7110    1    702        ANS ZZ&'   BEGIN' &ZZ;
7120    1    703        ANS ZZ&'$CODE       L       R15,A1            '&ZZ;
7130    1    704        ANS ZZ&'$CODE       L,U     A1,'&TRIM(W1)&ZZ;
7140    1    705        ANS ZZ&'$CODE       ER      TWAIT$'&ZZ;
7150    1    706        ANS ZZ&'$CODE       L       A1,R15            '&ZZ;
7160    1    707        ANS WEND  & ZZ;
7170    1    708     END;
7180         709
7190         710
7200         711
7210         712
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7220          713     MACRO SUSPEND? TRIG PROT<'SUSPEND'(SL)OP(SL)W1:<ID>(SL)W3:<CP(SL)(';')>>;
7230    1     714        IF TRIM(W3)E*,1) EQC ';' THEN WEND='END;';  ELSE WEND='END';
7240    1     715        ANS ZZ&'$CODE      SUSPEND   KEYWORD         '&ZZ;
7250    1     716        ANS ZZ&   W1 &' :=    0 ;    ' & ZZ;
7260    1     717        ANS ZZ&'   BEGIN' &ZZ;
7270    1     718        ANS ZZ&'$CODE       ER      TWAIT$'&ZZ;
7280    1     719        ANS ZZ&'$CODE       L       A1,R15           '&ZZ;
7290    1     720        ANS WEND  & ZZ;
7300    1     721     END;
7310          722
7320          723
7330          724
7340          725     MACRO CPS2 TRIG PROT <MCPS  W1:<ID> W2:<ID> ',' 'USER' '=' W3:< ID > > ;
7350    1     726        SLVTASKNAME = TRIM(W3);
7360    1     727        SLVTASKCNT  = SLVTASKCNT + 1 ;
7370    1     728        CPS_COUNT =CPS_COUNT +1;
7380    1     729        ELTNAME(CPS_COUNT)=TRIM(W2);
7390    1     730        IF CPS_COUNT NE 1
7400    1     731         THEN BEGIN
7410    1     732                 M=CPS_COUNT - 1 ;
7420    2     733                 W3=ELTNAME(M);
7430    2     734                 ANS QQ&'@CTS,N                 '&ZZ;
7440    2     735                 ANS QQ&'OLD   TPF$.PA$CODE     '&ZZ;
7450    2     736                 ANS QQ&'ASSUME ASCII OFF       '&ZZ;
7460    2     737                 ANS QQ&'CALL   UNIVAC*CPS.CLEAR'&ZZ;
7470    2     738                 ANS QQ&'SAVE     '&TRIM(W3) &ZZ;
7480    2     739                 ANS QQ&'XCTS                 '&ZZ;
7490    2     740              END;
7500    1     741        ANS QQ&'@BU*PASCAL.S,'&TRIM(W1)&ZZ;
7510    1     742     END;
7520          743
7530          744
7540          745
7550          746
7560          747     MACRO CPS TRIG PROT <MCPS W1:<ID> W2:<ID> >;
7570    1     748        CPS_COUNT =CPS_COUNT +1;
7580    1     749        ELTNAME(CPS_COUNT)=TRIM(W2);
7590    1     750        IF CPS_COUNT NE 1
7600    1     751         THEN BEGIN
7610    1     752                 M=CPS_COUNT - 1 ;
7620    2     753                 W3=ELTNAME(M);
7630    2     754                 ANS QQ&'@CTS,N                 '&ZZ;
7640    2     755                 ANS QQ&'OLD   TPF$.PA$CODE     '&ZZ;
7650    2     756                 ANS QQ&'ASSUME ASCII OFF       '&ZZ;
7660    2     757                 ANS QQ&'CALL  UNIVAC*CPS.CLEAR '&ZZ;
7670    2     758                 ANS QQ&'SAVE     '&TRIM(W3) &ZZ;
7680    2     759                 ANS QQ&'XCTS                 '&ZZ;
7690    2     760              END;
7700    1     761        ANS QQ&'@BU*PASCAL.S,'&TRIM(W1)&ZZ;
7710    1     762     END;
7720          763
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7730          764
7740          765
7750          766     MACRO END_OF_TEXT TRIG PROT <EOTX>;
7760    1     767        N=SIZE(ELTNAME);
7770    1     768        W3=ELTNAME(N);
7780    1     769        ANS QQ&'@CTS,N                 '&ZZ;
7790    1     770        ANS QQ&'OLD      TPFS*PASCODE '&ZZ;
7800    1     771        ANS QQ&'ASSUME ASCII OFF     '&ZZ;
7810    1     772        ANS QQ&'CALL    UNIVAC*CPS,CLEAR '&ZZ;
7820    1     773        ANS QQ&'SAVE      '& TRIM(W3)  &ZZ;
7830    1     774        ANS QQ&'XCTS                 ' &ZZ;
7840    1     775        J=I;
7850    1     776        WHILE  J  LE  N
7860    1     777          DO BEGIN
7870    1     778                ANS QQ&'@CPS,S,N     '&ELTNAME(J)&',CPS,S/3,'& 'TPFS*PASCODE'&ZZ;
7880    2     779                ANS QQ&'@ELT,IN      '&ELTNAME(J)&ZZ;
7890    2     780                ANS QQ&'@ADD         TPFS*PASCODE'&ZZ;
7900    2     781                ANS QQ&'@ASM,US                '& ELTNAME(J)&ZZ;
7910    2     782                J=J+I;
7920    2     783             END;
7930    1     784        M=FIRST(ELTNAME);
7940    1     785        ANS QQ&'@MAP,I         ,'&ELTNAME(M)&ZZ;
7950    1     786        ANS QQ&'IN      '&ELTNAME(M)&ZZ;
7960    1     787        ANS QQ&'LIB      BU*PASCAL,'&ZZ;
7970    1     788        ANS QQ&'END              '&ZZ;
7980    1     789        ANS QQ&'@USE     INFOTABLE,INFOS,'&ZZ;
7990    1     790        ANS QQ&'@USE     PA&QQQQQQ,INFOS,'&ZZ;
8000    1     791        ANS QQ&'@SETC,D          '&ZZ;
8010    1     792        ANS QQ&'@XQT    '&ELTNAME(M)&ZZ;
8020    1     793     END;
8030          794
8040          795
8050          796
8060          797     MACRO SNAPDUMP TRIG PROT <'SNAPDUMP'(SL)OP(SL)WI:<ID>(SL)W2:<CP(SL)(';')>>;
8070    1     798         IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
8080    1     799         ANS ZZ&'BEGIN'&ZZ;
8090    1     800         ANS ZZ&'$CODE  L$SNAP '''&TRIM(W1)&''',0,'&NTSCELL&',RSCELL';
8100    1     801         ANS ZZ& WEND  &ZZ;
8110    1     802      END;
8120          803
8130          804
8140          805
8150          806      MACRO SNOOPYON  TRIG PROT <'SNOOPY'(SL)WI:<'ON'(SL)(';')>>;
8160    1     807         IF TRIM(WI)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
8170    1     808         ANS ZZ&'BEGIN'&ZZ;
8180    1     809         ANS ZZ&'$CODE    SLJ   TON$';
8190    1     810         ANS ZZ& WEND  &ZZ;
8200    1     811      END;
8210          812
8220          813
8230          814
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8240          815
8250          816
8260          817
8270          818       MACRO SNOOPYOFF   TRIG PROT <'SNOOPY'(SL) W1:<'OFF'(SL)(';')>>;
8280    1     819          IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
8290    1     820          ANS ZZ&'BEGIN'&ZZ;
8300    1     821          ANS ZZ&'%CODE     SLJ    TOFF%';
8310    1     822          ANS ZZ& WEND  &ZZ;
8320    1     823       END;
8330          824
8340          825
8350          826
8360          827       MACRO CLEAR TRIG PROT <'CLEAR'(SL) OP(SL)W1:<ID>(SL)W2:<CP(SL)(';')>>;
8370    1     828          IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
8380    1     829          IF VOID(QUEUES,TRIM(W1)) THEN WRITE ERROR026&LINE;
8390    1     830          ANS ZZ&'BEGIN'&ZZ;
8400    1     831          ANS '%CODE      SZ       '&W1&ZZ;
8410    1     832          ANS WEND  &ZZ;
8420    1     833       END;
8430          834
8440          835
8450          836
8460          837       MACRO QUITBY TRIG PROT<'QUIT'(SL)'BY'(SL)'CHECKING'(SL)OP(SL)W1:<ID> W2:<(SL)CP (';')>>;
8470    1     838          IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
8480    1     839          IF VOID(QUEUES,TRIM(W1)) THEN WRITE ERROR026&LINE;
8490    1     840          ANS ZZ&'BEGIN'&ZZ;
8500    1     841          ANS '%CODE      TNZ       '&W1&ZZ;
8510    1     842          ANS '%CODE      ER         EXIT% '&ZZ;
8520    1     843          ANS WEND  &ZZ;
8530    1     844       END;
8540          845
8550          846
8560          847
8570          848
8580          849       MACRO QUIT TRIG <W1:<'QUIT' (SL)(';')>>;
8590    1     850          IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
8600    1     851          ANS ZZ&'       BEGIN ' & ZZ;
8610    1     852          ANS ZZ&QQ&'%CODE     ER      EXIT%'&ZZ;
8620    1     853          ANS WEND &ZZ ;
8630    1     854       END;
8640          855
8650          856
8660          857
8670          858       MACRO SLVSTARTUP TRIG PROT <'STARTUP'(SL)'SLAVETASK'(SL)OP(SL)W1:< ID >(SL)W2:< CP(SL)(';')>>;
8680    1     859          IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
8690    1     860          ANS QQ & ' BEGIN ' & ZZ ;
8700    1     861          ANS QQ & '     BEGIN ' & ZZ ;
8710    1     862          ANS QQ&' %CODE     L     X10,CX10%' & ZZ ;
8720    1     863          ANS QQ&' %CODE     L     R15,A8                ' & ZZ ;
8730    1     864          ANS QQ&' %CODE     L,H2   A8,3,X10' & ZZ ;
8740    1     865          ANS QQ&' %CODE     L,U    X9,START%' & ZZ ;
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8750  1    866        ANS QQ & '    END;  ' & ZZ ;
8760  1    867        ANS QQ&'  CASE '& W1 & ' OF ' &       ZZ ;
8770  1    868         K = 1 ;
8780  1    869         WHILE K  LE  NT
8790  1    870           DO  BEGIN
8800  1    871                 ANS QQ & '      '& K & ';  BEGIN  ' & ZZ ;
8810  2    872                 ANS QQ&'  $CODE  L   A0,(0U0001,SLAVETASK'&K&')'&ZZ;
8820  2    873                 ANS QQ&'  $CODE  SZ        INTACTNAME'&K&ZZ ;
8830  2    874                 ANS QQ&'  $CODE  L,U    X7,INTACTNAME'&K&ZZ ;
8840  2    875                 ANS QQ & '       END;   ' & ZZ ;
8850  2    876                 K = K+1 ;
8860  2    877               END;
8870  1    878        ANS QQ&'         END;          ' & ZZ ;
8880  1    879        ANS QQ&'     BEGIN           ' & ZZ ;
8890  1    880        ANS QQ&' $CODE  ER    FORK$  ' & ZZ ;
8900  1    881        ANS QQ&' $CODE  TZ    ,*X7       ' &     ZZ ;
8910  1    882        ANS QQ&' $CODE  J     $+4     ' &ZZ;
8920  1    883        ANS QQ&' $CODE  L,U   A1,10   ' &ZZ;
8930  1    884        ANS QQ&' $CODE  ER    TWAIT$  ' &ZZ;
8940  1    885        ANS QQ&' $CODE  J     $-4     ' &ZZ;
8950  1    886        ANS QQ&' $CODE  L   X10,CX10$' &ZZ;
8960  1    887        ANS QQ&' $CODE    L    A8,R15             ' & ZZ ;
8970  1    888        ANS QQ&'    END;          ' &ZZ;
8980  1    889        ANS QQ& WEND              &ZZ;
8990  1    890    END;
9000       891
9010       892
9020       893
9030       894
9040       895     MACRO ACTIVATE TRIG PROT<'ACTIVATE'(SL)'SLAVETASK'(SL)OP(SL) W1:< ID >(SL) W2:< CP(SL)(';')>>;
9050  1    896        IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
9060  1    897        ANS QQ & '   BEGIN                ' &ZZ ;
9070  1    898        ANS QQ & '     CASE ' & W1 & '  OF ' &ZZ ;
9080  1    899        K =1 ;
9090  1    900        WHILE  K LE  NT
9100  1    901         DO BEGIN
9110  1    902               ANS QQ&'   '&K&':  BEGIN ' & ZZ ;
9120  2    903               ANS QQ&' $CODE    L   A0,INTACTNAME'&K&ZZ;
9130  2    904               ANS QQ&'   '& '    END;'&ZZ ;
9140  2    905               K = K+1;
9150  2    906            END;
9160  1    907        ANS QQ& '    END;             '&ZZ ;
9170  1    908        ANS QQ& '$CODE   ER     ACT$  '&ZZ ;
9180  1    909        ANS QQ&    WEND                &ZZ ;
9190  1    910    END;
9200       911
9210       912
9220       913
9230       914
9240       915     MACRO DEACTIVATE TRIG PROT<'DEACTIVATE'(SL)'SLAVETASK'(SL)OP(SL)W1:< ID >(SL)W2:< CP(SL)(';')>>;
9250  1    916        IF TRIM(W2)[*,1] EQC ';' THEN WEND='END;';   ELSE WEND='END';
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9260  1   917         ANS QQ & '   BEGIN                    ' &ZZ ;
9270  1   918         ANS QQ & '     CASE ' & W1 & '  OF ' &ZZ ;
9280  1   919         K =' ;
9290  1   920         WHILE  K LE  NT
9300  1   921          DO BEGIN
9310  1   922                 ANS QQ&'   '&K&': BEGIN ' & ZZ ;
9320  2   923                 ANS QQ&' $CODE    L   AD,INTACTNAME'&K&ZZ;
9330  2   924                 ANS QQ&'   '& '    END;' & ZZ ;
9340  2   925                 K = K+1;
9350  2   926              END;
9360  1   927       ANS QQ& '    END;              '&ZZ ;
9370  1   928       ANS QQ& '$CODE   ER     TNT$  '&ZZ ;
9380  1   929       ANS QQ&    WEND                &ZZ ;
9390  1   930 END;
9400      931
9410      932
9420      933
9430      934     MACRO TERMINATE TRIG PROT< W1:< 'TERMINATE'(SL)(';')>>;
9440  1   935         IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
9450  1   936         ANS QQ&'   BEGIN  ' &ZZ;
9460  1   937         ANS QQ&'  $CODE    ER  ABORT$    ' &ZZ;
9470  1   938         ANS QQ&  WEND           &ZZ;
9480  1   939     END;
9490      940
9500      941
9510      942
9520      943     MACRO INITIOTERMIO TRIG PROT<W1:<'WRITE'\'WRITELN'>(SL)W2:<(OP<<(SL)TO(SL)(',')>>,>(SL)CP)(SL)';'>>;
9530  1   944         IF SLVTASKNAME EQC S'NUL' THEN FAIL ;
9540  1   945         ANS  QQ & '   BEGIN                    '& ZZ;
9550  1   946         ANS  QQ & ' $CODE    TS   '&IOINITLOCK   & ZZ;
9560  1   947         ANS  QQ & ' $CODE    TS   '&IOINITFLAG   & ZZ;
9570  1   948         ANS  QQ & ' $CODE    C$TSA  '& IOINITFLAG   & ZZ;
9580  1   949         ANS  QQ & ' $CODE    ER     DACT$       '& ZZ;
9590  1   950         ANS  QQ & ' $CODE    TS   RSCELL        '& ZZ;
9600  1   951         ANS  QQ & '   END  ;                   '& ZZ;
9610  1   952         ANS  QQ & W1 & W2 & ZZ;
9520  1   953         ANS  QQ & '   BEGIN                    '& ZZ;
9530  1   954         ANS  QQ & ' $CODE    C$TS  RSCELL       '& ZZ;
9540  1   955         ANS  QQ & ' $CODE    TS   '&IOTERMLOCK   & ZZ;
9550  1   956         ANS  QQ & ' $CODE    TS   '&IOTERMFLAG   & ZZ;
9660  1   957         ANS  QQ & ' $CODE    C$TSA  '&IOTERMFLAG   & ZZ;
9670  1   958         ANS  QQ & ' $CODE    ER     DACT$       '& ZZ;
9580  1   959         ANS  QQ & '   END  ;                   '& ZZ;
9590  1   960     END;
9700      961
9710      962
9720      963
9730      964     MACRO  ENDPOINT TRIG PROT < 'END;' > ;
9740  1   965        IF  SLVTASKNAME EQC S'NUL' THEN  FAIL;
9750  1   966        ANS QQ& '$CODE    SZ  INTACTNAME'& SLVTASKCNT & ZZ ;
9760  1   967        ANS QQ& '$CODE    TS  SYSTEMHOLD'& ZZ ;
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9770   1      963        ANS QQ& '*CODE   C$TSQ   SYSTEMHOLD'& ZZ ;
9780   1      969        ANS QQ& '   END;                    '& ZZ ;
9790   1      970      END;
9800          971      MACRO FETCHING TRIG PROT<'FETCH'(SL)'STATUS'(SL)'OF'(SL) W1:<'SLAVETASKS'(SL)(';')> >;
9810   1      972        IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
9820   1      973        ANS ZZ & ' BEGIN     ' & ZZ ;
9830   1      974        I = 1;
9840   1      975        WHILE  I LE NT
9850   1      976          DO BEGIN
9860   1      977               ANS QQ& 'STATUS[' & I & ']  := FALSE ;'&ZZ;
9870   2      978               ANS QQ& '$CODE   TNZ  INTACTNAME'& I &ZZ;
9880   2      979               ANS QQ& '$CODE   J    $+3           '&ZZ;
9890   2      980               ANS QQ& 'STATUS[' & I & ']  := TRUE  ;'&ZZ;
9900   2      981               I = I +1 ;
9910   2      982             END;
9920   1      983        ANS   WEND & ZZ ;
9930   1      984      END;
9940          985
9950          986
9960          987
9970          988      MACRO FORKEY TRIGGER PROTECT    <'FOR' (SL) W1:<ID> ':=' >;
9980   1      989        IF SLVTASKNAME NEC S'NUL' THEN FAIL;
9990   1      990        ANS   QQ & '$CODE   FOR  KEYWORD    ' & ZZ ;
10000  1      991        ANS         '  FOR  ' & W1 & ' := '   ;
10010  1      992      END;
10020         993
10030         994
10040         995
10050         996      MACRO WAITFOREVER TRIGGER PROTECT < 'WAIT' W1:<'FOREVER' (';')>>;
10060  1      997        IF TRIM(W1)[*,1] EQC ';' THEN WEND='END;';  ELSE WEND='END';
10070  1      998        ANS  ZZ & 'BEGIN  ' & ZZ;
10080  1      999        ANS  QQ & '$CODE      TS    SYSTEMHOLD' & ZZ ;
10090  1     1000        ANS  QQ & '$CODE    C$TSQ   SYSTEMHOLD' & ZZ ;
10100  1     1001        ANS  ZZ &  WEND     & ZZ;
10110  1     1002      END;
10120        1003
10130        1004
10140        1005
10150        1006
10160        1007
10170        1008      MACRO CREGION TRIG PROT <'CREGION' ';' > ;
10180  1     1009        ANS  ZZ & ' BEGIN ' & ZZ ;
10190  1     1010        ANS  QQ & '$CODE     TS   RSCALL ' & ZZ ;
10200  1     1011        ANS  QQ & '$CODE     L    R15,R13' & ZZ ;
10210  1     1012        ANS  QQ & '$CODE     L,U  R13,1   ' & ZZ ;
10220  1     1013        ANS  QQ & '$CODE     CREGION ON   ' & ZZ ;
10230  1     1014        ANS  QQ & '   END;  ' & ZZ ;
10240  1     1015      END;
10250        1016
10260        1017
10270        1018
```

```
10280          1019
10290          1020
10300          1021
10310          1022        MACRO CEND TRIG  PROT <'CEND' ';' > ;
10320    1     1023           ANS  QQ & ' BEGIN    ' & ZZ ;
10330    1     1024           ANS  QQ & '*CODE     CSTS   RSCELL ' & ZZ ;
10340    1     1025           ANS  QQ & '*CODE     L      R13,R15' & ZZ ;
10350    1     1026           ANS  QQ & '*CODE     CREGION OFF   ' & ZZ ;
10360    1     1027           ANS  QQ & ' END;     ' & ZZ ;
10370    1     1028        END;
END MDC 0 ERRORS 0 WARNINGS 0 REMARKS
```

D.4 - POSTSCANNER

```
@CPS.C,SR   CPS,MACRO3,CPS.S/3
MACRO COMPILER LEVEL 7R1 07/27/83 06:36:36
   100          1     //   ************************************************************   //
   110          2     //   *                                                          *   //
   120          3     //   *                                                          *   //
   130          4     //   *            CPS/1100    P O S T S C A N N E R           *   //
   140          5     //   *                                                          *   //
   150          6     //   *     ASSEMBLER CODES PRODUCED BY PASCAL COMPILER ARE      *   //
   160          7     //   *     PROCESSED VIA THIS PROGRAM.MODIFICATIONS ON THE      *   //
   170          8     //   *     CODES ARE PERFORMED ACCORDING  TO THE  MESSAGES      *   //
   180          9     //   *     WHICH ARE INSERTED TO THE TEXT BY  SECOND PHASE      *   //
   190         10     //   *     OF CPS/1100 PRESCANNER.                              *   //
   200         11     //   *                                                          *   //
   210         12     //   *                                                          *   //
   220         13     //   ************************************************************   //
   230         14
   240         15
   250         16
   260         17     DEBUG ON;
   270         18     SET ALPHA <'A'..'Z'>;
   280         19     SET ID_CHAR <'0'..'9'\'A'..'Z'\'_'\'$'\';'\','\'('\')'\'+'>;
   290         20     SET DIGIT <'0'..'9'>;
   300         21
   310         22
   320         23     TOKEN DOT   <'.'>;
   330         24     TOKEN ID <ALPHA(ID_CHAR) ..>;
   340         25     TOKEN IDA <ALPHA(ALPHA) ...>;
   350         26     TOKEN NUM <DIGIT(DIGIT) ...>;
   360         27     TOKEN MISC   <ID_CHAR(ID_CHAR) ..>;
   370         28     TOKEN BLANK IGNORE < ' ' ... >;
   380         29     TOKEN AST < '*' >;
   390         30     TOKEN COM < ',' >;
   400         31     TOKEN R13 < 'R13' >;
   410         32     TOKEN AZERO < 'A0' >;
   420         33
   430         34
   440         35
   450         36     DECLARE   PROCTYPE;
   460         37     DEL_FLAG = 0 ;
   470         38     DEL_FLAG2= 0 ;
   480         39     PROCTYPE = S'NUL';
   490         40     PROCNAME = S'NUL';
   500         41     CALLEDPROC = S'NUL';
   510         42     DECLARE  DEL(*);
   520         43     DELJ=0;
   530         44     DEL_FLAG= 0;
   540         45     PN_FLAG= 0;
   550         46     STARTUP_FLAG= 0;
   560         47     SLAVEFLAG= 0;
   570         48     FORFLAG  = 0  ;
   580         49     FORNUM   = -36;
```

```
590          50     SUSFLAG  = 0 ;
600          51     CREGION_FLAG  = 0 ;
610          52
620          53
630          54     DECLARE   FOR$AV(**);
640          55
650          56
660          57
670          58     MACRO M0 TRIGGER PROTECT< W1:<'$(1)'>>;
680   1      59        PN_FLAG = 1;
690   1      60        ANSWER S'DELB'&TRIM(W1);
700   1      61     END;
710          62
720          63
730          64
740          65     MACRO M1 TRIGGER PROTECT < '*' 'RES' 'SIZE$'>;
750   1      66        PROCTYPE = 'MAINPROG' ;
760   1      67        ANSWER  '*     RES  136' ;
770   1      68     END;
780          69
790          70
800          71
810          72     MACRO M2 TRIGGER PROTECT  < 'LMJ' 'A1,PENT$'>;
820   1      73        IF TRIM(PROCTYPE) NEC 'MAINPROG'
830   1      74          THEN  IF SLAVEFLAG   EQ   1
840   1      75                  THEN  BEGIN
950   1      76                          ANSWER S'EOL'&'          L       A0,A8' & S'EOL';
860   2      77                          SLAVEFLAG = 0 ;
870   2      78                        END;
880   1      79                  ELSE BEGIN
890   1      80                          ANSWER S'EOL'&'          L       A0,R15' & S'EOL' ;
900   2      81                          ANSWER S'EOL'&'          L       R13,,*A0'& S'EOL' ;
910   2      82                          ANSWER '          TZ      F$'&PROCNAME&S'EOL';
920   2      83                          ANSWER '          J       ENTER '& S'EOL' ;
930   2      84                          ANSWER '          L       X10,XS$'&PROCNAME&S'EOL';
940   2      85                          ANSWER '          J       PPOCST'& S'EOL';
950   2      86                          ANSWER 'ENTER                     '&S'EOL';
960   2      87                        END;
970   1      88           ANSWER '          LMJ     A1,PENT$' ;
980   1      89       END;
990          90
1000         91
1010         92
1020         93     MACRO M3 TRIGGER PROTECT <W1:<ID > '*' > ;
1030  1      94        IF PN_FLAG EQ 0 THEN FAIL;
1040  1      95        PROCNAME=TRIM(W1);
1050  1      96        PN_FLAG = 0;
1060  1      97        RETURN  S'DELB'& W1&'*';
1070  1      98     END;
1080         99
1090        100
```

```
1100          101     MACRO M4  TRIGGER PROTECT <'STARTUP'  W1:<ID>>;
1110    1     102        CALLEDPROC = TRIM(W1);
1120    1     103        DEL_FLAG = 1;
1130    1     104        STARTUP_FLAG=1;
1140    1     105        J=1;
1150    1     106        WHILE J LE 50 DO BEGIN
1160    1     107                           DEL(J)=0;
1170    2     108                           J=J+1;
1180    2     109                        END;
1190    1     110        RETURN ;
1200    1     111     END;
1210          112
1220          113
1230          114
1240          115     MACRO M5  TRIGGER PROTECT <'FORK'  W1:<ID>>;
1250    1     116        CALLEDPROC = TRIM(W1);
1260    1     117        DEL_FLAG = 1;
1270    1     118        J=1;
1280    1     119        WHILE J LE 50 DO BEGIN
1290    1     120                           DEL(J)=0;
1300    2     121                           J=J+1;
1310    2     122                        END;
1320    1     123        RETURN ;
1330    1     124     END;
1340          125
1350          126
1360          127
1370          128     MACRO M6 TRIGGER PROTECT <'LMJ'   ID > ;
1380    1     129        IF DEL_FLAG EQ 0 THEN  FAIL;
1390    1     130                        ELSE BEGIN
1400    1     131                                J=1;
1410    2     132                                WHILE J LE 50 DO BEGIN
1420    2     133                                                 DEL(J)=0;
1430    3     134                                                 J=J+1;
1440    3     135                                                END;
1450    2     136                                DEL_FLAG = 0;
1460    2     137                                DEL_FLAG2 = 0;
1470    2     138                             END;
1480    1     139     END;
1490          140
1500          141
1510          142
1520          143     MACRO M7 TRIGGER PROTECT <W1:<'L'\'L,U'> W2:<ID>>;
1530    1     144        IF DEL_FLAG2 EQ 0 THEN FAIL;
1540    1     145        DELJ=DELJ+1;
1550    1     146        IF DEL(DELJ) EQ 0 THEN RETURN W1&'   '&W2;
1560    1     147     END;
1570          148
1580          149
1590          150
1600          151
```

```
1610          152     MACRO M8 TRIGGER PROTECT <W1:<'S'> W2:<ID>>;
1620    1     153        IF DEL_FLAG2 EQ 0 THEN FAIL;
1630    1     154        IF DELJ      EQ 0 THEN FAIL;
1640    1     155        IF DEL(DELJ) EQ 0 THEN RETURN W1&'   '&W2;
1650    1     156     END;
1660          157
1670          158
1680          159
1690          160     MACRO M9 TRIGGER PROTECT<'L,H2' 'A0,3,X10'>;
1700    1     161        IF DEL_FLAG EQ 0 THEN FAIL;
1710    1     162        IF( TRIM(PROCTYPE) EQC 'MAINPROG') AND
1720    1     163          ( STARTUP_FLAG   EQ  1 )
1730    1     164          THEN BEGIN
1740    1     165                  ANSWER '    L,H2    A0,3,X10';
1750    2     166                  STARTUP_FLAG = 0;
1760    2     167               END;
1770    1     168          ELSE  ANSWER '    L        A0,XSS'& CALLEDPROC ;
1780    1     169        DEL_FLAG2=1;
1790    1     170        DELJ=0;
1800    1     171     END;
1810          172
1820          173
1830          174
1840          175     MACRO M11 TRIGGER PROTECT <'DELETE' 'ARGUMENT' W1:<NUM>>;
1850    1     176        J=TRIM(W1);
1860    1     177        DEL(J)=1;
1870    1     178     END;
1880          179
1890          180
1900          181
1910          182
1920          183     MACRO M12 TRIGGER PROTECT< 'SLAVETASK' 'ENTRY' >;
1930    1     184        SLAVEFLAG= 1;
1940    1     185     END;
1950          186
1960          187
1970          188
1980          189     MACRO FORMAC TRIGGER PROTECT< 'FOR' 'KEYWORD' >;
1990    1     190        FORFLAG = 1 ;    FORNUM = FORNUM + 36 ;
2000    1     191        IF FORNUM GE 900
2010    1     192          THEN ANSWER S'EOL'&S'EOL'&' MAXIMUM NUMBER OF FOR STATEMENT ' &
2020    1     193                      'EXCEEDED '  & S'EOL' & S'EOL' ;
2030    1     194     END;
2040          195
2050          196
2060          197
2070          198
2080          199     MACRO DSMAC TRIGGER PROTECT <'DS'  W1:< ID > >;
2090    1     200       IF FORFLAG NE 1 THEN FAIL;
2100    1     201       IF TRIM(W1)[1,3] NEC 'A0,' THEN FAIL;
2110    1     202       FORFLAG = 0 ;
```

```
2120   1      203       FORSAV(TRIM(W1)) = FORNUM ;
2130   1      204       ANSWER S'EOL' & '       L      R15,X11 ' &
2140   1      205              S'EOL' & '       L      X11,R13 ' &
2150   1      206              S'EOL' & '       S      A0,SVRGA0+' & FORNUM & ',X11' &
2160   1      207              S'EOL' & '       S      A1,SVRGA1+' & FORNUM & ',X11' &
2170   1      208              S'EOL' & '       L      X11,R15' & S'EOL' ;
2180   1      209     END;
2190          210
2200          211
2210          212
2220          213     MACRO DLMAC TRIGGER PROTECT <'DL'  W1:< ID > >;
2230   1      214        IF VOID(FORSAV,TRIM(W1)) THEN FAIL ;
2240   1      215        ANSWER S'EOL' & '    L    R15,X11  ' &
2250   1      216               S'EOL' & '    L    X11,R13  ' &
2260   1      217               S'EOL' & '    L    A0,SVRGA0+' & FORSAV(TRIM(W1)) & ',X11' &
2270   1      218               S'EOL' & '    L    A1,SVRGA1+' & FORSAV(TRIM(W1)) & ',X11' &
2280   1      219               S'EOL' ;
2290   1      220     END;
2300          221
2310          222
2320          223
2330          224     MACRO STORER13  TRIGGER PROTECT < 'S'   W1:< ID > >;
2340   1      225         A = TRIM(W1)[1,3];
2350   1      226         B = TRIM(W1)[5,LENGTH(W1)];
2360   1      227         IF A  NEC 'R13' THEN  FAIL ;
2370   1      228         ANSWER S'EOL' & '    L,U       R15,1 ' &
2380   1      229                S'EOL' & '    S         R15,' & B & S'EOL';
2390   1      230     END;
2400          231
2410          232
2420          233
2430          234     MACRO  SUSKEY TRIGGER   <'SUSPEND' 'KEYWORD'>;
2440   1      235          SUSFLAG=1;
2450   1      236     END;
2460          237
2470          238
2480          239
2490          240
2500          241     MACRO  SUSKEY2 TRIGGER   <'SZ'  W1:<ID>>;
2510   1      242          IF SUSFLAG EQ 0 THEN FAIL;
2520   1      243          SUSFLAG = 0;
2530   1      244          ANSWER  S'EOL'& '    L      R15,A1' & S'EOL';
2540   1      245          ANSWER  S'EOL'& '    L      A1,' & TRIM(W1) &  S'EOL';
2550   1      246     END;
2570          247
2580          248
2590          249
2600          250     MACRO R15IGNORE TRIGGER PROTECT < 'L,U' W1:<ID> >;
2610   1      251        IF CREGION_FLAG EQ 0 THEN FAIL;
2620   1      252        IF TRIM(W1)[1,4] NEC 'R15,'  THEN  FAIL;
2630   1      253     END;
```

```
  2680          254     MACRO CREGIONON TRIGGER PROTECT <'CREGION' 'ON' >;
  2690    1     255        CREGION_FLAG = 1;
  2700    1     256     END;
  2710          257
  2720          258
  2730          259
  2740          260
  2750          261
  2760          262     MACRO CREGIONOFF TRIGGER PROTECT <'CREGION' 'OFF' >;
  2770    1     263        CREGION_FLAG = 0;
  2780    1     264     END;
END MDC 0 ERRORS 0 WARNINGS 0 REMARKS
```

APPENDIX E - PROGRAM LISTINGS OF CASE STUDIES

E.1 - CASE STUDY ONE: Producer - Consumer Problem

```
@CPS$S,S   ,CPS$S/O,
MACRO INTERPRETER LEVEL 7RT 02/03/84 1T:27:36
     T   *COMPILE     OPTIONS=IRSLM,ELTNAME=TPFS$MAIN
     T     PROGRAM MAIN(INPUT,OUTPUT);
     T     TYPE LABELS=(RECEIVE,SEND,INIT);
     T     PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);MONITOR;
     T     PROCEDURE CARDPROC;PROCESS;
     T     PROCEDURE PRINTPROC;PROCESS;
     T     VAR  RECEIVER    :  QUEUE     ;
     T          SENDER      :  QUEUE     ;
     T          LOCKV       :  QUEUE     ;
     T          ENTRY       :  LABELS    ;
     T          INP         :  INTEGER   ;
     T          OUTP        :  INTEGER   ;
     T          HOLDPERIOD  :  INTEGER   ;
     T     BEGIN
     T      HOLDPERIOD := 500;
     T      ENTRY := INIT;
     T      STARTUP WITH TASKNAME(T1) BUFFER(ENTRY,INP FORWARD ,OUTP FORWARD);
     T      COBEGIN(STARTER);
     T        STARTUP WITH TASKNAME(T2) CARDPROC;
     T        STARTUP WITH TASKNAME(T3) PRINTPROC;
     T      COEND;
     T      SUSPEND(HOLDPERIOD);
     T      TERMINATE;
     T     END;
     T   *COMPILE     OPTIONS=IRSLMV,ELTNAME=TPFS$CARD
     T     PROGRAM DEFINE(CARDPROC);
     T     TYPE LABELS=(RECEIVE,SEND,INIT);
     T     PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);MONITOR;
     T     PROCEDURE CARDPROC;
     T     VAR ENTRY :  LABELS ;
     T         I     :  INTEGER;
     T         INP   :  INTEGER;
     T         OUTP  :  INTEGER;
     T     BEGIN
     T       RELEASE(CARDPROC);
     T       AWAIT(STARTER);
     T       I:=1;
     T       WHILE TRUE DO
     T        BEGIN
     T         INP:=I*1;
     T         LOCK(LOCKV);
     T         ENTRY:= SEND;
     T         FORK WITH TASKNAME(CT) BUFFER(ENTRY,INP,OUTP FORWARD);
     T         AWAIT(C1);
     T         I:=I+1;
     T        END;
     T    END;
     T   *COMPILE     OPTIONS=IRSLMV,ELTNAME=TPFS$PRINT
```

```
1     PROGRAM DEFINE(PRINTPROC);
1     TYPE LABELS=(RECEIVE,SEND,INIT);
1     PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);MONITOR;
1     PROCEDURE PRINTPROC;
1     VAR ENTRY :  LABELS ;
1         INP   :  INTEGER;
1         OUTP  :  INTEGER;
1     BEGIN
1       RELEASE(PRINTPROC);
1       AWAIT(STARTER);
1       WHILE TRUE DO
1        BEGIN
1         LOCK(LOCKV);
1         ENTRY:= RECEIVE;
1         FORK WITH TASKNAME(P1) BUFFER(ENTRY,INP FORWARD ,OUTP);
1         AWAIT(P1);
1         CREGION; WRITELN(OUTP); CEND;
1        END;
1     END;
1   *COMPILE      OPTIONS=IRSLMV,ELTNAME=TPF$.BUFFER
1     PROGRAM DEFINE(BUFFER);
1     TYPE LABELS =(RECEIVE,SEND,INIT);
1     PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);
1     VAR     FULL     : BOOLEAN ;
1             CONTENTS: INTEGER ;
1     BEGIN
1        CASE ENTRY OF
1         RECEIVE:
1           BEGIN
1            UNLOCK(LOCKV);
1            LOCK(RECEIVER);
1            IF NOT FULL THEN WAIT(RECEIVER)
1                        ELSE UNLOCK(RECEIVER);
1            OUTP := CONTENTS ;
1            LOCK(SENDER);
1            FULL  := FALSE ;
1            SIGNAL(SENDER);
1            QUIT;
1           END;
1         SEND:
1           BEGIN
1            UNLOCK(LOCKV);
1            LOCK(SENDER);
1            IF FULL THEN WAIT(SENDER)
1                    ELSE UNLOCK(SENDER);
1            CONTENTS:= INP;
1            LOCK(RECEIVER);
1            FULL := TRUE;
1            SIGNAL(RECEIVER);
1            QUIT;
1           END;
```

```
                BEGIN
                 FULL := FALSE;
                 RELEASE(BUFFER);
                 WAIT FOREVER ;
                END;
          END;
        END;
@CPS$S,N   SCRATCH$ SCRATCH1,CPS$S/1,SCRATCH$ SCRATCH2
MACRO INTERPRETER LEVEL 7R1 02/03/84 11:31:13
@CPS$S,N   SCRATCH$ SCRATCH2,CPS$S/2,
MACRO INTERPRETER LEVEL 7R1 02/03/84 11:32:10
@CPS$X
@BU*PASCAL$S,IRSLM
PASCAL 8R1A RLIB  FRIDAY, 1984 FEBRUARY 3, 11:34:30
```

```
  2   PROGRAM MAIN(INPUT,OUTPUT);
  3   TYPE LABELS=(RECEIVE,SEND,INIT);
  4   PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);EXTERNAL ;
  5   PROCEDURE CARPROC;EXTERNAL ;
  6   PROCEDURE PRINTPROC;EXTERNAL ;
  7   VAR GLOBALS : ARRAY (.1..1819.) OF INTEGER ;
  8       ENTRY : LABELS ;
  9       HOLDPERIOD : INTEGER ;
 10       INP : INTEGER ;
 11       OUTP : INTEGER ;
 12 $CODE RSCELL*       T$CELL
 13 $CODE CBGNST*       T$CELL
 14 $CODE SYSTEMHOLD*   T$CELL
 15 $CODE LOCKV*         T$CELL
 16 $CODE RECEIVER*      T$CELL
 17 $CODE SENDER*        T$CELL
 18 $CODE T$BUFFER*        T$CELL
 19 $CODE T$CARDPROC*      T$CELL
 20 $CODE T$MAIN*          T$CELL
 21 $CODE T$PRINTPROC*     T$CELL
 22 $CODE XS$BUFFER*        RES    1
 23 $CODE XS$CARDPROC*      RES    1
 24 $CODE XS$MAIN*          RES    1
 25 $CODE XS$PRINTPROC*     RES    1
 26 $CODE CBGNAME*         RES     1
 27 $CODE F$BUFFER*        RES     4
 28 $CODE F$CARDPROC*      RES     4
 29 $CODE F$MAIN*          RES     4
 30 $CODE F$PRINTPROC*     RES     4
 31 $CODE SVRGA0*   RES    900
 32 $CODE SVRGA1*   RES    900
 33 $CODE        RES       SIZE$:1369819
 34
```

```
1                0   135
2                0     7
2                0     4
2                0     4
1              136   1954
1             1955  1955
1             1956  1956
1             1957  1957
1             1958  1958
1      0      0
1      1      1
1      2      2
1      3      3
1      4      4
1      5      5
1      6      6
1      7      7
1      8      8
1      9      9
1     10     10
1     11     11
1     12     12
1     13     13
1     14     14
1     15     15
1     16     16
1     17     17
1     18     18
1     19     19
1     20     20
1     21     21
1     22     22
```

```
                35 $CODE $(1)                                                                    1     23     23
                36
                37 $CODE COBEGIN*                                                                1     24     24
                38 $CODE     L          A0,('CBG')                                               1     25     25
                39 $CODE     ER         NAME$                                                    1     26     26
                40 $CODE     S          A0,CBGNAME                                               1     27     27
                41
                42 $CODE     TS         CBGNST                                                   1     28     28
                43
                44 $CODE     C$TSA      CBGNST                                                   1     29     29
                45 $CODE     ER         DACT$                                                    1     30     30
                46 $CODE     ER         EXIT$                                                    1     31     31
1               47   BEGIN                                                                       1
2               48      BEGIN                                                                    1     32     36
                49 $CODE      S       X10,XS$MAIN                                               1     37     37
                50 $CODE       L,U     A0,057                                                   1     38     38
                51 $CODE I DO 11 , SZ    RSCELL+1+I                                             1     39     39
                52 $CODE I DO 11 , S,S2 A0,RSCELL+1+I                                           1     40     40
                53 $CODE       ER      TSQRG$                                                   1     41     41
                54 $CODE       L,U     R13,0                                                    1     42     42
2               55   END;                                                                        1
                56    HOLDPERIOD := 500;                                                        1     43     45
                57    ENTRY := INIT;                                                            1     46     48
                58 $CODE        STARTUP  BUFFER                                                 1     49     49
                59 $CODE   DELETE ARGUMENT 2                                                    1     50     50
                60 $CODE   DELETE ARGUMENT 3                                                    1     51     51
                61 $CODE   L      X10,CX10$                                                     1     52     52
                62  BUFFER(ENTRY,INP,OUTP);                                                     1     53     62
                63 $CODE   L,U      R15,1                                                       1     63     63
                64 $CODE   S        R15,0,A0                                                    1     64     64
                65 $CODE   L        R15,A0                                                      1     65     65
                66 $CODE   TS    T$BUFFER                                                       1     66     66
                67 $CODE   L  A0,(000101,BUFFER)                                                1     67     67
                68 $CODE   ER     FORK$                                                         1     68     68
                69 $CODE  C$TSQ   T$BUFFER                                                      1     69     69
                70 $CODE   L      A0,R15                                                        1     70     70
                71
                72
2               73   BEGIN                                                                      1
                74
                75 $CODE      L       R15,A0                                                    1     71     71
                76 $CODE      L      A0,(000207,COBEGIN)                                        1     72     72
                77 $CODE      ER     FORK$                                                      1     73     73
                78
                79 $CODE      L       A0,R15                                                    1     74     74
                80 $CODE      TS       CBGNST                                                   1     75     75
                81 $CODE      C$TSQ    CBGNST                                                   1     76     76
2               82 END;                                                                         1
                83
                84 $CODE        STARTUP  CARDPROC                                               1     77     77
                85 $CODE   L      X10,CX10$                                                     1     78     78
```

```
       CARDPROC;                                          1    79    82
      $CODE   L,U      R15,3                              1    83    83
      $CODE   S        R15,0,A0                           1    84    84
      $CODE   L        R15,A0                             1    85    85
      $CODE   TS   T$CARDPROC                             1    86    86
      $CODE   L  A0,(000301,CARDPROC)                     1    87    87
      $CODE   ER     FORK$                                1    88    88
      $CODE  C$TSQ  T$CARDPROC                            1    89    89
      $CODE   L      A0,R15                               1    90    90

      $CODE          STARTUP  PRINTPROC                   1    91    91
      $CODE   L      X10,CX10$                            1    92    92
       PRINTPROC;                                         1    93    96
      $CODE   L,U      R15,4                              1    97    97
      $CODE   S        R15,0,A0                           1    98    98
      $CODE   L        R15,A0                             1    99    99
      $CODE   TS   T$PRINTPROC                            1   100   100
      $CODE - L  A0,(000401,PRINTPROC)                    1   101   101
      $CODE   ER     FORK$                                1   102   102
      $CODE  C$TSQ  T$PRINTPROC                           1   103   103
      $CODE   L      A0,R15                               1   104   104


2        BEGIN                                            1

      $CODE     L    R15,A0                               1   105   105
      $CODE     L       A0,CBGNAME                        1   106   106
      $CODE     ER      ACT$                              1   107   107
      $CODE       L     A0,R15                            1   108   108
   2  END;                                                1


      $CODE     SUSPEND   KEYWORD                         1   109   109

      HOLDPERIOD :=   0 ;                                 1   110   111

2         BEGIN                                           1

      $CODE      ER     TWAIT$                            1   112   112

      $CODE      L      A1,R15                            1   113   113
   2  END;                                                1

2         BEGIN                                           1
        $CODE    ER  ABORT$                               1   114   114
   2  END;                                                1

   1     END.                                             1   115   115
```

PROGRAM MAIN CONTAINS 133 LINES AND 3 PROCEDURES/3 EXTERNALS

```
INPUT AND OUTPUT ARE ASCII FILES
STORAGE: 2080/5179   TIME USED: 6 SECONDS
END PASCAL 8R1A      NO ERRORS  NO WARNINGS   116 I-BANK   3072 D-BANK
@CTS,N
CTS    7R1B  28 JUL 83 AT 17:46:43
THE ASSUMED MODE IS FIELDATA
OLD    TPF$.PA$CODE
COMPILER TYPE:     ASM,S
ASSUME ASCII OFF
CALL  UNIVAC*CPS.CLEAR
SAVE     TPF$.MAIN
@CT$
IN EXEC MODE
@BU*PASCAL.S,IRSLMV
PASCAL 8R1A RLIB   THURSDAY, 1983 JULY 28, 17:46:49
                1
```

```
                2   PROGRAM  DEFINE(CARDPROC);                                                    : 1                    0  135
                3   TYPE LABELS=(RECEIVE,SEND,INIT);                                             1
                4   PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);EXTERNAL ;  2                    0    7
                5   PROCEDURE CARDPROC;                                                          2                    0    4
                6   VAR ENTRY :  LABELS ;                                                        2                    5    5
                7       I     :  INTEGER;                                                        2                    6    6
                8       INP   :  INTEGER;                                                        2                    7    7
                9       OUTP  :  INTEGER;                                                        2                    8    8
1               10 BEGIN                                                                         2
2               11   BEGIN                                                                       2          0     4
                12 $CODE    SZ       F$CARDPROC                                                  2          5     5
                13 $CODE    S        X10,XS$CARDPROC                                             2          6     6
                14 $CODE PROCST                                                                  2          7     7
    2           15   END;                                                                        2
                16
2               17 BEGIN                                                                         2
                18 $CODE       TS       T$CARDPROC                                               2          8     8
                19 $CODE       C*TSA    T$CARDPROC                                               2          9     9
    2           20 END;                                                                          2
                21
2               22   BEGIN                                                                       2
                23 $CODE       L        R15,A0                                                   2         10    10
                24 $CODE       LA       A0,(4)                                                   2         11    11
                25 $CODE       EP       AWAIT$                                                   2         12    12
                26 $CODE       L        A0,R15                                                   2         13    13
    2           27 END;                                                                          2
                28
                29     I:=1;                                                                     2         14    15
                30     WHILE TRUE DO                                                             2         16    18
2               31      BEGIN                                                                    2
                32        INP:=I*1;                                                              2         19    23
                33
3               34 BEGIN                                                                         2
```

```
                35 $CODE       TS     LOCKV                                    2    24    24
    1           36 END;                                                        2
                37
                38       ENTRY:= SEND;                                         2    25    26
                39 $CODE      FORK     BUFFER                                 2    27    27
                40 $CODE    DELETE ARGUMENT $                                 2    28    28
                41  BUFFER(ENTRY,INP,OUTP);                                    2    29    38
                42 $CODE    L,0    R15,S                                      2    39    39
                43 $CODE    S      R15,0,A0                                   2    40    40
                44 $CODE    L      R15,A0                                     2    41    41
                45 $CODE    L   A0,(000501,BUFFER)                            2    42    42
                46 $CODE    ER     FORK$                                      2    43    43
                47 $CODE     L     A0,R15                                     2    44    44
                48
    3           49   BEGIN                                                    2
                50 $CODE         L        R15,A0                             2    45    45
                51 $CODE         LA       A0,(32)                            2    46    46
                52 $CODE         ER       AWAIT$                             2    47    47
                53 $CODE         L        A0,R15                             2    48    48
    3           54 END;                                                        2
                55
                56       I:=I+1;                                               2    49    52
    2           57      END;                                                   2    53    53
    1           58  END;                                                       2    54    54

PROGRAM DEFINE CONTAINS 58 LINES AND 2 PROCEDURES/2 EXTERNALS
NO MAIN PROGRAM  INPUT AND OUTPUT ARE ASCII FILES
STORAGE: 2153/5179  TIME USED: 3015 MILLISECONDS
END PASCAL 8R1A  CP  NO ERRORS  NO WARNINGS  55 LINES
@CTS,N
OLD   TPF$.PA$CODE
ASSUME ASCII OFF
CALL  UNIVAC*CPS.CLEAR
SAVE    TPF$.CARD
XCTS
IN EXEC MODE
@BU*PASCAL.S,IRSLMV
PASCAL 8R1A CLIB  THURSDAY, 1983 JULY 28, 17:46:54
                 1

                 2   PROGRAM  DEFINE(PRINTPROC);                                1                 0   135
                 3   TYPE LABELS=(RECEIVE,SEND,INIT);                          1                 0
                 4   PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);EXTERNAL ;   2                 0     7
                 5   PROCEDURE PRINTPROC;                                      2                 0     4
                 6   VAR ENTRY :  LABELS ;                                     2                 5     5
                 7       INP   :  INTEGER;                                     2                 6     6
                 8       OUTP  :  INTEGER;                                     2                 7     7
                 9 BEGIN                                                        2
                10   BEGIN                                                     2           0     4
```

```
                11 $CODE     SZ       F$PRINTPROC                                  2      5      5
                12 $CODE     $        X10,XS$PRINTPROC                            2      6      6
                13 $CODE PROCST                                                    2      7      7
    2           14   END;                                                         2
                15
2               16 BEGIN                                                         2
                17 $CODE       TS       T$PRINTPROC                              2      8      8
                18 $CODE       C$TSA    T$PRINTPROC                              2      9      9
    2           19 END;                                                          2
                20
2               21   BEGIN                                                       2
                22 $CODE       L        R15,A0                                   2     10     10
                23 $CODE       LA       A0,(4)                                   2     11     11
                24 $CODE       EP       AWAIT$                                   2     12     12
                25 $CODE       L        A0,R15                                   2     13     13
    2           26 END;                                                          2
                27
                28     WHILE TRUE DO                                             2     14     16
2               29      BEGIN                                                    2
                30
3               31 BEGIN                                                         2
                32 $CODE       TS    LOCKV                                      2     17     17
    3           33 END;                                                          2
                34
                35       ENTRY:= RECEIVE;                                        2     18     19
                36 $CODE      FORK    BUFFER                                     2     20     20
                37 $CODE   DELETE ARGUMENT 2                                     2     21     21
                38  BUFFER(ENTRY,INP,OUTP);                                      2     22     31
                39 $CODE   L,U    R15,6                                          2     32     32
                40 $CODE   S      R15,0,A0                                       2     33     33
                41 $CODE   L      R15,A0                                         2     34     34
                42 $CODE   L   A0,(000601,BUFFER)                                2     35     35
                43 $CODE   ER     FORK$                                          2     36     36
                44 $CODE    L     A0,R15                                        2     37     37
                45
3               46   BEGIN                                                       2
                47 $CODE       L        R15,A0                                   2     38     38
                48 $CODE       LA       A0,(64)                                  2     39     39
                49 $CODE       EP       AWAIT$                                   2     40     40
                50 $CODE       L        A0,R15                                   2     41     41
    3           51 END;                                                          2
                52
                53
3               54  BEGIN                                                       2
                55 $CODE       TS   RSCELL                                       2     42     42
                56 $CODE       L    R15,R13                                      2     43     43
                57 $CODE       L,U  R13,1                                        2     44     44
                58 $CODE       CREGION ON                                        2     45     45
    3           59    END;                                                       2
3               60  WRITELN(OUTP); BEGIN                                        2     46     50
                61 $CODE       C$TS   RSCELL                                     2     51     51
```

```
                62 $CODE      L       R13,R15                                    2    52    52
                63 $CODE      CREGION OFF                                        2    53    53
    3           64   END;                                                       2
                65
    2           66       END;                                                   2    54    54
    1           67   END;                                                       2    55    55


PROGRAM DEFINE CONTAINS 67 LINES AND 2 PROCEDURES/2 EXTERNALS
NO MAIN PROGRAM  INPUT AND OUTPUT ARE ASCII FILES
STORAGE: 2147/5179  TIME USED: 3283 MILLISECONDS
END PASCAL 8R1A    NO ERRORS  NO WARNINGS  56 I BANK
@CTS,N
OLD   TPF$.PA$CODE
ASSUME ASCII OFF
CALL  UNIVAC*CPS.CLEAR
SAVE    TPF$.PRINT
XCTS
IN EXEC MODE
@BU*PASCAL.S,IRSLMV
PASCAL 8R1A PLT8  THURSDAY, 1983 JULY 28, 17:46:58
                 1


                 2   PROGRAM  DEFINE(BUFFER);                                   1                    0    135
                 3   TYPE LABELS =(RECEIVE,SEND,INIT);                          1
                 4   PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);  2                    0      7
                 5   VAR     FULL     : BOOLEAN ;                               2                    8      8
                 6           CONTENTS: INTEGER ;                                2                    9      9
 1               7 BEGIN                                                        2
 2               8    BEGIN                                                     2    0     4
                 9 $CODE     SZ       F$BUFFER                                  2    5     5
                10 $CODE     S        X10,XS$BUFFER                             2    6     6
                11 $CODE PROCST                                                 2    7     7
    2           12   END;                                                       2
 2              13      CASE ENTRY OF                                          2    8    11
                14        RECEIVE:                                             2
 3              15          BEGIN                                              2
                16
 4              17 BEGIN                                                       2
                18 $CODE       C$TS    LOCKV                                   2   12    12
    4           19 END;                                                        2
                20
                21
 4              22 BEGIN                                                       2
                23 $CODE       TS    RECEIVER                                  2   13    13
    4           24 END;                                                        2
                25
                26           IF NOT FULL THEN                                  2   14    16
 4              27 BEGIN                                                       2
                28 $CODE       C$TSQ    RECEIVER                              2   17    17
```

```
4          29 END
           30                    ELSE
4          31 BEGIN
           32 $CODE       C*TS    RECEIVER
4          33 END;
           34
           35          OUTP := CONTENTS ;
           36
4          37 BEGIN
           38 $CODE       TS    SENDER
4          39 END;
           40
           41          FULL  := FALSE ;
           42
4          43 BEGIN
           44 $CODE       C*TSA    SENDER
4          45 END;
           46
           47
4          48       BEGIN
           49
           50 $CODE    EP     EXIT*
4          51 END;
           52
3          53         END;
           54       SEND:
3          55         BEGIN
           56
4          57 BEGIN
           58 $CODE       C*TS    LOCKV
4          59 END;
           60
           61
4          62 BEGIN
           63 $CODE       TS    SENDER
4          64 END;
           65
           66          IF FULL THEN
4          67 BEGIN
           68 $CODE       C*TSQ    SENDER
4          69 END
           70                ELSE
4          71 BEGIN
           72 $CODE       C*TS    SENDER
4          73 END;
           74
           75          CONTENTS:= INP;
           76
4          77 BEGIN
           78 $CODE       TS    RECEIVER
4          79 END;
```

```
2
2
2    18    18
2    19    19
2
2    20    23
2
2    24    24
2
2    25    26
2
2    27    27
2
2
2    28    28
2
2    29    29
2
2
2
2    30    30
2
2
2    31    31
2
2    32    34
2
2    35    35
2
2
2    36    36
2    37    37
2
2
2    38    41
2
2    42    42
2
```

```
                 FULL := TRUE;                                   2    43   44

4         BEGIN                                                  2
          $CODE       C$TSA     RECEIVER                         2    45   45
   4      END;                                                   2


4                BEGIN                                           2

          $CODE     ER      EXIT$                                2    46   46
   4      END;                                                   2

   3               END;                                          2    47   47
                INIT:                                            2
3                  BEGIN                                         2
                    FULL := FALSE;                               2    48   49

4         BEGIN                                                  2
          $CODE        TS          T$BUFFER                      2    50   50
          $CODE        C$TSA       T$BUFFER                      2    51   51
   4      END;                                                   2


4         BEGIN                                                  2
          $CODE        TS     SYSTEMHOLD                         2    52   52
          $CODE     C$TSQ     SYSTEMHOLD                         2    53   53

   4      END;                                                   2

   3               END;                                          2    54   54
   2           END;                                              2    55   62
   1          END;                                               2    63   63

PROGRAM DEFINE CONTAINS 112 LINES AND 1 PROCEDURE/1 EXTERNAL
NO MAIN PROGRAM  INPUT AND OUTPUT ARE ASCII FILES
STORAGE: 2142/5179  TIME USED: 4365 MILLISECONDS
END PASCAL 8R1A     NO ERRORS  NO WARNINGS  64 I BANK
@CTS,N
OLD       TPF$.PA$CODE
ASSUME ASCII OFF
CALL   UNIVAC*CPS.CLEAR
SAVE      TPF$.BUFFER
XCTS
IN EXEC MODE
@CPS.S,N    TPF$.MAIN,CPS.S/3,TPF$.PA$CODE
MACRO INTERPRETER LEVEL 7R1 07/28/83 17:47:06
@ELT,IN       TPF$.MAIN
ELT 8R1 S74Q1C 07/28/83 17:47:16 (0>0)
```

```
END ELT.  ERRORS: NONE. TIME:  2.057 SEC. IMAGE COUNT: 131
@ASM,US                 TPF1,MAIN
ASM 15R1 S73010 07/28/83 17:47:18 (0,1)

                                                     AXR$ RU0715
    U                      000000000000               RCONV$ EQU ASCFDASC$
                           000000000001               ASCIO$* EQU 1
                           000000000115               RSL$* EQU 77
                                                      $(30),KS1T$*
                           000000006000               SIZE$* EQU 3072
          36    000000                                START$*      RES  136
                000210  00 57 00 000000               RSCELL*       T$CELL
                000211  00 57 00 000000               CBGNST*       T$CELL
                000212  00 57 00 000000               SYSTEMHOLD*   T$CELL
                000213  00 57 00 000000               LOCKV*         T$CELL
                000214  00 57 00 000000               RECEIVER*      T$CELL
                000215  00 57 00 000000               SENDER*        T$CELL
                000216  00 57 00 000000               STOPPER*       T$CELL
                000217  00 57 00 000000               T$BUFFER*        T$CELL
                000220  00 57 00 000000               T$CARDPROC*      T$CELL
                000221  00 57 00 000000               T$MAIN*          T$CELL
                000222  00 57 00 000000               T$PRINTPROC*     T$CELL
                000223                                XS$BUFFER*        RES     1
                000224                                XS$CARDPROC*      RES     1
                000225                                XS$MAIN*          RES     1
                000226                                XS$PRINTPROC*     RES     1
                000227                                CBGNAME*         RES     1
                000230                                F$BUFFER*        RES    1
                000231                                F$CARDPROC*      RES    1
                000232                                F$MAIN*          RES    1
                000233                                F$PRINTPROC*     RES    1
                000234                                SVRGA0*   RES    900
                002040                                SVRGA1*   RES    900
                003644                                      RES      SIZE$-136-1820
                                                      $(1)
                                                      COBEGIN*
          01    000000  27 00 14 00 0 000000             L          A0,('CBG')
    U           000001  72 11 00 00 0 000000             ER         NAME$
                000002  06 00 14 00 0 000227             S          A0,CBGNAME
                000003  73 17 00 00 0 000211             TS         CBGNST
                000004  05 15 00 00 0 000211             C$TSA      CBGNST
                000005  50 01 00 00 0 000211
                000006  72 11 00 00 0 000000
    U           000007  72 11 00 00 0 000000             ER         DACT$
    U           000010  72 11 00 00 0 000000             ER         EXIT$

                                                      $(1)
                                                      MAIN$*
    U           000011  74 13 15 00 0 000000                    LMJ      A1,PENT$
                000012  003650 000210                       +MA$,136
```

```
45.            000013  000000000001          000000000001 .
46.            000014  220616230505          'MAIN        '
               000015  050505050505
47.            000016  06 00 12 00 0 000225      S       X10,XS$'ATN
48.            000017  27 16 14 00 000057        L,U     A0,057
49.                                          T 00 11 , SZ    RSCELL;1+T
               000020  05 00 00 00 0 000210
               000021  05 00 00 00 0 000211
               000022  05 00 00 00 0 000212
               000023  05 00 00 00 0 000213
               000024  05 00 00 00 0 000214
               000025  05 00 00 00 0 000215
               000026  05 00 00 00 0 000216
               000027  05 00 00 00 0 000217
               000030  05 00 00 00 0 000220
               000031  05 00 00 00 0 000221
               000032  05 00 00 00 0 000222
50.                                          I 00 11 , S,S2 A0,RSCELL+1
               000033  06 14 14 00 0 000210
               000034  06 14 14 00 0 000211
               000035  06 14 14 00 0 000212
               000036  06 14 14 00 0 000213
               000037  06 14 14 00 0 000214
               000040  06 14 14 00 0 000215
               000041  06 14 14 00 0 000216
               000042  06 14 14 00 0 000217
               000043  06 14 14 00 0 000220
               000044  06 14 14 00 0 000221
               000045  06 14 14 00 0 000222
51. U          000046  72 11 00 00 0 000000        EP      TSQR3$
52.            000047  23 16 15 00 000000        L,U     R13,0
53.            000050  23 16 17 00 000070      L,U       R15,56
54.            000051  27 16 14 00 000764      L,U       A0,500
55.            000052  06 00 14 00 0 003645    S         A0,START$+1957
56.            000053  23 16 17 00 000071      L,U       R15,57
57.            000054  27 16 14 00 000002      L,U       A0,2
58.            000055  06 00 14 00 0 003644    S         A0,START$+1956
59.
60.
61.
62. U          000056  27 00 12 00 0 000000    L       X10,CX10$
63.            000057  23 16 17 00 000076      L,U       R15,62
64.            000060  27 01 14 12 0 000003        L,H2    A0,3,X10
65.            000061  27 16 01 00 003644      L,U         X1,START$+1956
66.            000062  06 00 01 14 0 000005    S           X1,5,A0
67.
68.
69.
70.
71.            000063  27 16 11 00 000000      L,U         X9,START$
72.
```

```
 73.            000064  23 16 17 00 000001      L,U     R15,1
 74.            000065  04 00 _7 14 0 000000    S       R15,0,A0
 75.            000066  23 00 17 00 0 000014    L       R15,A0
 76.            000067  73 17 00 00 0 000217    TS   T$BUFFER
 77. U          000070  27 00 14 00 0 000001    L  A0,(000101,BUFFER)
 78. U          000071  72 11 00 00 0 000000    ER    FORK$
 79.            000072  74 06 00 00 0 000217  C$TSQ  T$BUFFER
     U          000073  72 11 00 00 0 000000
 90.            000074  27 00 14 00 0 000117    L     A0,R15
 91.            000075  23 00 17 00 0 000014      L     R15,A0
 92.            000076  27 00 14 00 0 000002      L     A0,(000201,COBEGIN)
 93. U          000077  72 11 00 00 0 000000      ER    FORK$
 94.            000100  27 00 14 00 0 000117      L     A0,R15
 95.            000101  73 17 00 00 0 000211      TS    CBGNST
 96.            000102  74 06 00 00 0 000211      C$TSQ   CBGNST
     U          000103  72 11 00 00 0 000000
 97.
 98. U          000104  27 00 12 00 0 000000    L     X10,CX10$
 99.            000105  23 16 17 00 000126      L,U     R15,R5
 90.            000106  27 01 14 12 0 000003        L,H2    A0,3,X10
 91.            000107  27 16 11 00 000000      L,U       X9,START$
 92.
 93.            000110  23 16 17 00 000003      L,U     R15,3
 94.            000111  04 00 17 14 0 000000    S       R15,0,A0
 95.            000112  23 00 17 00 0 000014    L       R15,A0
 96.            000113  73 17 00 00 0 000220    TS   T$CARDPROC
 97. U          000114  27 00 14 00 0 000003    L  A0,(000301,CARDPROC)
 98. U          000115  72 11 00 00 0 000000    ER    FORK$
 99.            000116  74 06 00 00 0 000220  C$TSQ  T$CARDPROC
     U          000117  72 11 00 00 0 000000
100.            000120  27 00 14 00 0 000117    L     A0,R15
101.
102. U          000121  27 00 12 00 0 000000    L     X10,CX10$
103.            000122  23 16 17 00 000142      L,U     R15,98
104.            000123  27 01 14 12 0 000003        L,H2    A0,3,X10
105.            000124  27 16 11 00 000000      L,U       X9,START$
106.
107.            000125  23 16 17 00 000004      L,U     R15,4
108.            000126  04 00 17 14 0 000000    S       R15,0,A0
109.            000127  23 00 17 00 0 000014    L       R15,A0
110.            000130  73 17 00 00 0 000222    TS   T$PRINTPROC
111. U          000131  27 00 14 00 0 000004    L  A0,(000401,PRINTPROC)
112. U          000132  72 11 00 00 0 000000    ER    FORK$
113.            000133  74 06 00 00 0 000222  C$TSQ  T$PRINTPROC
     U          000134  72 11 00 00 0 000000
114.            000135  27 00 14 00 0 000117    L     A0,R15
115.            000136  23 00 17 00 0 000014      L     R15,A0
116.            000137  27 00 14 00 0 000227      L     A0,CBGNAME
117. U          000140  72 11 00 00 0 000000      ER    ACT$
118.            000141  27 00 14 00 0 000117        L     A0,R15
119.
```

```
  120.                 000142  23 16 17 00 000170        L,U       R15,120
  121.
  122.                 000143  23 00 17 00 0 000015        L       R15,A1
  123.
  124.                 000144  27 00 15 00 0 003645        L       A1,START$+1957
  125.
  126. U               000145  72 11 00 00 0 000000          ER      TWAIT$
  127.                 000146  27 00 15 00 0 000117        L       A1,R15
  128. U               000147  72 12 00 00 0 000000       EP  ABORT$
  129. U               000150  74 04 00 00 0 000000      J           PEND$
  130.                         000000003650             MA$ EQU 1950
  131.                                                    END
               00      000000  000000001D0714
                       000001  000101 000000
                       000002  000201 000000
                       000003  000301 000000
                       000004  000401 000000

UNDEFINED SYMBOLS:
PEND$        ABORT$       TWAIT$       ACT$         PRINTPROC    CARDPROC     CTSQ$        FORK$        BUFFER       CX1D$        TSORG$
PENT$        EXIT$        DACT$        NAME$        CTSA$        CTSS         ASCFDASC$

END ASM, ERRORS : NONE   ITEM COUNT:   131
@CP$,S,N    TPF$,CARD,CPS,S/3,TPF$,PA$CODE
MACRO INTERPRETER LEVEL 7R1 07/28/83 17:47:24
@ELT,IN      TPF$,CARD
ELT 8R1 S7401C 07/28/83 17:47:30 (=>0)

END ELT.  ERRORS: NONE. TIME:  1.696 SEC. IMAGE COUNT: 78
@ASM,US              TPF$,CARD
ASM 15R1 S7301D 07/28/83 17:47:31 (0,1)


    1,                                              AXR$ 800715
    2, U                000000000000                PCONV$ EQU ASCFDASC$
    3,
    4,                                              $(1)
    5,                                              CARDPROC*
    6,
    7,          01      000000  27 00 14 00 0 000117          L       A0,R15
    8,
    9,                  000001  23 00 15 14 2 000000          L       R13,,*A0
   10, U                000002  58 00 00 00 0 000000          TZ      F$CARDPROC
   11,                  000003  74 04 00 00 0 000006          J       ENTER
   12, U                000004  27 00 12 00 0 000000          L       X1D,XS$CARDPROC
   13,                  000005  74 04 00 00 0 000015          J       PROCST
   14,                                              ENTER
   15, U                000006  74 13 15 00 0 000000          LMJ     A1,PENT$
   16,                  000007  000011 000005              *01$,5
   17,                  000010  000000000000              000000000000 .              U
   18,                  000011  1D0627112527              *CARDPROC     *
```

```
                000012  24100500505C5
19. U           000013  05 00 00 00 0 000000        SZ      F$CARDPROC
20. U           000014  06 00 12 00 0 000000        S       X10,XS$CARDPROC
21.                                             PROCST
22. U           000015  73 17 00 00 0 000000          TS      T$CARDPROC
23. U           000016  05 15 00 00 0 000000          C$TSA   T$CARDPROC
                000017  50 01 00 00 0 000000
                000020  72 1_ 00 00 0 000000
24.             000021  23 00 17 00 0 000014          L       R15,A0
25.             000022  10 00 00 00 0 000000          LA      A0,(0)
26. U           000023  72 11 00 00 0 000000          ER      AWAIT$
27.             000024  27 00 14 00 0 000117          L       A0,R15
28.             000025  23 16 17 00 000035        L,U       R15,29
29.
30.             000026  23 16 17 00 000001          L,U       R15,1
31.             000027  04 00 17 12 0 000006        S         R15,6,X10
32.
33.                                             ZU$
34.             000030  23 16 17 00 000036        L,U       R15,30
35.             000031  74 04 00 00 0 000033      J         $+2
36.             000032  74 04 00 00 0 000072      J         Z1$
37.             000033  23 16 17 00 000040        L,U       R15,32
38.             000034  27 00 14 12 0 000006      L         A0,6,X10
39.             000035  31 16 00 00 000001        MSI,U     A0,1
40.             000036  24 16 14 00 000000        A,U       A0,0
41.             000037  06 00 14 12 0 000007      S         A0,7,X10
42. U           000040  73 17 00 00 0 000000          TS    LOCKV
43.             000041  23 16 17 00 000046        L,U       R15,38
44.
45.             000042  23 16 17 00 000001          L,U       R15,1
46.             000043  04 00 17 12 0 000005        S         R15,5,X10
47.
48.
49.
50.             000044  23 16 17 00 000051        L,U       R15,41
51. U           000045  27 00 14 00 0 000000            L     A0,XS$BUFFER
52.             000046  27 16 01 12 0 000005      L,U         X1,5,X10
53.             000047  06 00 01 14 0 000005      S           X1,5,A0
54.             000050  27 16 01 12 0 000007      L,U         X1,7,X10
55.             000051  06 00 01 14 0 000006      S           X1,6,A0
56.
57.
58. U           000052  27 16 11 00 000000        L,U         X9,START$
59.
60.             000053  23 16 17 00 000005        L,U   R15,5
61.             000054  04 00 17 14 0 000000      S     R15,0,A0
62.             000055  23 00 17 00 0 000014      L     R15,A0
63. U           000056  27 00 14 00 0 000001      L   A0,(000501,BUFFER)
64. U           000057  72 1_ 00 00 0 000000      ER    FORK$
65.             000060  27 00 14 00 0 000117       L    A0,R15
66.             000061  23 00 17 00 0 000014         L       R15,A0
```

```
   67.            000062  10 00 00 00 0 000002          LA      A0,(32)
   68. U          000063  72 11 00 00 0 000000          LP      AWAIT$
   69.            000064  27 00 14 00 0 000117          L       A0,R15
   70.            000065  23 16 17 00 000070        L,U         R15,56
   71.            000066  27 00 14 12 0 000006          L       A0,6,X10
   72.            000067  24 16 14 00 000001          A,U       A0,1
   73.            000070  06 00 14 12 0 000006          S       A0,6,X10
   74.            000071  74 04 00 00 0 000039          J       Z0$
   75.                                              Z1$
   76. U          000072  74 04 00 00 0 000000          J       PRET$
   77.                    000000000011              01$ EQU *
   78.                                                END

         00   000000  000000000004
              000001  000501 000000
              000002  000000000040

UNDEFINED SYMBOLS:
PRET$       FORK$       BUFFER      START$      XS$BUFFER   LOCKV       AWAIT$      T$CARDPROC  PENT$       XS$CARDPROC F$CARDPROC
CTSA$       CTS$        ASCEDASC$

END ASM, ERRORS : NONE   ITEM COUNT:    78
@CPS S,N    TPF$.PRINT,CPS S/3,TPF$.PA$CODE
MACRO INTERPRETER LEVEL 7R1 07/28/83 17:47:35
@ELT,IN     TPF$.PRINT
ELT 8R1 S74Q1C 07/28/83 17:47:42 (=>0)

END ELT, ERRORS: NONE, TIME:  1.707 SEC, IMAGE COUNT: 73
@ASM,US             TPF$.PRINT
ASM 15R1 S73Q1D 07/28/83 17:47:43 (0,1)


    1.                                              AXR$ 800715
    2. U                    000000000000        PCONV$ EQU ASCEDASC$
    3.
    4.                                          $(1)
    5.                                          PRINTPROC*
    6.
    7.          01  000000  27 00 14 00 0 000117          L       A0,R15
    8.
    9.              000001  23 00 15 14 2 000000          L       R13,;*A0
   10. U            000002  50 00 00 00 0 000000          TZ      F$PRINTPROC
   11.              000003  74 04 00 00 0 000006          J       ENTER
   12. U            000004  27 00 17 00 0 000000          L       X10,XS$PRINTPROC
   13.              000005  74 04 00 00 0 000015          J       PROCST
   14.                                          ENTER
   15. U            000006  74 13 15 00 0 000000          LMJ     A1,PENT$
   16.              000007  000010 000005            *D1$,5
   17.              000010  000000000000            000000000000 .              U
   18.              000011  252716233125            *PRINTPROC   *
                    000012  272410050505
   19. U            000013  05 00 00 00 0 000000        SZ      F$PRINTPROC
```

```
20, U          000014  06 00 17 00 0 000000      S       X10,XS$PRINTPROC
21,                                          PROCST
22, U          000015  73 17 00 00 0 000000        TS      T$PRINTPROC
23, U          000016  05 15 00 00 0 000000        CSTSA   T$PRINTPROC
               000017  50 01 00 00 0 000000
               000020  72 11 00 00 0 000000
24,            000021  23 00 17 00 0 000014        L       R15,A0
25,            000022  10 00 00 00 0 000000        LA      A0,(4)
26, U          000023  72 11 00 00 0 000000        ER      AWAIT$
27,            000024  27 00 14 00 0 000117        L       A0,R15
28,                                          ZJ$
29,            000025  23 16 17 00 000034      L,U     R15,29
30,            000026  74 04 00 00 0 000030      J       $+2
31,            000027  74 04 00 00 0 000070      J       Z1$
32, U          000030  73 17 00 00 0 000000        TS    LOCKV
33,            000031  23 16 17 00 000043      L,U     R15,35
34,            000032  05 00 00 12 0 000005    SZ      5,X10
35,
36,
37,            000033  23 16 17 00 000046      L,U     R15,38
38, U          000034  27 00 14 00 0 000000        L     A0,XS$BUFFER
39,            000035  27 16 01 12 0 000005    L,U       X1,5,X10
40,            000036  06 00 01 14 0 000005    S         X1,5,A0
41,
42,
43,            000037  27 16 01 12 0 000007    L,U       X1,7,X10
44,            000040  06 00 01 14 0 000007    S         X1,7,A0
45, U          000041  27 16 11 00 000000      L,U       X9,START$
46,
47,            000042  23 16 17 00 000006      L,U   R15,6
48,            000043  04 00 17 14 0 000000    S     R15,0,A0
49,            000044  23 00 17 00 0 000014    L     R15,A0
50, U          000045  27 00 14 00 0 000001    L   A0,(000501,BUFFER)
51, U          000046  72 11 00 00 0 000000    ER    FORK$
52,            000047  27 00 14 00 0 000117     L    A0,R15
53,            000050  23 00 17 00 0 000014       L       R15,A0
54,            000051  10 00 00 00 0 000002       LA      A0,(64)
55, U          000052  72 11 00 00 0 000000       ER      AWAIT$
56,            000053  27 00 14 00 0 000117       L       A0,R15
57, U          000054  73 17 00 00 0 000000     TS    RSCELL
58,            000055  23 00 17 00 0 000115     L     R15,R13
59,            000056  23 16 15 00 000001       L,U   R13,1
60,
61,
62, U          000057  27 16 14 00 000113      L,U       A0,START$+75
63,            000060  27 00 15 12 0 000007    L         A1,7,X10
64, U          000061  74 13 13 00 0 000000    LMJ       X11,PWR$
65, U          000062  74 13 13 00 0 000000    LMJ       X11,PWLN$
66, U          000063  05 15 00 00 0 000000      CSTS    RSCELL
               000064  50 01 00 00 0 000000
               000065  72 11 00 00 0 000000
```

```
  57.            000066  23 00 15 00 0 000017        L       R13,R15
  58.
  59.            000067  74 04 00 00 0 000025        J       Z0$
  70.                                               Z1$
  71. U          000073  74 04 00 00 0 000000        J       PRET$
  72.                    0000000000010              D1$ EQU 8
  73.                                                 END
           00    000000  0000000000004
                 000001  000601 000000
                 000002  0000000000100

UNDEFINED SYMBOLS:
PRET$       PWLN$       PWR$        RSCELL      FORK$       BUFFER      START$      XS$BUFFER   LOCKV       AWAIT$      T$PRINTPROC
PENT$       XS$PRINTPROC F$PRINTPROC CTSA$       CTS$        ASCFDASC$

END ASM, ERRORS : NONE   ITEM COUNT:    73
@CPS,S,N    TPF$.BUFFER,CPS,S/3,TPF$.PA$CODE
MACRO INTERPRETER LEVEL 7R1 07/28/83 17:47:47
@ELT,IN     TPF$,BUFFER
ELT 8R1 S7401C 07/28/83 17:47:52 (=>0)

END ELT,  ERRORS: NONE,  TIME:  1.825 SEC.  IMAGE COUNT: 92
@ASM,US             TPF$,BUFFER
ASM 1SR1 S73010 07/28/83 17:47:54 (0,1)


   1.                                               AXR$ 800715
   2. U                    000000000000             PCONV$ EQU ASCFDASC$
   3.
   4.                                               $(1)
   5.                                               BUFFER*
   6.
   7.       01     000000  27 00 14 00 0 000017            L       A0,R15
   8.
   9.              000001  23 00 15 14 2 000000            L       R13,,*A0
  10. U           000002  50 00 00 00 0 000000            ST      F$BUFFER
  11.             000003  74 04 00 00 0 000006            J       ENTER
  12. U           000004  27 00 12 00 0 000000            L       X10,XS$BUFFER
  13.             000005  74 04 00 00 0 000015            J       PROCST
  14.                                              ENTER
  15. U           000006  74 13 15 00 0 000000            LMJ     A1,PENT$
  16.             000007  000012 000010                *D0$,8
  17.             000010  0000000000000                0000000000000 ;             0
  18.             000011  0732131131227                *BUFFER     *
                  000012  0505050505050
  19. U           000013  05 00 00 00 0 000000          S7      F$BUFFER
  20. U           000014  06 00 12 00 0 000000          S       X10,XS$BUFFER
  21.                                              PROCST
  22.             000015  23 16 17 00 000015            L,U     R15,13
  23.             000016  27 01 13 12 0 000005          L,H2    X11,5,X10
  24.             000017  27 00 14 13 0 000000          L       A0,0,X11
```

```
25,          000020  74 04 00 00 0 000126      J          Z0$
26,                                          C0$0
27, U        000021  05 15 00 00 0 000000        C$TS     LOCKV
             000022  50 01 00 00 0 000000
             000023  72 11 00 00 0 000000
28, U        000024  73 17 00 00 0 000000          TS     RECEIVER
29,          000025  23 16 17 00 000032        L,U        R15,26
30,          000026  50 00 00 12 0 000010      TZ         9,X10
31,          000027  74 04 00 00 0 000133      J          Z3$
32, U        000030  74 06 00 00 0 000000        C$TSQ    RECEIVER
    U        000031  72 11 00 00 0 000000
33,          000032  74 04 00 00 0 000136      J          Z4$
34,                                          Z3$
35, U        000033  05 15 00 00 0 000000        C$TS     RECEIVER
             000034  50 01 00 00 0 000000
             000035  72 11 00 00 0 000000
36,                                          Z4$
37,          000036  23 16 17 00 000043        L,U        R15,35
38,          000037  27 00 14 12 0 000011      L          A0,9,X10
39,          000040  27 01 13 12 0 000007      L,H2       X11,7,X10
40,          000041  06 00 14 13 0 000000      S          A0,0,X11
41, U        000042  73 17 00 00 0 000000          TS     SENDER
42,          000043  23 16 17 00 000051        L,U        R15,41
43,          000044  05 00 00 12 0 000010      SZ         9,X10
44, U        000045  05 15 00 00 0 000000        C$TSA    SENDER
             000046  50 01 00 00 0 000000
             000047  72 11 00 00 0 000000
45, U        000050  72 11 00 00 0 000000      ER       EXIT$
46,          000051  74 04 00 00 0 000126      J          Z2$
47,                                          C0$1
48, U        000052  05 15 00 00 0 000000        C$TS     LOCKV
             000053  50 01 00 00 0 000000
             000054  72 11 00 00 0 000000
49, U        000055  73 17 00 00 0 000000          TS     SENDER
50,          000056  23 16 17 00 000102        L,U        R15,66
51,          000057  51 00 00 12 0 000010      TNZ        9,X10
52,          000060  74 04 00 00 0 000064      J          Z5$
53, U        000061  74 06 00 00 0 000000        C$TSQ    SENDER
    U        000062  72 11 00 00 0 000000
54,          000063  74 04 00 00 0 000167      J          Z6$
55,                                          Z5$
56, U        000064  05 15 00 00 0 000000        C$TS     SENDER
             000065  50 01 00 00 0 000000
             000066  72 11 00 00 0 000000
57,                                          Z6$
58,          000067  23 16 17 00 000113        L,U        R15,75
59,          000070  27 01 13 12 0 000006      L,H2       X11,5,X10
60,          000071  27 00 14 13 0 000000      L          A0,0,X11
61,          000072  06 00 14 12 0 000011      S          A0,9,X10
62, U        000073  73 17 00 00 0 000000          TS     RECEIVER
63,          000074  23 16 17 00 000121        L,U        R15,81
```

```
64.
65.                 000075  23 16 17 00 000001          L,U       R15,1
66.                 000076  04 00 17 12 0 000000        S         R15,9,X10
67.
68. U               000077  05 15 00 00 0 000000          C*TSA   RECEIVER
                    000100  50 01 00 00 0 000000
                    000101  72 11 00 00 0 000000
69. U               000102  72 11 00 00 0 000000        EP    EXIT$
70.                 000103  74 04 00 00 0 000126        J       Z2$
71.                                                   C$12
72.                 000104  23 16 17 00 000140          L,U     R15,96
73.                 000105  05 00 00 12 0 000010        SZ      9,X10
74. U               000106  73 17 00 00 0 000000          TS      T$BUFFER
75. U               000107  05 15 00 00 0 000000          C*TSA   T$BUFFER
                    000110  50 01 00 00 0 000000
                    000111  72 11 00 00 0 000000
76. U               000112  73 17 00 00 0 000000          TS    SYSTEMHOLD
77. U               000113  74 06 00 00 0 000000        C*TSQ   SYSTEMHOLD
    U               000114  72 11 00 00 0 000000
78.                 000115  74 04 00 00 0 000126        J       Z2$
79.                                                   Z0$
80.                 000116  55 16 00 00 000000          TG,U    A0,0
81.                 000117  55 16 00 00 000003          TG,U    A0,3
82.                 000120  74 04 00 00 0 000125        J       Z1$
83.                 000121  74 04 00 14 1 000122        J       *$+1,A0
84.                 000122  000000000021                  +C0$0
85.                 000123  000000000052                  +C0$1
86.                 000124  000000000104                  +C0$2
87.                                                   Z1$
88. U               000125  74 13 13 00 0 000000        LM,J    X11,PXCS$
89.                                                   Z2$
90. U               000126  74 04 00 00 0 000000        J       PRET$
91.                         000000000012              DU$ EQU 10
92.                                                     END

UNDEFINED SYMBOLS:
PRET$       PXCS$       SYSTEMHOLD  T$BUFFER    EXIT$       SENDER      CTSQ$       RECEIVER    LOCKV       PENT$       XS$BUFFER
F$BUFFER    CTSA$       CTS$        ASCEDASC$

END ASM. ERRORS : NONE   ITEM COUNT:    92
BMAP,I          ,TPF$.MAIN
MAP 30R1 S74T11 07/28/93 17:47:57


ADDRESS LIMITS    001000 011420      4369 IBANK WORDS DECIMAL
                  040000 046424      3349 DBANK WORDS DECIMAL
STARTING ADDRESS  005660
```

```
          SEGMENT $MAIN$          001000 011420     040000 046424

EDASC$/SYS74              $(1)    001000 001174                          07 AUG 78   09:04:51
EDIT$/SYS74               $(1)    001175 001570                          07 AUG 78   09:04:26
ERU$/SYS74R1                                                             20 DEC 78   17:30:56
TABLE$/SYS74              $(1)    001571 001770                          07 AUG 78   09:11:06
P$LEVEL/PAS8R1            $(1)    001771 002004                          23 OCT 78   11:52:20
P$PNF/PAS8R1                                                             17 JUL 78   13:55:38
P$CASE/PAS8R1             $(1)    002005 002024     $(2)    040000 040000  18 MAR 80   14:27:44
                          $(3)    002025 002031
P$FPAR/PAS8R1                                       $(2)    040001 040036  30 AUG 79   10:44:44
P$WRITE/PAS8R1            $(1)    002032 002232     $(2)    040037 040152  11 DEC 79   16:52:28
                          $(3)    002233 002257
P$TRACE/PAS8R1            $(1)    002260 002433                          23 OCT 78   11:52:21
                          $(3)    002434 002466
P$DUMP/PAS8R1             $(1)    002467 002653     $(2)    040153 040164  23 OCT 78   11:52:18
                          $(3)    002654 002670
P$NUM/PAS8R1              $(1)    002671 004044     $(2)    040155 040174  17 JUL 78   13:55:46
P$READ/PAS8R1             $(1)    004045 004622     $(2)    040175 040204  23 APR 82   10:40:57
                          $(3)    004623 004660
P$INTRPT/PAS8R1           $(1)    004661 005450     $(2)    040205 040305  23 APR 82   10:37:37
                          $(3)    005451 005545
P$STDERR/PAS8R1           $(1)    005546 005615                          10 DEC 79   17:45:17
                          $(3)    005616 005651
P$RS/PAS8R1               $(1)    005652 007010     $(2)    040306 040411  23 JUL 80   13:49:59
                          $(3)    007011 007220
P$ID/PAS8R1               $(1)    007221 010531                          23 APR 82   10:40:32
                          $(3)    010532 010734
BUFFER                    $(1)    010735 011063                          28 JUL 83   17:47:56
PRINT                     $(1)    011064 011154     $(0)    040412 040414  28 JUL 83   17:47:45
CARD                      $(1)    011155 011247     $(0)    040415 040417  28 JUL 83   17:47:33
MAIN                      $(1)    011250 011420     $(0)    040420 040424  28 JUL 83   17:47:21
                                                    $(036)  040425 046424

SYS$*RLIB$: LEVEL
END MAP,  ERRORS: 0  TIME: 13,652  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$.
@USE    PA$000000,INFO$.
@SETC,D
@XQT    TPF$.MAIN
1
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```

```
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41
42
ER ABORT%     ABORT ADR: 011420  BDI:000004
ER ABORT%     ABORT ADR: 011052  BDI:000004
  ID: 000001
ER ABORT%     ABORT ADR: 011133  BDI:000004
  ID: 000004
ER ABORT%     ABORT ADR: 011241  BDI:000004
  ID: 000003
ER ABORT%     ABORT ADR: 010735  BDI:000004
  ID: 000006
RUNSTREAM ANALYSIS TERMINATED
```

E.2 - CASE STUDY TWO: Dining Philosophers

```
@CPS.S,S   ,CPS,S/O,
MACRO INTERPRETER LEVEL 7R1 07/27/83 07:51:28
    1   *COMPILE     OPTIONS=ISRLM,ELTNAME=TPFS,MAIN
    1     PROGRAM MAIN(INPUT,OUTPUT);
    1     TYPE LABELS=(PICKUP,PUTDOWN,INIT);
    1     TYPE PHILENT=(PHIL0,PHIL1,PHIL2,PHIL3,PHIL4,PINIT);
    1     PROCEDURE FORKS(VAR FENTRY:LABELS;VAR PHILID:INTEGER);MONITOR;
    1     PROCEDURE PHILS(VAR PENTRY:PHILENT);PROCESS;
    1     VAR  FENTRY    :   LABELS ;
    1          PENTRY    :   PHILENT ;
    1          PHILID    :   INTEGER ;
    1          PHILQ0    :   QUEUE   ;
    1          PHILQ1    :   QUEUE   ;
    1          PHILQ2    :   QUEUE   ;
    1          PHILQ3    :   QUEUE   ;
    1          PHILQ4    :   QUEUE   ;
    1          ENTRYLOCK:   QUEUE   ;
    1          WAITWD    :   QUEUE   ;
    1          PHILST    :   QUEUE   ;
    1     BEGIN
    1       FENTRY := INIT ;
    1       STARTUP WITH TASKNAME(F00) FORKS(FENTRY,PHILID FORWARD);
    1       PENTRY := PINIT ;
    1       STARTUP WITH TASKNAME(P00) PHILS(PENTRY);
    1       COBEGIN(STARTER);
    1         LOCK(PHILST);
    1         PENTRY  := PHIL0  ;
    1         FORK WITH TASKNAME(P0) PHILS(PENTRY);
    1         WAIT(PHILST);
    1         LOCK(PHILST);
    1         PENTRY  := PHIL1  ;
    1         FORK WITH TASKNAME(P1) PHILS(PENTRY);
    1         WAIT(PHILST);
    1         LOCK(PHILST);
    1         PENTRY  := PHIL2  ;
    1         FORK WITH TASKNAME(P2) PHILS(PENTRY);
    1         WAIT(PHILST);
    1         LOCK(PHILST);
    1         PENTRY  := PHIL3  ;
    1         FORK WITH TASKNAME(P3) PHILS(PENTRY);
    1         WAIT(PHILST);
    1         LOCK(PHILST);
    1         PENTRY  := PHIL4  ;
    1         FORK WITH TASKNAME(P4) PHILS(PENTRY);
    1         WAIT(PHILST);
    1       COEND;
    1       WAIT(WAITWD);
    1       CLEAR(WAITWD);
    1       SUSPEND(1000);
    1       TERMINATE;
    1     END;
```

```
1   *COMPILE     OPTIONS=ISRLMV,ELTNAME=TPF$.PHILS
1     PROGRAM DEFINE(PHILS);
1     TYPE LABELS=(PICKUP,PUTDOWN,INIT);
1     TYPE PHILENT=(PHIL0,PHIL1,PHIL2,PHIL3,PHIL4,PINIT);
1     PROCEDURE PHILS(VAR PENTRY:PHILENT;VAR I:INTEGER);
1     PROCEDURE FORKS(VAR FENTRY:LABELS;VAR I:INTEGER);MONITOR;
1     VAR  PHID0     : INTEGER ;
1          PHID1     : INTEGER ;
1          PHID2     : INTEGER ;
1          PHID3     : INTEGER ;
1          PHID4     : INTEGER ;
1          FENTRY    : LABELS  ;
1     BEGIN
1       CASE PENTRY OF
1        PHIL0:
1           BEGIN
1           LOCK(PHILST);
1           SIGNAL(PHILST);
1           AWAIT(STARTER);
1           PHID0 := 0;
1           WHILE  TRUE DO
1             BEGIN
1              SUSPEND(3);
1              LOCK(ENTRYLOCK);
1              LOCK(PHIL00);
1              FENTRY := PICKUP ;
1              FORK WITH TASKNAME(F0) FORKS(FENTRY,PHID0);
1              WAIT(PHIL00);
1              AWAIT(F0);
1              SUSPEND(8);
1              LOCK(ENTRYLOCK);
1              FENTRY := PUTDOWN ;
1              FORK WITH TASKNAME(F0) FORKS(FENTRY,PHID0);
1              AWAIT(F0);
1              QUIT BY CHECKING(WAITW0);
1            END;
1         END;
1        PHIL1:
1           BEGIN
1           LOCK(PHILST);
1           SIGNAL(PHILST);
1           AWAIT(STARTER);
1           PHID1 := 1;
1           WHILE  TRUE DO
1             BEGIN
1              SUSPEND(2);
1              LOCK(ENTRYLOCK);
1              LOCK(PHIL01);
1              FENTRY := PICKUP ;
1              FORK WITH TASKNAME(F1) FORKS(FENTRY,PHID1);
1              WAIT(PHIL01);
```

```
1             AWAIT(F1);
1             SUSPEND(1);
1             LOCK(ENTRYLOCK);
1             FENTRY := PUTDOWN ;
1             FORK WITH TASKNAME(F1) FORKS(FENTRY,PHID1);
1             AWAIT(F1);
1             QUIT BY CHECKING(WAITWD);
1           END;
1         END;
1       PHIL2:
1         BEGIN
1         LOCK(PHILST);
1         SIGNAL(PHILST);
1         AWAIT(STARTER);
1         PHID2 := 2;
1         WHILE  TRUE DO
1           BEGIN
1             SUSPEND(5);
1             LOCK(ENTRYLOCK);
1             LOCK(PHILQ2);
1             FENTRY := PICKUP ;
1             FORK WITH TASKNAME(F2) FORKS(FENTRY,PHID2);
1             WAIT(PHILQ2);
1             AWAIT(F2);
1
1             SUSPEND(2);
1             LOCK(ENTRYLOCK);
1             FENTRY := PUTDOWN ;
1             FORK WITH TASKNAME(F2) FORKS(FENTRY,PHID2);
1             AWAIT(F2);
1             QUIT BY CHECKING(WAITWD);
1           END;
1         END;
1       PHIL3:
1         BEGIN
1         LOCK(PHILST);
1         SIGNAL(PHILST);
1         AWAIT(STARTER);
1         PHID3 := 3;
1         WHILE  TRUE DO
1           BEGIN
1             SUSPEND(6);
1             LOCK(ENTRYLOCK);
1             LOCK(PHILQ3);
1             FENTRY := PICKUP ;
1             FORK WITH TASKNAME(F3) FORKS(FENTRY,PHID3);
1             WAIT(PHILQ3);
1             AWAIT(F3);
1             SUSPEND(3);
1             LOCK(ENTRYLOCK);
1             FENTRY := PUTDOWN ;
```

```
1              FORK WITH TASKNAME(F3) FORKS(FENTRY,PHID3);
1              AWAIT(F3);
1              QUIT BY CHECKING(WAITWD);
1            END;
1          END;
1        PHIL4:
1           BEGIN
1           LOCK(PHILST);
1           SIGNAL(PHILST);
1           AWAIT(STARTER);
1           PHID4 := 4;
1           WHILE  TRUE DO
1             BEGIN
1              SUSPEND(4);
1              LOCK(ENTRYLOCK);
1              LOCK(PHILQ4);
1              FENTRY := PICKUP ;
1              FORK WITH TASKNAME(F4) FORKS(FENTRY,PHID4);
1              WAIT(PHILQ4);
1              AWAIT(F4);
1              SUSPEND(9);
1              LOCK(ENTRYLOCK);
1              FENTRY := PUTDOWN ;
1              FORK WITH TASKNAME(F4) FORKS(FENTRY,PHID4);
1              AWAIT(F4);
1              QUIT BY CHECKING(WAITWD);
1            END;
1          END;
1        PINIT:
1           BEGIN
1             RELEASE(PHILS);
1             WAIT FOREVER;
1             QUIT;
1           END;
1       END;
1     END;
1   *COMPILE      OPTIONS=ISRLMV,ELTNAME=TPFS.FORKS
1     PROGRAM DEFINE(FORKS);
1     TYPE LABELS=(PICKUP,PUTDOWN,INIT);
1     PROCEDURE FORKS(VAR FENTRY:LABELS;VAR I:INTEGER);
1     VAR    FRK        : ARRAY [ 0..4 ] OF 0..2 ;
1            WAITING    : ARRAY [ 0..4 ] OF BOOLEAN ;
1     BEGIN
1      CASE FENTRY OF
1       PICKUP:
1        BEGIN
1        CASE I OF
1         0: LOCK(PHILQ0);
1         1: LOCK(PHILQ1);
1         2: LOCK(PHILQ2);
1         3: LOCK(PHILQ3);
```

```
1          4: LOCK(PHILQ4);
1        END;
1
1          IF FRK[I] <> 2 THEN BEGIN
1                                WAITING[I] := TRUE;
1                                CASE I OF
1                                 0: UNLOCK(PHILQ0);
1                                 1: UNLOCK(PHILQ1);
1                                 2: UNLOCK(PHILQ2);
1                                 3: UNLOCK(PHILQ3);
1                                 4: UNLOCK(PHILQ4);
1                                END;
1          CREGION;
1           WRITELN;
1           WRITELN('  OPERATION      : PICKUP / REZERV FORKS ');
1           WRITE('  PHILOSOPHER    : ',I,'    FORKS ON THE TABLE : ');
1           WRITE(FRK[0],' ',FRK[1],' ',FRK[2],' ',FRK[3],' ',FRK[4]);WRITELN;
1           WRITE('  WAITING ARRAY : ');
1           WRITE(WAITING[0],' ',WAITING[1],' ',WAITING[2],' ',WAITING[3],' ',WAITING[4]);
1           WRITELN;
1          CEND;
1                                UNLOCK(ENTRYLOCK);
1                                QUIT;
1                                END
1          ELSE BEGIN
1           WAITING[I] := FALSE ;
1           FRK [(I+4) MOD 5 ]:= FRK [(I+4) MOD 5 ] - 1;
1           FRK [(I+1) MOD 5 ]:= FRK [(I+1) MOD 5 ] - 1;
1           CASE I OF
1            0: SIGNAL(PHILQ0);
1            1: SIGNAL(PHILQ1);
1            2: SIGNAL(PHILQ2);
1            3: SIGNAL(PHILQ3);
1            4: SIGNAL(PHILQ4);
1           END;
1          CREGION;
1           WRITELN;
1           WRITELN('  OPERATION      : PICKUP / GET FORKS    ');
1           WRITE('  PHILOSOPHER    : ',I,'    FORKS ON THE TABLE : ');
1           WRITE(FRK[0],' ',FRK[1],' ',FRK[2],' ',FRK[3],' ',FRK[4]);WRITELN;
1           WRITE('  WAITING ARRAY : ');
1           WRITE(WAITING[0],' ',WAITING[1],' ',WAITING[2],' ',WAITING[3],' ',WAITING[4]);
1           WRITELN;
1          CEND;
1           UNLOCK(ENTRYLOCK);
1           QUIT;
1         END;
1       END;
1      PUTDOWN:
1       BEGIN
1    FRK [(I+4) MOD 5 ]:= FRK [(I+4) MOD 5 ] + 1;
```

```
1      FRKC (I+1) MOD 5 ]:= FRKC (I+1) MOD 5 ] + 1;
1      IF ( FRKC (I+4) MOD 5 ] = 2 ) AND
1         ( WAITINGC (I+4) MOD 5 ]  ) THEN
1         BEGIN
1          WAITINGC (I+4) MOD 5 ] := FALSE ;
1          FRKC (I+3) MOD 5 ]:= FRKC (I+3) MOD 5 ] + 1;
1          FRKC I ] := FRKC I ] -1;
1          CASE (I+4) MOD 5 OF
1           0: SIGNAL(PHILQ0);
1           1: SIGNAL(PHILQ1);
1           2: SIGNAL(PHILQ2);
1           3: SIGNAL(PHILQ3);
1           4: SIGNAL(PHILQ4);
1          END;
1         END;
1      IF ( FRKC (I+1) MOD 5 ] = 2 ) AND
1         ( WAITINGC (I+1) MOD 5 ]  ) THEN
1         BEGIN
1          WAITINGC (I+1) MOD 5 ] := FALSE ;
1          FRKC (I+2) MOD 5 ]:= FRKC (I+2) MOD 5 ] + 1;
1          FRKC I ] := FRKC I ] -1;
1          CASE (I+1) MOD 5 OF
1           0: SIGNAL(PHILQ0);
1           1: SIGNAL(PHILQ1);
1           2: SIGNAL(PHILQ2);
1           3: SIGNAL(PHILQ3);
1           4: SIGNAL(PHILQ4);
1          END;
1         END;
1           CREGION;
1            WRITELN;
1            WRITELN('  OPERATION      : PUTDOWN                ');
1            WRITE('  PHILOSOPHER    : ',I,'    FORKS ON THE TABLE : ');
1            WRITE(FRKC0],' ',FRKC1],' ',FRKC2],' ',FRKC3],' ',FRKC4]);WRITELN;
1            WRITE('  WAITING ARRAY : ');
1            WRITE(WAITINGC0],' ',WAITINGC1],' ',WAITINGC2],' ',WAITINGC3],' ',WAITINGC4]);
1            WRITELN;
1           CEND;
1         UNLOCK(ENTRYLOCK);
1         QUIT;
1       END;
1      INIT:
1       BEGIN
1         FOR I:= 0 TO 4 DO BEGIN
1                           FRKC I ] := 2;
1                           WAITINGC I ]:= FALSE;
1                          END;
1         RELEASE(FORKS);
1         WAIT FOREVER;
1         SIGNAL(WAITWD);
1         QUIT;
```

```
    1      END;
    1    END;
    1  END;
    1
@CPS~S,N   SCRATCH$,SCRATCH1,CPS~S/1,SCRATCH$,SCRATCH2
MACRO INTERPRETER LEVEL 7R1 07/27/83 07:56:06
@CPS~S,N   SCRATCH$,SCRATCH2,CPS~S/2,
MACRO INTERPRETER LEVEL 7R1 07/27/83 07:56:44
@CPS~X
@BU*PASCAL~S,ISRLM
PASCAL 8R1A PLTB  WEDNESDAY, 1983 JULY 27, 7:58:13
                1


                2   PROGRAM MAIN(INPUT,OUTPUT);
                3   TYPE LABELS=(PICKUP,PUTDOWN,INIT);
                4   TYPE PHILENT=(PHIL0,PHIL1,PHIL2,PHIL3,PHIL4,PINIT);
                5   PROCEDURE FORKS(VAR FENTRY:LABELS;VAR PHILID:INTEGER);EXTERNAL ;
                6   PROCEDURE PHILS(VAR PENTRY:PHILENT);EXTERNAL ;
                7   VAR GLOBALS : ARRAY (.1 ~. 1821.) OF INTEGER ;
                8       FENTRY : LABELS ;
                9       PENTRY : PHILENT ;
               10       PHILID : INTEGER ;
               11 $CODE RSCELL*      T$CELL
               12 $CODE CBGNST*      T$CELL
               13 $CODE SYSTEMHOLD*  T$CELL
               14 $CODE ENTRYLOCK*    T$CELL
               15 $CODE PHILQ0*       T$CELL
               16 $CODE PHILQ1*       T$CELL
               17 $CODE PHILQ2*       T$CELL
               18 $CODE PHILQ3*       T$CELL
               19 $CODE PHILQ4*       T$CELL
               20 $CODE PHILST*       T$CELL
               21 $CODE WAITWD*       T$CELL
               22 $CODE T$FORKS*        T$CELL
               23 $CODE T$MAIN*         T$CELL
               24 $CODE T$PHILS*        T$CELL
               25 $CODE XS$FORKS*        RES    1
               26 $CODE XS$MAIN*         RES    1
               27 $CODE XS$PHILS*        RES    1
               28 $CODE CBGNAME*         RES    1
               29 $CODE F$FORKS*         RES    1
               30 $CODE F$MAIN*          RES    1
               31 $CODE F$PHILS*         RES    1
               32 $CODE SVRGA0*   RES    900
               33 $CODE SVRGA1*   RES    900
               34 $CODE       RES       SIZE$_136_1821
               35 $CODE $(1)
               36
               37 $CODE COBEGIN*
               38 $CODE    L          A0,('CBG')

1                    0=  135
1
1
2                    0=    6
2                    0=    5
1                  136= 1956
1                 1957= 1957
1                 1958= 1958
1                 1959= 1959
1     0=    0
1     1=    1
1     2=    2
1     3=    3
1     4=    4
1     5=    5
1     6=    6
1     7=    7
1     8=    8
1     9=    9
1    10=   10
1    11=   11
1    12=   12
1    13=   13
1    14=   14
1    15=   15
1    16=   16
1    17=   17
1    18=   18
1    19=   19
1    20=   20
1    21=   21
1    22=   22
1    23=   23
1    24=   24
1    25=   25
1    26=   26
```

```
P$CHECK/PAS8P1          $(1)    010735 011044    $(2)    040412 040417      18 MAR 80   14:27:55
                        $(3)    011045 011070
FORKS                   $(1)    011071 012516                               27 JUL 83   08:01:06
                        $(3)    012517 012604
PHILS                   $(1)    012605 013407    $(0)    040420 040432      27 JUL 83   08:00:11
MAIN                    $(1)    013410 013701    $(0)    040433 040443      27 JUL 83   07:59:28
                                                 $(036)  040444 046444
SYS$*RLIB$* LEVEL
END MAP,  ERRORS: 0  TIME: 14.671  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$,
@USE    PA$000000,INFO$,
@SETC,D
@XQT    TPF$,MAIN

  OPERATION      : PICKUP / GET FORKS
  PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 2 1 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PICKUP / GET FORKS
  PHILOSOPHER    : 1    FORKS ON THE TABLE : 0 2 1 1 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PUTDOWN
  PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 1 2 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PUTDOWN
  PHILOSOPHER    : 1    FORKS ON THE TABLE : 2 2 2 2 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PICKUP / GET FORKS
  PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 2 1 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PICKUP / GET FORKS
  PHILOSOPHER    : 1    FORKS ON THE TABLE : 0 2 1 1 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PUTDOWN
  PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 1 2 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PUTDOWN
  PHILOSOPHER    : 1    FORKS ON THE TABLE : 2 2 2 2 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PICKUP / GET FORKS
  PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 2 1 2
  WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

  OPERATION      : PICKUP / GET FORKS
```

```
PHILOSOPHER    : 1    FORKS ON THE TABLE : 0 2 1 1 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 1 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 1    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 2 1 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 1    FORKS ON THE TABLE : 0 2 1 1 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 1 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 1    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 4    FORKS ON THE TABLE : 1 2 2 1 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / REZERV FORKS
PHILOSOPHER    : 0    FORKS ON THE TABLE : 1 2 2 1 2
WAITING ARRAY : TRUE  FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 4    FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 3    FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 0    FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 3    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE
```

```
OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PUTDOWN
PHILOSOPHER   : 3    FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE

OPERATION     : PICKUP / GET FORKS
PHILOSOPHER   : 0    FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY : FALSE FALSE FALSE FALSE FALSE
```

```
OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 1 1 2 0
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 2 1 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PUTDOWN
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 2 2 2 2
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 0     FORKS ON THE TABLE : 2 1 2 2 1
WAITING ARRAY  : FALSE FALSE FALSE FALSE FALSE

OPERATION      : PICKUP / GET FORKS
PHILOSOPHER    : 3     FORKS ON THE TABLE : 2 1 1 2 0
```

E.3.1 - CASE STUDY THREE: Quicksort (Without Processor Dedication)

```
@CPS-S,S   ,CPS#S/0,
MACRO INTERPRETER LEVEL 7R1 07/27/83 08:03:12
    1   *COMPILE     OPTIONS=IRSLMG,ELTNAME=TPFS-MAIN
    1       PROGRAM MAIN(INPUT,OUTPUT);
    1       CONST  N=1000;
    1       TYPE   Q1ENTRIES =( Q1INIT , Q1START );
    1              Q2ENTRIES =( Q2INIT , Q2START );
    1              ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
    1       PROCEDURE  DIVIDETWO(VAR X : ARRAYTYPE; N : INTEGER); PROCESS;
    1       PROCEDURE  QUICKONE(VAR Q1ENTRY : Q1ENTRIES;VAR X : ARRAYTYPE; LOWER1 : INTEGER; UPPER1 : INTEGER); PROCESS;
    1       PROCEDURE  QUICKTWO(VAR Q2ENTRY : Q2ENTRIES;VAR X : ARRAYTYPE; LOWER2 : INTEGER; UPPER2 : INTEGER); PROCESS;
    1       VAR  FINISH     :  QUEUE      ;
    1            QLOCK1     :  QUEUE      ;
    1            QLOCK2     :  QUEUE      ;
    1            FORKLOCK   :  QUEUE      ;
    1            Q1ENTRY    :  Q1ENTRIES  ;
    1            Q2ENTRY    :  Q2ENTRIES  ;
    1            DMINT      :  INTEGER    ;
    1            I,CP       :  INTEGER    ;
    1            X          :  ARRAYTYPE  ;
    1       BEGIN
    1        CREGION;
    1          READLN;
    1          PAGE; WRITELN; WRITELN;
    1          WRITELN('            ** UNSORTED ARRAY (1000 ELEMENTS) **      ');
    1          WRITELN; WRITELN; WRITELN;
    1        CEND;
    1        FOR I := 1 TO N
    1          DO BEGIN
    1               CREGION;   READ(X(I)); WRITE(X(I):5); CEND;
    1               IF ( I MOD 20 ) = 0 THEN BEGIN  CREGION; WRITELN; CEND; END;
    1             END;
    1        LOCK(FINISH); LOCK(QLOCK1); LOCK(QLOCK2);
    1        CREGION;  CP := CPTIME(3); CEND;
    1        Q1ENTRY := Q1INIT;
    1        STARTUP WITH TASKNAME(TO1) QUICKONE(Q1ENTRY,X,DMINT FORW,DMINT FORW);
    1        Q2ENTRY := Q2INIT;
    1        STARTUP WITH TASKNAME(TO2) QUICKTWO(Q2ENTRY,X,DMINT FORW,DMINT FORW);
    1        STARTUP WITH TASKNAME(TOO) DIVIDETWO(X,N);
    1        WAIT(FINISH);
    1        CREGION;
    1          CP := CPTIME(3)-CP;
    1          PAGE; WRITELN; WRITELN; WRITELN('      TIME CONSUMED : ',CP,' MSEC');
    1          WRITELN; WRITELN;
    1          WRITELN; WRITELN; WRITELN('            ** SORTED ARRAY **       ');
    1          WRITELN; WRITELN;
    1        CEND;
    1        FOR I := 1 TO N
    1           DO BEGIN
    1                CREGION; WRITE(X(I):5); CEND;
    1                IF (I MOD 20) = 0 THEN BEGIN  CREGION; WRITELN; CEND; END;
```

```
I            END;
I       LOCK(QLOCK1);
I       SIGNAL(QLOCK1);
I       LOCK(QLOCK2);
I       SIGNAL(QLOCK2);
I       QUIT;
I     END;
I  *COMPILE      OPTIONS=IRSLMVG,ELTNAME=TPFS,DIVIDE2
I     PROGRAM DEFINE(DIVIDETWO);
I     CONST  N=1000;
I     TYPE   Q1ENTRIES =( Q1INIT , Q1START );
I            Q2ENTRIES =( Q2INIT , Q2START );
I            ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
I     PROCEDURE DIVIDETWO(VAR X : ARRAYTYPE; N : INTEGER);
I     PROCEDURE  QUICKONE(VAR Q1ENTRY : Q1ENTRIES;VAR X : ARRAYTYPE; LOWER1 : INTEGER; UPPER1 : INTEGER); PROCESS;
I     PROCEDURE  QUICKTWO(VAR Q2ENTRY : Q2ENTRIES;VAR X : ARRAYTYPE; LOWER2 : INTEGER; UPPER2 : INTEGER); PROCESS;
I     VAR  UP,DOWN,A : INTEGER    ;
I          LB,UB,J   : INTEGER    ;
I          Q1ENTRY   : Q1ENTRIES  ;
I          Q2ENTRY   : Q2ENTRIES  ;
I          I,JP1,JM1 : INTEGER    ;
I          TEMP      : INTEGER    ;
I     BEGIN
I      RELEASE(DIVIDETWO);
I      LB := 1 ;    UB := N ;  A := X [ LB ] ;
I      UP := UB ;   DOWN := LB ;
I      REPEAT
I         WHILE ( UP > DOWN ) AND ( X [ UP ] > A ) DO  UP := UP -1;
I          J := UP ;
I          IF   UP <>  DOWN THEN BEGIN
I                                  TEMP :=    X [ DOWN ] ;
I                                  X [ DOWN ] := X [ UP ] ;
I                                  X [ UP ] := TEMP ;
I                                  WHILE ( DOWN < UP ) AND ( X [ DOWN ] <= A ) DO DOWN := DOWN + 1;
I                                  J := DOWN;
I                                  IF DOWN <> UP THEN BEGIN
I                                                      TEMP     := X [ UP   ];
I                                                      X [ UP ] := X [ DOWN ];
I                                                      X [DOWN] := TEMP      ;
I                                                     END;
I                                END;
I      UNTIL DOWN = UP ;
I      X [ J ] := A ;
I      JP1 := J + 1;
I      JM1 := J - 1;
I      IF UB > JP1 THEN BEGIN
I                         LOCK(FORKLOCK);
I                         Q1ENTRY := Q1START ;
I                         FORK WITH TASKNAME(T06) QUICKONE(Q1ENTRY,X,JP1,UB);
I                         WAIT(FORKLOCK);
I                       END;
```

```
      IF JM1 > LB THEN BEGIN
                          LOCK(FORKLOCK);
                          Q2ENTRY := Q2START ;
                          FORK WITH TASKNAME(TO7) QUICKTWO(Q2ENTRY,X,LB,JM1);
                          WAIT(FORKLOCK);
                        END;
      AWAIT(TO6,TO7);
      LOCK(FINISH);
      SIGNAL(FINISH);
      QUIT;
      END;
  *COMPILE     OPTIONS=IRSLMVG,ELTNAME=TPF$,QUICK1
      PROGRAM DEFINE(QUICKONE);
      CONST  N=1000;
      TYPE  Q1ENTRIES =( Q1INIT , Q1START );
            Q2ENTRIES =( Q2INIT , Q2START );
            ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
      PROCEDURE QUICKONE(VAR ENTRY : Q1ENTRIES; VAR X:ARRAYTYPE; LOWER : INTEGER; UPPER : INTEGER);
      TYPE   STACKITEM = RECORD
                           LB  : INTEGER ;
                           UB  : INTEGER ;
                         END;
             STACK = RECORD
                           TOP  : INTEGER ;
                           ITEM : ARRAY [ 1 .. N ] OF STACKITEM ;
                         END;
      VAR    S       :  STACK     ;
             NEWBNDS :  STACKITEM ;
             I,J,A   :  INTEGER   ;
             UP,DOWN :  INTEGER   ;
             TEMP    :  INTEGER   ;
       BEGIN
        CASE ENTRY OF
         Q1START:
          BEGIN
          LOCK(FORKLOCK);
          SIGNAL(FORKLOCK);
          WITH  NEWBNDS
           DO BEGIN
               LB := LOWER;   UB := UPPER;
               S.TOP := S.TOP +1;
               S.ITEM[ S.TOP ].LB := LB;
               S.ITEM[ S.TOP ].UB := UB;
               WHILE NOT(S.TOP = 0)
                 DO BEGIN
                  LB := S.ITEM[ S.TOP ].LB;
                 UB := S.ITEM[ S.TOP ].UB;
                 S.TOP := S.TOP - 1;
                 WHILE  UB > LB DO BEGIN
                                    A := X [ LB ]; J:= LB; UP := UB; DOWN:= LB;
                                    REPEAT
```

```
                         WHILE(UP > DOWN)AND(X [ UP] >= A ) DO  UP:= UP-1;
                         J:= UP ;
                         IF UP <> DOWN THEN BEGIN
                                                 TEMP      := X [ UP    ];
                                                 X [ UP ] := X [ DOWN ];
                                                 X [DOWN] := TEMP       ;
                                            END;
                                             WHILE(DOWN < UP) AND(X[DOWN]<=A)
                                                  DO DOWN := DOWN +1;
                                             J := DOWN;
                                             IF DOWN<>UP THEN  BEGIN
                                                                TEMP      := X [ UP    ];
                                                                X [ UP ] := X [ DOWN ];
                                                                X [DOWN] := TEMP       ;
                                                               END;
                       UNTIL DOWN = UP ;
                       X [ J ] := A;
                       IF J-LB > UB -J THEN BEGIN
                                             I:=UB; UB:= J-1;
                                             S.TOP := S.TOP +1;
                                             S.ITEM[ S.TOP ].LB := LB;
                                             S.ITEM[ S.TOP ].UB := UB;
                                             LB := J+1;
                                             UB := I;
                                            END
                                       ELSE BEGIN
                                             I:=LB; LB:= J+1;
                                             S.TOP := S.TOP +1;
                                             S.ITEM[ S.TOP ].LB := LB;
                                             S.ITEM[ S.TOP ].UB := UB;
                                             LB := I  ;
                                             UB := J-1;
                                            END;
                     END;
                   END;
              END;
        QUIT;
        END;
   Q1INIT: BEGIN
           S.TOP := 0;
           RELEASE(QUICKONE);
           WAIT(QLOCK1);
           QUIT;
          END;
   END;
 END;
*COMPILE      OPTIONS=IRSLMVG,ELTNAME=TPF$,QUICK2
   PROGRAM DEFINE(QUICKTWO);
   CONST  N=1000;
   TYPE  Q1ENTRIES =( Q1INIT , Q1START );
         Q2ENTRIES =( Q2INIT , Q2START );
```

```
        ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
PROCEDURE QUICKTWO(VAR ENTRY : Q2ENTRIES; VAR X:ARRAYTYPE; LOWER : INTEGER; UPPER : INTEGER);
TYPE    STACKITEM = RECORD
                      LB   : INTEGER ;
                      UB   : INTEGER ;
                    END;
          STACK = RECORD
                    TOP  : INTEGER ;
                    ITEM : ARRAY [ 1 .. N ] OF STACKITEM ;
                  END;
VAR   S       :  STACK     ;
      NEWBNDS :  STACKITEM ;
      I,J,A   :  INTEGER   ;
      UP,DOWN :  INTEGER   ;
      TEMP    :  INTEGER   ;
 BEGIN
  CASE ENTRY OF
   Q2START:
    BEGIN
    LOCK(FORKLOCK);
    SIGNAL(FORKLOCK);
    WITH  NEWBNDS
     DO BEGIN
         LB := LOWER;   UB := UPPER;
         S.TOP := S.TOP +1;
         S.ITEM[ S.TOP ].LB := LB;
         S.ITEM[ S.TOP ].UB := UB;
         WHILE NOT(S.TOP = 0)
           DO BEGIN
                LB := S.ITEM[ S.TOP ].LB;
              UB := S.ITEM[ S.TOP ].UB;
              S.TOP := S.TOP -1;
              WHILE  UB > LB DO BEGIN
                                  A := X [ LB ]; J:= LB; UP := UB; DOWN:= LB;
                                  REPEAT
                                  WHILE(UP > DOWN)AND(X [ UP ] >= A ) DO  UP:= UP-1;
                                    J:= UP ;
                                    IF UP <> DOWN THEN BEGIN
                                                        TEMP     := X [ UP   ];
                                                        X [ UP ] := X [ DOWN ];
                                                        X [DOWN] := TEMP      ;
                                                       END;
                                                       WHILE(DOWN < UP) AND(X[DOWN]<=A)
                                                            DO DOWN := DOWN +1;
                                                       J := DOWN;
                                                       IF DOWN<>UP THEN  BEGIN
                                                                           TEMP     := X [ UP   ];
                                                                           X [ UP ] := X [ DOWN ];
                                                                           X [DOWN] := TEMP      ;
                                                                         END;
                                  UNTIL DOWN = UP ;
```

```
                                        X [ J ] := A;
                                        IF J=LB > UB =J THEN BEGIN
                                                             I:=UB; UB:= J-1;
                                                             S.TOP := S.TOP +1;
                                                             S.ITEM[ S.TOP ].LB := LB;
                                                             S.ITEM[ S.TOP ].UB := UB;
                                                             LB := J+1;
                                                             UB := I;
                                                            END
                                                       ELSE BEGIN
                                                             I:=LB; LB:= J+1;
                                                             S.TOP := S.TOP +1;
                                                             S.ITEM[ S.TOP ].LB := LB;
                                                             S.ITEM[ S.TOP ].UB := UB;
                                                             LB := I  ;
                                                             UB := J-1;
                                                            END;
                                    END;
                                END;
                            END;
                    QUIT;
                   END;
        Q2INIT: BEGIN
                S.TOP := 0;
                RELEASE(QUICKTWO);
                WAIT(QLOCK2);
                QUIT;
                END;
      END;
    END;
@CPS=S,N   SCRATCH$.SCRATCH1,CPS=S/1,SCRATCH$.SCRATCH2
MACRO INTERPRETER LEVEL 7R1 07/27/83 08:10:41
@CPS=S,N   SCRATCH$.SCRATCH2,CPS=S/2,
MACRO INTERPRETER LEVEL 7R1 07/27/83 08:11:55
@CPS=X
@BU*PASCAL=S,IRSLMG
PASCAL 8R1A RLIB  WEDNESDAY, 1983 JULY 27, 8:15:44
    1

    2   PROGRAM MAIN(INPUT,OUTPUT);                                                                    1          0   135
    3   CONST  N=1000;                                                                                 1
    4   TYPE   Q1ENTRIES =( Q1INIT , Q1START );                                                        1
    5          Q2ENTRIES =( Q2INIT , Q2START );                                                        1
    6          ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;                                               1
    7   PROCEDURE  DIVIDETWO(VAR X : ARRAYTYPE; N : INTEGER);EXTERNAL ;                                2          0     6
    8   PROCEDURE  QUICKONE(VAR Q1ENTRY : Q1ENTRIES;VAR X : ARRAYTYPE; LOWER1 : INTEG                  2          0     8
    9   PROCEDURE  QUICKTWO(VAR Q2ENTRY : Q2ENTRIES;VAR X : ARRAYTYPE; LOWER2 : INTEG                  2          0     8
   10   VAR GLOBALS : ARRAY [1 .. 1820] OF INTEGER ;                                                   1        136  1955
   11      CP : INTEGER ;                                                                              1       1956  1956
   12      DMINT : INTEGER ;                                                                           1       1957  1957
```

```
P$TRACE/PAS8R1          $(1)    003516 003671                                   23 OCT 78   11:52:21
                        $(3)    003672 003724
P$WRITE/PAS8P1          $(1)    003725 005125     $(2)    040077 040212         11 DEC 79   16:52:28
                        $(3)    005126 005152
P$INTRPT/PAS8R1         $(1)    005153 005742     $(2)    040213 040313         23 APR 82   10:37:37
                        $(3)    005743 006037
P$RS/PAS8R1             $(1)    006040 007176     $(2)    040314 040417         23 JUL 80   13:49:59
                        $(3)    007177 007406
P$IO/PAS8R1             $(1)    007407 010717                                   23 APR 82   10:40:32
                        $(3)    010720 011122
QUICK2                  $(1)    011123 011710     $(0)    040420 040421         27 JUL 83   08:21:23
QUICK1                  $(1)    011711 012476     $(0)    040422 040423         27 JUL 83   08:20:13
DIVIDE2                 $(1)    012477 013105     $(0)    040424 040427         27 JUL 83   08:19:11
MAIN                    $(1)    013106 013555     $(0)    040430 040433         27 JUL 83   08:18:23
                        $(3)    013556 013601     $(036)  040434 040435
SYS$*RLIB$; LEVEL
END MAP, ERRORS: 0  TIME: 14.353  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$.
@USE    PA$000000,INFO$.
@SETC,D
@XQT    TPF$,MAIN
```

** UNSORTED ARRAY (1000 ELEMENTS) **

674	137	901	506	283	761	416	940	896	976	311	875	367	723	967	842	993	460	703	475
835	338	788	825	743	503	814	956	746	197	193	901	36	25	881	516	889	977	262	754
436	511	486	335	328	245	388	766	885	485	474	129	462	63	269	31	313	678	717	563
366	137	117	110	890	617	459	288	144	292	837	286	679	396	1	343	70	979	899	52
440	377	465	676	240	601	687	597	328	574	402	527	506	391	47	31	243	456	979	434
427	592	807	104	572	945	511	604	996	693	0	167	91	330	63	400	894	469	548	125
756	870	909	695	12	579	163	131	142	820	559	849	998	463	203	775	288	642	130	43
579	299	241	512	685	143	803	740	406	761	97	84	161	292	115	7	171	337	75	684
420	469	836	455	748	941	171	613	975	892	181	551	110	593	979	175	230	974	114	40
763	895	69	571	461	361	478	241	464	63	573	529	450	396	720	952	949	265	724	431
505	768	948	733	447	14	121	679	646	87	73	297	710	366	442	52	671	140	790	770
316	670	370	812	887	574	142	573	4	623	489	291	225	763	420	666	769	386	879	733
516	605	153	912	494	495	179	120	657	990	929	307	845	334	860	740	427	711	804	826
195	907	458	250	706	543	47	639	321	674	515	982	835	257	973	443	622	180	988	239
883	317	605	660	613	244	865	332	552	997	931	253	439	458	738	116	493	689	490	911
168	731	95	754	760	130	50	349	605	643	66	495	163	319	113	474	373	355	383	168
281	854	17	171	28	819	304	193	859	456	366	457	942	48	239	816	358	419	546	746
709	185	848	348	413	742	83	990	824	133	340	136	921	686	581	429	391	484	741	35
547	517	2	717	595	506	867	119	363	176	19	151	707	932	762	382	395	625	226	787
358	310	341	185	814	629	911	155	833	648	5	192	527	715	184	349	144	122	955	548
915	59	177	239	628	585	974	54	473	52	90	540	809	629	417	78	91	304	816	504
292	957	163	964	744	815	907	980	429	806	279	676	322	86	620	588	506	173	143	442
360	904	805	763	205	599	778	135	420	561	379	413	87	260	149	147	867	248	125	950
855	103	169	510	800	380	597	428	132	799	166	999	868	605	837	561	518	242	562	986
754	236	701	348	668	354	513	788	40	868	502	68	147	948	257	244	228	924	752	397
802	396	930	300	660	873	734	384	412	843	583	326	87	893	657	52	365	739	167	928
630	699	159	359	97	415	229	6	898	305	878	284	67	468	65	794	997	474	878	771
997	701	85	655	196	584	644	300	139	367	143	360	981	682	427	817	317	466	573	610
263	472	663	785	486	850	687	552	491	966	237	105	572	880	487	38	398	587	329	645
332	390	334	372	159	432	596	149	986	701	329	306	691	476	440	249	372	449	157	19
853	454	111	358	384	955	139	848	296	168	401	170	418	910	251	503	707	981	666	531
601	112	840	530	207	231	940	429	546	2	821	763	643	337	885	847	371	767	67	519
530	323	319	236	749	734	768	286	392	531	93	356	730	825	504	651	253	253	42	233
82	820	771	223	22	58	777	978	914	171	723	297	527	530	66	234	311	116	876	6
955	205	545	984	756	858	518	727	431	420	518	472	62	540	584	465	498	856	590	0
588	782	740	986	251	501	896	335	470	513	431	445	862	796	649	490	633	866	635	250
254	715	789	614	324	877	81	924	683	516	462	755	911	733	677	703	955	928	83	239
720	333	904	631	52	517	738	418	632	894	909	897	899	979	672	528	209	369	70	160
34	116	612	424	96	419	771	624	927	238	672	924	441	686	130	592	692	749	606	527
92	174	446	280	984	660	130	240	318	133	103	607	611	779	94	283	797	247	687	736
242	339	234	399	639	132	62	105	921	796	257	543	172	629	157	700	171	564	24	679
254	611	219	320	821	425	549	447	863	391	267	587	513	372	605	452	705	433	515	442
603	629	653	911	598	118	505	888	210	604	858	428	379	322	699	728	173	516	947	625
85	536	280	35	641	459	648	398	157	300	921	125	77	640	463	540	414	691	254	766
399	550	537	475	559	611	813	383	24	811	347	865	950	632	176	998	562	457	994	835

396	149	78	674	907	393	819	557	734	585	223	189	472	782	108	962	916	397	572	710
331	114	638	311	384	641	830	207	1	703	797	388	455	845	897	357	631	368	58	56
489	927	32	697	330	33	519	936	580	928	478	757	400	22	294	945	510	292	295	950
210	769	483	461	744	453	157	940	511	716	479	847	179	492	855	267	782	148	361	96
432	528	272	946	639	679	125	342	394	823	553	828	763	206	498	989	808	991	249	437

TIME CONSUMED : 1010 MSEC

** SORTED ARRAY **

0	0	1	1	2	2	4	5	6	6	7	12	14	17	19	19	22	22	24	24
25	28	31	31	32	33	34	35	35	36	38	40	40	42	43	47	47	48	50	52
52	52	52	52	54	56	58	58	59	62	62	63	63	63	65	66	66	67	67	68
69	70	70	73	75	77	78	78	81	82	83	83	84	85	85	86	87	87	87	90
91	91	92	93	94	95	96	96	97	97	103	103	104	105	105	108	110	110	111	112
113	114	114	115	116	116	116	117	118	119	120	121	122	124	125	125	125	125	129	130
130	130	130	131	132	132	133	133	135	136	137	137	139	139	140	142	142	143	143	143
144	144	147	147	148	149	149	149	151	153	155	157	157	157	157	159	159	160	161	163
163	163	164	167	167	168	168	168	169	170	171	171	171	171	171	172	173	173	175	176
176	177	179	179	180	181	184	185	185	189	192	193	193	195	196	197	203	205	205	206
207	207	209	210	210	219	223	223	225	226	228	229	230	231	233	234	234	236	236	237
238	239	239	239	239	240	240	241	241	242	242	243	244	244	245	247	248	249	249	250
250	251	251	253	253	253	254	254	254	257	257	257	260	262	263	265	267	267	269	272
279	280	280	281	283	283	284	286	286	288	288	291	292	292	292	292	294	295	296	297
297	299	300	300	300	304	304	305	306	307	310	311	311	311	313	316	317	317	318	319
319	320	321	322	322	323	324	326	328	328	329	329	330	330	331	332	332	333	334	334
335	335	337	337	338	339	340	341	342	343	347	348	348	349	349	354	355	356	357	358
358	358	359	360	360	361	361	363	365	366	366	366	367	367	368	369	370	371	372	372
372	373	377	379	379	380	382	383	383	384	384	384	386	388	388	390	391	391	391	392
393	394	395	396	396	396	396	397	397	398	398	399	399	400	400	401	402	406	412	413
413	414	415	416	417	418	418	419	419	420	420	420	420	424	425	427	427	427	428	428
429	429	429	431	431	431	432	432	433	434	436	437	439	440	440	441	442	442	442	443
445	446	447	447	449	450	452	453	454	455	455	456	456	457	457	458	458	459	459	460
461	461	462	462	463	463	464	465	465	466	468	469	469	470	472	472	472	473	474	474
474	475	475	476	478	478	479	482	483	484	485	486	486	487	489	489	490	490	491	493
494	495	495	498	498	501	502	503	503	504	504	505	505	506	506	506	506	510	510	511
511	511	512	513	513	513	515	515	516	516	516	516	517	517	518	518	518	519	519	527
527	527	527	528	528	529	530	530	530	531	531	536	537	540	540	540	543	543	545	546
546	547	548	548	549	550	551	552	552	553	557	559	559	561	561	562	562	563	564	571
572	572	572	573	573	573	574	574	579	579	580	581	583	584	584	585	585	587	587	588
588	590	592	592	593	595	596	597	597	598	599	601	601	603	604	604	605	605	605	605
605	606	607	610	611	611	611	612	613	613	614	617	620	622	623	624	625	625	628	629
629	629	629	630	631	631	632	632	633	635	638	639	639	639	640	641	641	642	643	643
644	645	646	648	648	649	651	653	655	657	657	660	660	660	663	666	666	668	670	671
672	672	674	674	674	676	676	677	678	679	679	679	679	682	683	684	685	686	686	687
687	687	689	691	691	692	693	695	697	699	699	700	701	701	701	703	703	703	705	706
707	707	709	710	710	711	715	715	717	717	718	720	720	723	723	724	727	728	730	731
733	733	733	734	734	734	736	738	738	739	740	740	740	741	742	743	744	744	746	746
748	749	749	752	754	754	754	755	756	756	757	760	761	761	762	763	763	763	763	763
766	766	767	768	768	769	769	770	771	771	771	775	777	778	779	782	782	782	785	787
788	788	789	790	794	796	796	797	797	799	800	802	803	804	805	806	807	808	809	811

812	813	814	814	815	816	816	817	819	819	820	820	821	821	823	824	825	825	826	828
830	833	835	835	835	836	837	837	840	842	843	845	845	847	847	848	848	849	850	853
854	855	855	856	858	858	859	860	862	863	865	865	866	867	867	868	868	870	873	875
876	877	878	878	879	880	881	883	885	885	887	888	889	890	892	893	894	894	895	896
896	897	897	898	899	899	901	901	904	904	907	907	907	909	909	910	911	911	911	911
912	914	915	916	921	921	921	924	924	924	927	927	928	928	928	929	930	931	932	936
940	940	940	941	942	945	945	946	947	948	948	949	950	950	950	952	954	955	955	955
955	956	957	962	964	966	967	973	974	974	975	976	977	978	979	979	979	979	980	981
981	982	984	986	986	986	988	989	990	990	991	993	994	996	997	997	997	998	998	999

E.3.2 - CASE STUDY THREE: Quicksort (With Processor Dedication)

```
1       IF JM1 > LB THEN BEGIN
1                          LOCK(FORKLOCK);
1                          Q2ENTRY := Q2START ;
1                          FORK WITH TASKNAME(TU7) QUICKTWO(Q2ENTRY,X,LB,JM1);
1                          WAIT(FORKLOCK);
1                        END;
1       AWAIT(TU6,TU7);
1       LOCK(FINISH);
1       SIGNAL(FINISH);
1       QUIT;
1       END;
1     *COMPILE      OPTIONS=IRSLMVG,ELTNAME=TPF$,QUICK1
1       PROGRAM DEFINE(QUICKONE);
1       CONST  N=1000;
1       TYPE   Q1ENTRIES =( Q1INIT , Q1START );
1              Q2ENTRIES =( Q2INIT , Q2START );
1              ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
1       PROCEDURE QUICKONE(VAR ENTRY : Q1ENTRIES; VAR X:ARRAYTYPE; LOWER : INTEGER; UPPER : INTEGER);
1       TYPE    STACKITEM = RECORD
1                             LB   : INTEGER ;
1                             UB   : INTGER ;
1                           END;
1               STACK = RECORD
1                           TOP  : INTEGER ;
1                           ITEM : ARRAY [ 1 .. N ] OF STACKITEM ;
1                         END;
1       VAR    S        :  STACK     ;
1              NEWBNDS  :  STACKITEM ;
1              I,J,A    :  INTEGER   ;
1              UP,DOWN  :  INTEGER   ;
1              TEMP     :  INTEGER   ;
1        BEGIN
1         CASE ENTRY OF
1          Q1START:
1           BEGIN
1           LOCK(FORKLOCK);
1           SIGNAL(FORKLOCK);
1           DEDICATE PROCESSOR(0);
1           WITH  NEWBNDS
1            DO BEGIN
1                LB := LOWER;   UB := UPPER;
1                S.TOP := S.TOP +1;
1                S.ITEM[ S.TOP ].LB := LB;
1                S.ITEM[ S.TOP ].UB := UB;
1                WHILE NOT(S.TOP = 0)
1                  DO BEGIN
1                   LB := S.ITEM[ S.TOP ].LB;
1                  UB := S.ITEM[ S.TOP ].UB;
1                  S.TOP := S.TOP - 1;
1                  WHILE  UB > LB DO BEGIN
1                                    A := X [ LB ]; J:= LB; UP := UB; DOWN:= LB;
```

```
1         Q2ENTRIES =( Q2INIT , Q2START );
1         ARRAYTYPE = ARRAY [ 1 .. N ] OF INTEGER ;
1    PROCEDURE QUICKTWO(VAR ENTRY : Q2ENTRIES; VAR X:ARRAYTYPE; LOWER : INTEGER; UPPER : INTEGER);
1    TYPE   STACKITEM = RECORD
1                         LB   : INTEGER ;
1                         UB   : INTEGER ;
1                       END;
1           STACK = RECORD
1                         TOP  : INTEGER ;
1                         ITEM : ARRAY [ 1 .. N ] OF STACKITEM ;
1                       END;
1    VAR    S        :  STACK     ;
1           NEWBNDS  :  STACKITEM ;
1           I,J,A    :  INTEGER   ;
1           UP,DOWN  :  INTEGER   ;
1           TEMP     :  INTEGER   ;
1     BEGIN
1      CASE ENTRY OF
1       Q2START:
1        BEGIN
1        LOCK(FORKLOCK);
1        SIGNAL(FORKLOCK);
1        DEDICATE PROCESSOR(1);
1        WITH  NEWBNDS
1         DO BEGIN
1              LB := LOWER;   UB := UPPER;
1              S.TOP := S.TOP +1;
1              S.ITEM[ S.TOP ].LB := LB;
1              S.ITEM[ S.TOP ].UB := UB;
1              WHILE NOT(S.TOP = 0)
1                DO BEGIN
1                     LB := S.ITEM[ S.TOP ].LB;
1                   UB := S.ITEM[ S.TOP ].UB;
1                   S.TOP := S.TOP - 1;
1                   WHILE  UB > LB DO BEGIN
1                                     A := X [ LB ]; J:= LB; UP := UB; DOWN:= LB;
1                                     REPEAT
1                                     WHILE(UP > DOWN)AND(X [ UP ] >= A ) DO  UP:= UP-1;
1                                       J:= UP ;
1                                       IF UP <> DOWN THEN BEGIN
1                                                           TEMP     := X [ UP   ];
1                                                           X [ UP ] := X [ DOWN ];
1                                                           X [DOWN] := TEMP      ;
1                                                         END;
1                                                         WHILE(DOWN < UP) AND(X[DOWN]<=A)
1                                                              DO DOWN := DOWN +1;
1                                                         J := DOWN;
1                                                         IF DOWN<>UP THEN  BEGIN
1                                                                             TEMP     := X [ UP   ];
1                                                                             X [ UP ] := X [ DOWN ];
1                                                                             X [DOWN] := TEMP      ;
```

```
QUICK1                          $(1)     011715 012506      $(0)     040422 040423        27 JUL 83    08:39:01
DIVIDE2                         $(1)     012507 013115      $(0)     040424 040427        27 JUL 83    08:38:30
MAIN                            $(1)     013116 013565      $(0)     040430 040433        27 JUL 83    08:38:06
                                $(3)     013566 013611      $(036)   040434 140435

SYS$*RLIB$: LEVEL
END MAP,  ERRORS: 0  TIME: 14,313  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$,
@USE    PA$UD0000,INFO$,
@SETC,D
@XQT    TPF$,MAIN
```

```
  396  149   78  674  907  393  819  557  734  585  223  189  472  782  108  962  916  397  572  710
  331  114  638  311  384  641  830  207    1  703  797  388  455  845  897  357  631  368   58   56
  489  927   32  697  330   33  519  936  580  928  478  757  400   22  294  945  510  292  295  950
  218  769  483  461  744  453  157  940  511  718  479  847  179  482  855  267  782  148  361   96
  432  528  272  946  639  679  125  342  394  823  553  828  763  206  498  989  808  991  249  437
ER    TYPE 04 CODE 77 CONT 12      REENT ADR:  011152 BDI: 000004
 PACKET ADR 000001  ID: 000005
PROCESSOR REQUESTED ON ADED$ CALL WAS UNAVAILABLE AT THE
TIME OF THE ER ADED$ OR WAS DOWNED BY THE SYSTEM OPERATOR.
OCCURRED IN DIVIDETWO (LINE 1)
*** WALK-BACK FROM DIVIDETWO (LINE 1) ***
DYNAMIC LEVEL: 4, STATIC LEVEL: 2.
CALLED FROM QUICKTWO      (LINE  23667)
CALLED FROM QUICKONE      (LINE  21649)
CALLED FROM MAIN          (LINE  19631)
EXECUTION TERMINATED IN ERROR
```

** UNSORTED ARRAY (1000 ELEMENTS) **

674	137	901	506	283	761	416	940	896	976	311	875	367	723	967	842	993	460	703	475
835	338	788	825	743	503	814	956	746	197	193	901	36	25	881	516	889	977	262	754
436	511	486	335	328	245	388	766	885	485	474	129	462	63	269	31	313	678	717	563
366	137	117	110	890	617	459	288	144	292	837	286	679	396	1	343	70	979	899	52
440	377	465	676	240	601	687	597	328	574	402	527	506	391	47	31	243	456	979	434
427	592	807	104	572	945	511	604	996	693	0	167	91	330	63	400	894	469	548	125
756	870	909	695	12	579	163	131	142	820	559	849	998	463	203	775	288	642	130	43
579	299	241	512	685	143	803	740	406	761	97	84	161	292	115	7	171	337	75	684
420	469	836	455	748	941	171	613	975	892	181	551	110	593	979	175	230	974	114	40
763	895	69	571	461	361	478	241	464	63	573	529	450	396	720	952	949	265	724	431
505	768	948	733	447	14	121	679	646	87	73	297	710	366	442	52	671	140	790	770
316	670	370	812	887	574	142	573	4	623	489	291	225	763	420	666	769	386	879	733
516	605	153	912	494	495	179	120	657	990	929	307	845	334	860	740	427	711	804	826
195	907	458	250	706	543	47	639	321	674	515	982	835	257	973	443	622	180	988	239
883	317	605	660	613	244	865	332	552	997	931	253	439	458	738	116	493	689	490	911
168	731	95	754	760	130	50	349	605	643	66	495	163	319	113	474	373	355	383	168
281	854	17	171	28	819	304	193	859	456	366	457	942	48	239	816	358	419	546	746
709	185	848	348	413	742	83	990	824	133	340	136	921	686	581	429	391	484	741	35
547	517	2	717	595	506	867	119	363	176	19	151	707	932	762	382	395	625	226	787
358	310	341	185	814	629	911	155	833	648	5	192	527	715	184	349	144	122	955	548
915	59	177	239	628	585	974	54	471	52	90	540	809	629	417	78	91	304	816	504
292	957	163	964	744	815	907	980	429	806	279	676	322	86	620	588	506	173	143	442
360	904	805	763	205	599	778	135	420	561	379	413	87	260	149	147	867	248	125	950
855	103	169	510	800	380	597	428	132	799	166	999	868	605	837	561	518	242	562	986
754	236	701	348	668	354	513	788	40	868	502	68	147	948	257	244	228	924	752	397
802	396	930	300	660	873	734	384	412	843	583	326	87	893	657	52	365	739	167	928
630	699	159	359	97	415	229	6	898	305	878	284	67	468	65	794	997	474	878	771
997	701	85	655	196	584	644	300	139	367	143	360	981	602	427	817	317	466	573	610
263	472	663	785	486	850	687	552	491	966	237	105	572	880	487	38	398	587	329	645
332	390	334	372	159	432	596	149	986	701	329	306	691	476	440	249	372	449	157	19
853	454	111	358	384	955	139	848	296	168	401	170	418	910	251	503	707	981	666	531
601	112	840	530	207	231	940	429	546	2	821	763	643	337	885	847	371	767	67	519
530	323	319	236	749	734	768	286	392	531	93	356	730	825	504	651	253	253	42	233
82	820	771	223	22	58	777	978	914	171	723	297	527	530	66	234	311	116	876	6
955	205	545	984	756	858	518	727	431	420	518	472	62	540	584	465	498	856	590	0
588	782	740	986	251	501	896	335	470	513	431	445	862	796	649	490	633	866	635	250
254	715	789	614	324	877	81	924	683	516	462	755	911	733	677	703	955	928	83	239
720	333	904	631	52	517	738	418	632	894	909	897	899	979	672	528	209	369	70	160
34	116	612	424	96	419	771	624	927	238	672	924	441	686	130	592	692	749	606	527
92	174	446	280	954	660	130	240	918	133	103	607	611	779	94	283	797	247	687	716
242	339	234	399	639	132	62	105	921	796	257	543	172	629	157	700	171	564	24	679
254	611	219	320	821	425	549	447	863	391	267	587	513	372	605	452	705	433	515	442
603	629	653	911	598	118	505	888	210	604	858	428	379	322	699	728	173	516	947	625
85	536	280	35	641	459	648	398	157	300	921	125	77	640	463	540	414	691	254	766
399	550	537	475	559	611	813	383	24	811	347	865	950	632	176	998	562	457	994	835

TIME CONSUMED : 379 MSEC

** SORTED ARRAY **

417	137	249	506	283	489	416	206	553	184	341	392	367	125	639	272	528	460	432	475
84	338	161	148	267	503	482	198	479	167	193	511	36	25	157	516	453	481	262	483
436	511	486	335	328	245	388	218	295	485	474	129	462	63	269	31	313	292	510	563
366	137	117	110	294	617	459	288	144	292	22	286	400	396	1	343	70	478	580	52
440	377	469	619	240	601	33	597	128	574	402	527	506	391	47	31	243	456	330	434
427	592	32	104	572	489	511	604	56	58	0	167	91	330	63	400	368	469	548	125
631	357	455	388	12	579	163	131	142	1	559	207	641	463	203	384	288	642	130	43
579	299	241	512	311	143	638	114	406	331	97	84	161	292	115	7	171	337	75	572
420	469	397	455	108	472	171	613	189	223	181	551	110	593	585	175	230	557	114	40
393	674	69	571	461	361	478	241	464	63	573	529	450	396	78	149	396	265	457	431
505	562	176	632	447	14	121	347	646	87	73	297	24	366	442	52	671	140	383	611
316	670	370	559	475	574	142	573	4	623	489	291	225	537	420	666	550	386	399	254
516	605	153	414	494	495	179	120	657	540	463	307	640	334	77	125	427	300	157	398
195	648	458	250	459	543	47	639	321	674	515	641	35	257	280	443	622	180	536	239
85	317	605	660	613	244	625	332	552	516	173	253	439	458	322	116	493	379	490	428
168	604	95	210	505	130	50	349	605	643	66	495	163	319	113	474	373	355	383	168
281	118	17	171	28	598	304	193	653	456	366	457	629	48	239	603	358	419	546	442
515	185	433	348	413	452	83	605	372	133	340	136	513	587	581	429	391	484	267	35
547	517	2	391	595	506	447	119	363	176	19	151	549	425	320	382	395	625	226	219
358	310	341	185	611	629	254	155	24	648	5	192	527	564	184	349	144	122	171	548
157	59	177	239	628	585	629	54	473	52	90	540	172	629	417	78	91	304	543	504
292	257	163	105	62	132	639	399	429	234	279	339	322	86	620	588	506	173	143	442
360	242	247	283	205	599	94	135	420	561	379	413	87	260	149	147	611	248	125	607
103	103	169	510	133	380	597	428	132	318	166	240	130	605	660	561	518	242	562	280
446	236	124	348	668	354	513	92	40	527	502	68	147	606	257	244	228	592	130	397
441	396	672	300	660	238	624	384	412	419	583	326	87	96	657	52	365	424	167	612
630	116	159	359	97	415	229	6	34	305	160	284	67	468	65	70	369	474	209	528
672	632	85	655	196	584	644	300	139	367	143	360	418	517	427	52	317	466	573	610
263	472	663	631	486	333	239	552	491	83	237	105	572	462	487	38	398	587	329	645
332	390	334	372	159	432	596	149	546	81	329	306	324	476	440	249	372	449	157	19
614	454	111	358	384	254	139	250	296	168	401	170	418	635	251	503	633	490	666	531
601	112	649	530	207	231	445	429	546	2	431	513	643	337	470	335	371	501	67	519
530	323	319	236	251	588	0	286	392	531	93	356	590	498	504	651	253	253	42	293
82	465	584	223	22	58	540	62	472	171	518	297	527	530	66	234	311	116	420	6
431	205	545	518	674	676	676	677	678	679	679	679	679	682	683	684	685	686	686	687
687	687	689	691	691	692	693	695	697	699	699	700	701	701	701	703	703	703	705	706
707	707	709	710	710	711	715	715	717	717	718	720	720	723	723	724	727	728	730	731
733	733	733	734	734	734	736	738	738	739	740	740	740	741	742	743	744	744	746	746
748	749	749	752	754	754	754	755	756	756	757	760	761	761	762	763	763	763	763	763
766	766	767	768	768	769	769	770	771	771	771	775	777	778	779	782	782	782	785	787
788	788	789	790	794	796	796	797	797	799	800	802	803	804	805	806	807	808	809	811

812	813	814	814	815	816	816	817	819	819	820	820	821	821	823	824	825	825	826	828
830	833	835	835	835	836	837	837	840	842	843	845	845	847	847	848	848	849	850	853
854	855	855	856	858	858	859	860	862	863	865	865	866	867	867	868	868	870	873	875
876	877	878	878	879	880	881	883	885	885	887	888	889	890	892	893	894	894	895	896
896	897	897	898	899	899	901	901	904	904	907	907	907	909	909	910	911	911	911	911
912	914	915	916	921	921	921	924	924	924	927	927	928	928	928	929	930	931	932	936
940	940	940	941	942	945	945	946	947	948	948	949	950	950	950	952	954	955	955	955
955	956	957	962	964	966	967	973	974	974	975	976	977	978	979	979	979	979	980	981
981	982	984	986	986	986	988	989	990	990	991	993	994	996	997	997	997	998	998	999

E.4.1 - CASE STUDY FOUR: Gaussian Elimination (Without Processor Dedication)

```
@CPS.S,S    ,CPS,S/O,
MACRO INTEPPRETER LEVEL 7R1 07/28/83 11:13:09
    1   *COMPILE  OPTIONS=IRSLM,ELTNAME=TPF$.MAIN
    1       PPOGRAM MAIN;
    1       CONST  N=20; NP1=21;
    1       TYPE  ENTRIES =(ENTRY1,ENTRY2,INIT);
    1             ARRTYPE=ARRAY [1..N,1..NP1 ] OF REAL;
    1       PROCEDURE GAUSS(ENTRY : ENTRIES; VAR A : ARRTYPE); PROCESS;
    1       VAR  A          :   ARRTYPE ;
    1            I,J,K      :   INTEGER ;
    1            L,M,CP,Z   :   INTEGER ;
    1            ENTRY      :   ENTRIES ;
    1            GLOCK      :   QUEUE ;
    1            ACT1,ACT2  :   QUEUE ;
    1            WAITWD     :   QUEUE ;
    1            FINISH     :   QUEUE ;
    1            S          :   REAL  ;
    1            X          :   ARRAY [1..N] OF REAL ;
    1       BEGIN
    1          CREGION;
    1            READLN;
    1            WRITELN; WRITELN; WRITELN('           ** INPUT MATRIX ** ');
    1            WRITELN; WRITELN('      20 X 20 COEFFICIENTS AND RIGHT HAND SIDE');
    1            WRITELN; WRITELN;
    1          CEND;
    1          FOR I := 1 TO N
    1            DO BEGIN
    1                CREGION; WRITELN; WRITE('   '); CEND;
    1                FOR  J := 1 TO (N+1)
    1                   DO BEGIN
    1                        Z := 5 ;
    1                        IF J = (N+1) THEN   Z := 8 ;
    1                        CREGION;  READ(A[I,J]); WRITE(A[I,J]:Z:1); CEND;
    1                      END;
    1                END;
    1          CREGION; CP := CPTIME(3); CEND;
    1          LOCK(WAITWD);
    1          LOCK(FINISH);
    1          STARTUP WITH TASKNAME(G0) GAUSS (INIT,A FORWARD);
    1          LOCK(GLOCK);
    1          FORK WITH TASKNAME(G1) GAUSS(ENTRY1,A);
    1          WAIT(GLOCK);
    1          LOCK(GLOCK);
    1          FORK WITH TASKNAME(G2) GAUSS(ENTRY2,A);
    1          WAIT(GLOCK);
    1          WAIT(WAITWD);
    1          CREGION; CP := CPTIME(3)- CP; CEND;
    1          X[N] := A[N,N+1];
    1           FOR L := (N-1) DOWNTO  1
    1              DO BEGIN
    1                   S := 0;
```

```
1                FOR J:= (L+1) TO N
1                  DO BEGIN
1                       S := S + X[J] * A[L,J];
1                     END;
1               X[L] := A[L, N+1] - S;
1             END;
1        CREGION;
1          WRITELN; WRITELN('  TIME CONSUMED : ',CP,' MSEC');
1          WRITELN; WRITELN('  ** SOLUTION ** ');
1          WRITELN('---------------- '); WRITELN ;
1        CEND;
1        FOR I := 1 TO N
1          DO BEGIN CREGION;  WRITELN(X(I)); CEND; END;
1        LOCK(FINISH);
1        SIGNAL(FINISH);
1        QUIT;
1     END;
1  *COMPILE  OPTIONS=IRSLMV,ELTNAME=TPF$_GAUSS
1     PROGRAM  DEFINE(GAUSS);
1      CONST N=20;  NP1=21;
1      TYPE  ENTRIES = (ENTRY1,ENTRY2,INIT);
1            ARRTYPE = ARRAY [1..N, 1 ..NP1] OF REAL;
1      PROCEDURE GAUSS(ENTRY : ENTRIES; VAR A : ARRTYPE);
1      VAR  I,J,K,L,M :  INTEGER;
1           PERMISSION  :  BOOLEAN;
1           P,Q,R       :  REAL   ;
1      BEGIN  CASE ENTRY OF
1       ENTRY1:
1         BEGIN
1         LOCK(GLOCK);
1         SIGNAL(GLOCK);
1         FOR  I:= 1  TO N
1          DO BEGIN
1               P := A[I,I];
1               FOR  J := I TO (N+1)
1                 DO BEGIN
1                      A[I,J] := A[I,J]/ P ;
1                    END;
1               IF I = N THEN BEGIN
1                               LOCK(WAITWD);
1                               SIGNAL(WAITWD);
1                               QUIT;
1                             END;
1               LOCK(ACT2);
1               PERMISSION := TRUE ;
1               SIGNAL(ACT2);
1               K := I+1 ;
1               WHILE K  <= N
1                 DO BEGIN
1                      Q := A[K,I];
1                      FOR J:= I TO (N+1)
```

```
1                       DO BEGIN
1                            A[K,J] := A[K,J] = A[I,J]* Q ;
1                          END;
1                       K := K +2 ;
1                      END;
1                LOCK(ACT1);
1                IF PERMISSION THEN WAIT(ACT1)
1                             ELSE UNLOCK(ACT1);
1             END;
1          END;
1       ENTRY2:
1          BEGIN
1           LOCK(GLOCK);
1           SIGNAL(GLOCK);
1           WHILE TRUE
1              DO BEGIN
1                 LOCK(ACT2);
1                 IF NOT PERMISSION THEN WAIT(ACT2)
1                                   ELSE UNLOCK(ACT2);
1                 L := I+2 ;
1                 WHILE L <= N
1                   DO BEGIN
1                        R := A[L,I];
1                        FOR M:= I TO (N+1)
1                          DO BEGIN
1                               A[L,M] := A[L,M] = A[I,M]* R ;
1                             END;
1                        L := L+2 ;
1                       END;
1                 LOCK(ACT1);
1                 PERMISSION := FALSE;
1                 SIGNAL(ACT1);
1                 IF I >= (N-1)  THEN QUIT;
1              END;
1            END;
1           INIT:
1             BEGIN
1                PERMISSION :=  FALSE;
1                RELEASE(GAUSS);
1                WAIT(FINISH);
1                QUIT;
1             END;
1        END;
1       END;
@CPS$S,N   SCRATCH$,SCRATCH1,CPS$S/1,SCRATCH$,SCRATCH2
MACRO INTERPPETER LEVEL 7R1 07/28/83 11:14:57
@CPS$S,N   SCRATCH$,SCRATCH2,CPS$S/2,
MACRO INTERPPETER LEVEL 7R1 07/28/83 11:15:45
@CPS$X
@BU*PASCAL$S,IPSLM
PASCAL 8R1A PLIB  THURSDAY, 1983 JULY 28, 11:16:04
```

```
                          $(3)     003164 003221
P$LEVEL/PAS8P1            $(1)     003222 003235                                        23 OCT 78   11:52:20
P$NUM/PAS8R1              $(1)     003236 003411     $(2)     040067 040076             17 JUL 78   13:55:46
P$STDERR/PASRR1           $(1)     003412 003461                                        10 DEC 79   17:45:17
                          $(3)     003462 003515
P$TRACE/PAS8P1            $(1)     003516 003671                                        23 OCT 78   11:52:21
                          $(3)     003672 003724
P$WRITE/PAS8P1            $(1)     003725 005125     $(2)     040077 040212             11 DEC 79   16:52:28
                          $(3)     005126 005152
P$INTRPT/PASRR1           $(1)     005153 005742     $(2)     040213 040313             23 APR 82   10:37:37
                          $(3)     005743 006037
P$RS/PASRR1               $(1)     006040 007176     $(2)     040314 040417             23 JUL 80   13:49:59
                          $(3)     007177 007406
P$IO/PASRR1               $(1)     007407 010717                                        23 APR 82   10:40:32
                          $(3)     010720 011122
GAUSS                     $(1)     011123 011731     $(0)     040420 040420             28 JUL 83   11:17:29
MAIN                      $(1)     011732 012567     $(0)     040421 040424             28 JUL 83   11:17:01
                          $(3)     012570 012621     $(036)   040425 046425

SYS$*RLIB$ LEVEL
END MAP,  ERRORS: 0  TIME: 13.806  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$,
@USE    PA$UDDDUD,INFO$,
@SETC,D
@XQT    TPF$,MAIN
```

** INPUT MATRIX **

20 X 20 COEFFICIENTS AND RIGHT HAND SIDE

9.6	5.4	9.7	1.6	9.2	8.8	3.4	0.3	1.0	3.6	2.5	8.2	4.5	6.4	8.6	9.2	1.5	0.1	4.2	8.8	425.1
1.6	9.4	0.3	5.4	3.5	3.7	2.6	5.1	8.4	2.9	3.8	1.9	1.3	6.3	1.9	1.7	3.4	1.0	5.6	1.1	314.5
7.0	4.9	3.9	0.7	7.8	1.0	7.2	0.0	5.4	0.7	2.3	3.1	6.4	8.4	4.6	4.5	6.4	1.2	5.9	2.7	349.0
5.3	9.8	6.1	8.5	6.3	3.6	7.4	9.5	4.9	2.7	9.5	3.1	4.4	4.7	6.5	3.6	8.4	1.1	9.2	9.5	514.6
3.3	0.3	7.0	0.8	8.2	3.1	9.5	1.6	3.8	7.7	7.4	4.0	3.2	6.3	2.2	2.7	9.5	7.2	3.7	3.5	384.6
6.6	7.8	1.5	6.8	9.3	7.8	7.7	4.5	9.2	5.6	2.9	8.3	0.2	7.3	0.9	9.5	7.1	9.5	2.9	5.1	508.0
8.6	0.0	7.7	7.4	2.9	6.8	4.7	6.1	7.4	9.6	0.6	2.3	0.4	2.1	7.9	8.7	2.1	5.3	5.1	1.0	334.7
7.7	6.3	9.4	3.0	0.2	7.2	3.1	3.1	6.2	4.8	9.0	1.1	2.3	8.0	0.8	8.7	6.1	5.6	6.2	5.2	458.4
3.2	2.5	0.8	0.6	3.7	7.5	1.5	3.9	0.3	4.3	4.9	1.9	5.6	5.8	5.8	9.3	9.0	4.9	2.7	5.0	353.4
8.8	7.3	9.5	9.0	2.1	8.9	7.6	1.0	9.4	1.1	2.4	0.1	3.4	3.6	1.2	4.4	2.8	4.7	4.9	7.9	382.2
5.0	5.2	6.1	4.5	1.4	0.7	8.4	5.6	0.4	0.3	5.7	4.0	0.6	4.9	2.9	1.4	3.9	8.9	6.4	2.9	333.6
1.0	8.5	2.3	1.3	0.7	2.6	3.0	8.8	3.0	2.4	3.4	1.8	0.1	8.2	9.4	8.4	2.1	8.6	5.1	9.5	390.4
1.5	1.7	9.7	8.8	0.4	1.0	5.6	2.7	0.0	8.5	7.1	3.9	3.2	1.7	6.7	2.8	9.6	9.3	0.0	4.7	322.6
6.8	0.1	7.6	8.4	3.1	0.6	0.1	1.7	1.0	6.1	6.7	8.9	8.6	1.6	9.2	9.5	8.8	8.4	4.1	8.3	419.6
5.8	8.6	0.8	8.8	2.9	5.7	3.2	2.6	2.1	3.1	5.5	4.8	8.6	7.4	4.2	5.2	2.9	0.0	3.4	2.6	378.7
6.0	1.1	1.1	5.5	2.9	8.3	5.2	2.5	0.4	5.8	8.2	8.0	7.5	4.3	8.4	1.9	0.9	8.5	9.0	9.1	421.4
3.9	6.6	5.2	4.0	2.3	6.2	2.4	0.5	7.8	1.9	0.4	3.1	7.3	5.4	5.4	6.7	2.7	5.3	3.7	6.0	348.5
4.9	5.6	0.6	3.8	9.7	8.4	3.7	7.8	6.3	0.7	5.4	2.3	4.1	2.9	9.9	7.8	6.1	4.1	7.0	4.5	427.4
6.3	2.0	4.4	4.4	4.3	3.4	5.5	1.9	4.9	1.8	9.6	0.3	0.8	6.0	6.0	1.8	7.7	2.6	4.2	5.1	335.9

3.1 8.5 6.7 8.2 9.7 3.6 6.4 6.1 4.6 4.1 4.5 9.2 9.3 3.3 3.8 1.5 0.0 6.1 5.7 2.7 419.3
TIME CONSUMED : 451 MSEC

** SOLUTION **

1.748940
4.122662
2.388854
1.755760
2.180330
4.095750
4.803126
3.328051
4.114559
2.013716
7.999725
6.916009
3.315470
5.775178
1.406205
7.269488
3.910773
2.801161
5.863460
3.406344

E.4.2 - CASE STUDY FOUR: Gaussian Elimination (With Processor Dedication)

```
1                FOR J:= (L+1) TO N
1                  DO BEGIN
1                       S := S + X[J] * A[L,J];
1                     END;
1                XCL] := A[L, N+1] - S;
1              END;
1        CREGION;
1          WRITELN; WRITELN('  TIME CONSUMED : ',CP,' MSEC');
1          WRITELN; WRITELN('  ** SOLUTION ** ');
1          WRITELN('---------------- '); WRITELN ;
1        CEND;
1        FOR I := 1 TO N
1          DO BEGIN CREGION;  WRITELN(X(I)); CEND; END;
1        LOCK(FINISH);
1        SIGNAL(FINISH);
1        QUIT;
1      END;
1    *COMPILE  OPTIONS=IRSLMV,ELTNAME=TPFS,GAUSS
1      PPROGRAM  DEFINE(GAUSS);
1       CONST N=20;  NP1=21;
1       TYPE  ENTRIES = (ENTRY1,ENTRY2,INIT);
1             ARRTYPE = ARRAY [1..N, 1 ..NP1] OF REAL;
1       PROCEDURE GAUSS(ENTRY : ENTRIES; VAR A : ARRTYPE);
1       VAR  I,J,K,L,M :  INTEGER;
1            PERMISSION  :  BOOLEAN;
1            P,Q,R       :  REAL    ;
1       BEGIN  CASE ENTRY OF
1        ENTRY1:
1          BEGIN
1          LOCK(GLOCK);
1          SIGNAL(GLOCK);
1          DEDICATE PROCESSOR(0);
1          FOR  I:= 1  TO N
1           DO BEGIN
1                P := A[I,I];
1                FOR  J := I TO (N+1)
1                  DO BEGIN
1                       A[I,J] := A[I,J]/ P ;
1                     END;
1                IF I = N THEN BEGIN
1                                LOCK(WAITWD);
1                                SIGNAL(WAITWD);
1                                QUIT;
1                              END;
1                LOCK(ACT2);
1                PERMISSION := TRUE ;
1                SIGNAL(ACT2);
1                K := I+1 ;
1                WHILE K  <= N
1                  DO BEGIN
1                       Q := A[K,I];
```

```
1                       FOR J:= I TO (N+1)
1                         DO BEGIN
1                              A[K,J] := A[K,J] = A[I,J]* Q ;
1                            END;
1                       K := K +2 ;
1                      END;
1                LOCK(ACT1);
1                IF PERMISSION THEN WAIT(ACT1)
1                             ELSE UNLOCK(ACT1);
1             END;
1          END;
1       ENTRY2:
1          BEGIN
1           LOCK(GLOCK);
1           SIGNAL(GLOCK);
1           DEDICATE PROCESSOR(1);
1           WHILE TRUE
1              DO BEGIN
1                 LOCK(ACT2);
1                 IF NOT PERMISSION THEN WAIT(ACT2)
1                                   ELSE UNLOCK(ACT2);
1                 L := I+2 ;
1                 WHILE L <= N
1                   DO BEGIN
1                        R := A[L,I];
1                        FOR M:= I TO (N+1)
1                          DO BEGIN
1                               A[L,M] := A[L,M] = A[I,M]* R ;
1                            END;
1                        L := L+2 ;
1                       END;
1                 LOCK(ACT1);
1                 PERMISSION := FALSE;
1                 SIGNAL(ACT1);
1                 IF I >= (N-1)  THEN QUIT;
1              END;
1           END;
1           INIT:
1             BEGIN
1                PERMISSION :=  FALSE;
1                RELEASE(GAUSS);
1                WAIT(FINISH);
1                QUIT;
1             END;
1        END;
1       END;
@CPS$S,N    SCRATCH$,SCRATCH1,CPS$S/1,SCRATCH$,SCRATCH2
MACRO INTERPRETER LEVEL 7R1 07/28/83 11:19:33
@CPS$S,N    SCRATCH$,SCRATCH2,CPS$S/2,
MACRO INTERPRETER LEVEL 7R1 07/28/83 11:19:58
@CPS$X
```

```
P$RS/PAS8R1                 $(1)    006040 007176     $(2)    040314 040417        23 JUL 80   13:49:59
                            $(3)    007177 007406
P$IO/PAS8R1                 $(1)    007407 010717                                  23 APR 82   10:40:32
                            $(3)    010720 011122
GAUSS                       $(1)    011123 011741     $(0)    040420 040420        28 JUL 83   11:22:37
MAIN                        $(1)    011742 012577     $(0)    040421 040424        28 JUL 83   11:22:03
                            $(3)    012600 012631     $(036)  040425 040425
SYS$*RLIB$ LEVEL
END MAP, ERRORS: 0  TIME: 13.953  STORAGE: 17792/4/040777/073777
@USE    INFOTABLE,INFO$,
@USE    PAS000000,INFO$,
@SETC,D
@XQT   TPF$,MAIN


          ** INPUT MATRIX **

     20 X 20 COEFFICIENTS AND RIGHT HAND SIDE


     9.6  5.4  9.7  1.6  9.2  8.8  3.4  0.3  1.0  3.6  2.5  8.2  4.5  6.4  8.6  9.2  1.5  0.1  4.2  8.8  425.1
     1.6  9.4  0.3  5.4  3.5  3.7  2.6  5.1  8.4  2.9  3.8  1.9  1.3  6.3  1.9  1.7  3.4  1.0  5.6  1.1  314.5
     7.0  4.9  3.9  0.7  7.8  1.0  7.2  0.0  5.1  0.7  2.3  3.1  6.4  8.4  4.6  4.5  6.4  1.2  5.9  2.7  349.0
     5.3  9.8  6.1  8.5  6.3  3.6  7.4  9.5  4.9  2.7  9.6  3.1  4.4  4.7  6.5  1.6  8.4  1.1  9.2  9.5  514.6
     3.3  0.1  7.0  0.8  8.2  3.1  9.5  1.6  3.8  7.7  7.4  4.0  3.2  6.3  2.2  2.7  9.5  7.2  3.7  3.5  384.6
     6.6  7.8  1.5  6.8  9.3  7.8  7.7  4.5  9.2  5.6  2.9  8.3  0.2  7.3  0.9  9.5  7.1  9.5  2.9  5.1  508.0
     8.6  0.0  7.7  7.4  2.9  6.8  4.7  6.1  7.4  9.6  0.6  2.3  0.4  2.1  7.9  8.7  2.1  5.3  5.1  1.0  334.7
     7.7  6.3  9.4  3.0  0.2  7.2  3.1  3.1  6.2  4.8  9.0  1.1  2.3  8.0  0.8  8.7  6.1  5.6  6.2  5.2  458.4
     3.2  2.5  0.8  0.6  3.7  7.5  1.5  3.9  0.3  4.3  4.9  1.9  5.6  5.8  5.8  9.3  9.0  4.9  2.7  5.0  353.4
     8.8  7.3  9.5  9.0  2.1  8.9  7.6  1.0  9.4  1.1  2.4  0.1  3.4  3.6  1.2  4.4  2.8  4.7  4.9  7.9  382.2
     5.0  5.2  6.1  4.5  1.4  0.7  8.4  5.6  0.4  0.3  5.7  4.0  0.6  4.9  2.9  1.4  3.9  8.9  6.4  2.9  333.6
     1.0  8.5  2.3  1.3  0.7  2.6  3.0  8.8  3.0  2.4  3.4  1.8  0.1  8.2  9.4  8.4  2.1  8.6  5.1  9.5  390.4
     1.5  1.7  9.7  8.8  0.4  1.0  5.6  2.7  0.0  8.5  7.1  3.9  3.2  1.7  6.7  2.8  9.6  9.3  0.0  4.7  322.6
     6.8  0.1  7.6  8.4  3.1  0.6  0.1  1.7  1.0  6.1  6.7  8.9  8.6  1.6  9.2  9.5  8.8  8.4  4.1  8.3  419.6
     5.8  8.6  0.8  8.8  2.9  5.7  3.2  2.6  2.1  3.1  5.5  4.8  9.6  7.4  4.2  5.2  2.9  0.0  3.4  2.6  378.7
     6.0  1.1  1.1  5.5  2.9  8.3  5.2  2.5  0.4  5.8  8.2  8.0  7.5  4.3  8.4  1.9  0.9  8.5  9.0  9.1  421.4
     3.9  6.6  5.2  4.0  2.3  6.2  2.4  0.5  7.8  1.9  0.4  3.1  7.3  5.4  5.4  6.7  2.7  5.3  3.7  6.0  348.5
     4.9  5.6  0.6  3.8  9.7  8.4  3.7  7.8  6.3  0.7  5.4  2.3  4.1  2.9  9.9  7.8  6.1  4.1  7.0  4.5  427.4
     6.3  2.0  4.4  4.4  4.3  3.4  5.5  1.9  4.9  1.8  9.6  0.3  0.8  6.0  6.0  1.8  7.7  2.6  4.2  5.1  335.9
     3.1  8.5  6.7  8.2  9.7  3.6  6.4  6.1  4.6  4.1  4.5  8.2  9.3  3.3  3.8  1.5  0.0  6.1  5.7  2.7  419.3
 ER    TYPE 04 CODE 77 CONT 12       REENT ADR:  011513 BDI:  000004
  PACKET ADR 000001  ID: 00000003
PROCESSOR REQUESTED ON ADED$ CALL WAS UNAVAILABLE AT THE
TIME OF THE ER ADED$ OR WAS DOWNED BY THE SYSTEM OPERATOR.
OCCURRED IN GAUSS (LINE 1)
*** WALKBACK FROM GAUSS (LINE 1) ***
DYNAMIC LEVEL: 2, STATIC LEVEL: 2.
CALLED FROM MAIN          (LINE  19506)
EXECUTION TEPMINATED IN ERROR
AD AMBIGUITY ABORT ADR: 011472  BDI:000004
```

```
  ID: 000002
AWAITS = DACTS AMBIGUITY?

  X                 000000 000052  000001 000005  000001 060663  000000 007045  000000 064061  000000 000000  000001 000003
    000000 000156   000000 040425  000000 046062  000000 000002  000000 000026  000000 000024  463146 314632  201042 242631

  A 000000 000026   000000 000024  463146 314632  201042 242631  463146 314631  000000 001211  777777 777776  000000 000001
    000000 000071   000000 000054  000000 040470  000000 000040  000000 400352  000000 046426  000000 000001  000000 000025
    000000 000000   000000 000000

  R                 000000 000040  073423 120010  000004 121746  000000 066243  000000 000064  000000 040470  000000 000003
    000000 000000   000000 000000  000000 000000  000000 000000  000000 444444  000000 000002  050505 050505  000000 000134
            ABORT ADR: 012310  BDI:000004

  X                 000000 044264  000001 000005  000001 060663  000000 007045  000000 064061  000000 000000  000001 000003
    000000 000156   000000 040425  000000 040425  000000 012220  000000 046062  000000 000002  000000 046425  000000 000002

  A 000000 046062   000000 000002  000000 046425  000000 000002  000000 001211  000000 001211  777777 777776  000000 000001
    000000 000071   000000 000054  000000 040470  000000 000040  000000 400352  000000 046426  000000 000001  000000 001000
    000000 000000   000000 000000

  R                 000000 000040  073423 120010  000004 121746  000000 066243  000000 000064  000000 040470  000000 000003
    000000 000000   000000 000000  000000 000000  000000 000000  000000 444444  000000 000000  050505 050505  000000 046062
            ABORT ADR: 011727  BDI:000004
  ID: 000001

  X                 000000 000052  000001 000005  000001 060663  000000 007045  000000 064061  000000 000000  000001 000003
    000000 000156   000000 040425  000000 046062  000000 012220  000000 000002  000000 011132  000000 040425  000001 006430

  A 000000 000002   000000 011132  000000 040425  000001 006430  000000 005464  000000 000314  777777 777776  000000 000001
    000000 000071   000000 000054  000000 040470  000000 000040  000000 400352  000000 046426  000000 000001  000000 000000
    000000 000000   000000 000000

  R                 000000 000000  073423 120010  000004 121746  000000 066243  000000 000064  000000 040470  000000 000003
    000000 000000   000000 000000  000000 000000  000000 000000  000000 444444  000000 000001  050505 050505  000000 000254
```

E.5 - CASE STUDY FIVE: A Model Operating System

```
@FREE  TPF$.
@ASG,T   TPF$.,F///1500
@CPS.S,S     ,CPS.S/D,
MACRO INTERPRETER LEVEL 7R1 07/31/83 19:42:01
    1   *COMPILE     OPTIONS=IRSLMG,ELTNAME=TPF$.MAIN
    1     PROGRAM MAIN(INPUT,OUTPUT);
    1     TYPE    ARRTYP1 = ARRAY [ 0 .. 19 ] OF INTEGER ;
    1             ARRTYP2 = ARRAY [ 1 .. 20 ] OF INTEGER ;
    1             MOSENTRIES =(MOSINIT,CLOCKSTART,REGULARINT,IOINITIATE,IOTERMINATE);
    1             ARRGENTRIES =( ARRGINIT , ARRGLIST) ;
    1     PROCEDURE MOS(VAR MOSENTRY : MOSENTRIES);PROCESS;
    1     PROCEDURE ARRANGE(VAR ARRANGENTRY : ARRGENTRIES ; VAR LIST : ARRTYP1;
    1                       LISHEAD : INTEGER;LISTAIL : INTEGER ;VAR SORTKEY : ARRTYP2); PROCESS;
    1     VAR   MOSLOCK      :  QUEUE  ;
    1           CLOCKLOCK    :  QUEUE  ;
    1           ACTIVATOR    :  QUEUE  ;
    1           FINISH       :  QUEUE  ;
    1           ARRANGELOCK  :  QUEUE  ;
    1           ARRFLAG      :  QUEUE  ;
    1           CLOCKINTRPT  :  QUEUE  ;
    1           MASTERLOCK   :  IOINITIATION LOCK OF  QUEUE  ;
    1           TERMLOCK     :  IOTERMINATION LOCK OF QUEUE  ;
    1           STARTER      :  QUEUE  ;
    1           IOINIT       :  IOINITIATION FLAG OF  QUEUE  ;
    1           IOTERM       :  IOTERMINATION FLAG OF QUEUE  ;
    1           EMPTYRQ      :  QUEUE  ;
    1           I            :  INTEGER;
    1           MOSENTRY     :  MOSENTRIES;
    1           ARRANGENTRY  :  ARRGENTRIES ;
    1           DUMINT       :  INTEGER ;
    1           DUMARR1      :  ARRTYP1 ;
    1           DUMARR2      :  ARRTYP2 ;
    1         BEGIN
    1           I := 1;
    1           WHILE  I <= 18 DO BEGIN
    1                            STARTUP SLAVETASK(I);
    1                            I := I +1;
    1                          END;
    1
    1           ARRANGENTRY := ARRGINIT  ;
    1           STARTUP WITH TASKNAME('ADD')
    1              ARRANGE(ARRANGENTRY,DUMARR1 FORW,DUMINT FORW,DUMINT FORW,DUMARR2 FORW);
    1
    1           MOSENTRY := MOSINIT ;
    1           STARTUP WITH TASKNAME('TOD') MOS(MOSENTRY);
    1
    1
    1           LOCK(MOSLOCK);
    1           MOSENTRY := CLOCKSTART;
    1           FORK WITH TASKNAME('TO1') MOS(MOSENTRY);
    1           WAIT(MOSLOCK);
```

```
1
1         LOCK(MOSLOCK);
1         MOSENTRY := REGULARINT;
1         FORK WITH TASKNAME(TO2) MOS(MOSENTRY);
1         WAIT(MOSLOCK);
1
1         LOCK(MOSLOCK);
1         MOSENTRY := IOINITIATE;
1         FORK WITH TASKNAME(TO3) MOS(MOSENTRY);
1         WAIT(MOSLOCK);
1
1         LOCK(MOSLOCK);
1         MOSENTRY := IOTERMINATE;
1         FORK WITH TASKNAME(TO4) MOS(MOSENTRY);
1         WAIT(MOSLOCK);
1
1         LOCK(STARTER);
1         SIGNAL(STARTER);
1         LOCK(FINISH);
1         WAIT(FINISH);
1         QUIT;
1     END.
1   *COMPILE      OPTIONS=IPSLMVG,ELTNAME=TPFS.ARRANG
1     PROGRAM  DEFINE(ARRANGE);
1
1     TYPE    ARRTYP1 = ARRAY [ 0 .. 19 ] OF INTEGER ;
1             ARRTYP2 = ARRAY [ 1 .. 20 ] OF INTEGER ;
1             ARRGENTRIES =( ARRGINIT , ARRGLIST) ;
1     PROCEDURE ARRANGE(VAR ENTRY  : ARRGENTRIES ; VAR LIST : ARRTYP1;
1                       LISHEAD : INTEGER;LISTAIL : INTEGER :VAR SORTKEY : ARRTYP2);
1     VAR     I,J,K    : INTEGER ;
1             TEMP     : INTEGER ;
1     BEGIN
1        CASE ENTRY OF
1           ARRGLIST:
1            BEGIN
1              LOCK(ARRFLAG);
1              SIGNAL(ARRFLAG);
1              J := (LISTAIL+20 -1) MOD 20;
1              I := (LISTAIL+20 -2) MOD 20;
1              WHILE ( J <> LISHEAD )  AND
1                    ( SORTKEY[ LIST[ J ]] < SORTKEY [ LIST[ I]] )
1                  DO BEGIN
1                       TEMP := LIST[J] ; LIST[J] := LIST[I] ; LIST[I]:= TEMP ;
1                       I := ( I+20 -1) MOD 20 ;
1                       J := ( J+20 -1) MOD 20 ;
1                     END;
1             QUIT;
1            END;
1           ARRGINIT:
1            BEGIN
```

```
1              RELEASE(ARRANGE);
1              LOCK(FINISH);
1              WAIT(FINISH);
1            END;
1         END;
1      END;
1    *COMPILE     OPTIONS=IPSLMVG,ELTNAME=TPFS,MODELOS
1      PROGRAM DEFINE(MOS);
1      TYPE MOSENTRIES =(MOSINIT,CLOCKSTART,REGULARINT,IOINITIATE,IOTERMINATE);
1           ARRGENTRIES =( ARRGINIT , APRGLIST) ;
1           ARRTYP1 = ARRAY [ 0 .. 19 ] OF INTEGER ;
1           ARRTYP2 = ARRAY [ 1 .. 20 ] OF INTEGER ;
1      PROCEDURE MOS(VAR ENTRY : MOSENTRIES);
1      PROCEDURE ARRANGE(VAR ARRANGENTRY : ARRGENTRIES ; VAR LIST : ARRTYP1;
1                        LISHEAD : INTEGER;LISTAIL : INTEGER ;VAR SORTKEY : ARRTYP2); PROCESS;
1       TYPE  SYSTEMTABLE =  RECORD
1                              CCU  : INTEGER;
1                              CIOJ : INTEGER;
1                            END;
1       VAR  LASTINTRPT     : INTEGER ;
1            LASTSWAP       : INTEGER ;
1            CLOCK          : INTEGER ;
1            I,J,K,II       : INTEGER ;
1            RQHEAD,RQTAIL  : INTEGER ;
1            BQHEAD,BQTAIL  : INTEGER ;
1            DIOQHEAD       : INTEGER ;
1            DIOQTAIL       : INTEGER ;
1            MAXRQLEN       : INTEGER ;
1            RQLIST         : ARRTYP1 ;
1            RQWAIT         : ARRTYP2 ;
1            BQLIST         : ARRTYP1 ;
1            DIOQLIST       : ARRTYP1 ;
1            LRQ            : INTEGER ;
1            SHIFT          : INTEGER ;
1            MAXWAIT        : INTEGER ;
1            CONTROLTABLE   : SYSTEMTABLE;
1            TIME           : ARRAY [ 1..100 ] OF INTEGER;
1            CPUUSER        : ARRAY [ 1..100 ] OF INTEGER;
1            DIOJOB         : ARRAY [ 1..100 ] OF INTEGER;
1            MEMIDLE        : ARRAY [ 1..100 ] OF INTEGER;
1            READYQUE       : ARRAY [ 1..100,0..19 ] OF INTEGER;
1            BLOCKEDQUE     : ARRAY [ 1..100,0..19 ] OF INTEGER;
1            DIOQUE         : ARRAY [ 1..100,0..19 ] OF INTEGER;
1            PRIORITY       : ARRTYP2 ;
1            STARTTIME      : ARRAY [ 1..20 ] OF INTEGER;
1            MEMREQ         : ARRAY [ 1..20 ] OF INTEGER;
1            STATUS         : ARRAY [ 1..20 ] OF BOOLEAN  ;
1            MEMUNUSED      : INTEGER;
1            TIMEINCREMENT  : INTEGER;
1            TIMEDECREMENT  : INTEGER;
1            TEMP           : INTEGER;
```

```
1           MEMSWAPABLE    : INTEGER;
1           INFOTABLE      : TEXT    ;
1           ARRANGENTRY    : ARRGENTRIES ;
1           QUANTUM        : ARRTYP2     ;
1           QUANTMAX       : INTEGER     ;
1           CPUIDLE        : INTEGER     ;
1           CPUIDLECUM     : REAL        ;
1           MEMIDLECUM     : REAL        ;
1           MEMUTILIZE     : REAL        ;
1           CPUUTILIZE     : REAL        ;
1       BEGIN
1         CASE ENTRY OF
1           CLOCKSTART:
1              BEGIN
1                 LOCK(MOSLOCK);
1                 SIGNAL(MOSLOCK);
1                 WHILE TRUE DO BEGIN
1                                SUSPEND(50);
1                                LOCK(CLOCKLOCK);
1                                CLOCK := CLOCK + 50;
1                                UNLOCK(CLOCKLOCK);
1                                IF CLOCK >= 30000 THEN TERMINATE;
1                                LOCK(CLOCKINTRPT);
1                                SIGNAL(CLOCKINTRPT);
1                               END;
1              END;
1           REGULARINT:
1              BEGIN
1               LOCK(MOSLOCK);
1               SIGNAL(MOSLOCK);
1               WHILE TRUE
1                DO BEGIN
1                    LOCK(CLOCKINTRPT);
1                    WAIT(CLOCKINTRPT);
1                    IF( RQTAIL = RQHEAD ) AND
1                      ( CONTROLTABLE.CCU  = 0  )
1                      THEN BEGIN
1                             LOCK(EMPTYRQ);
1                             WAIT(EMPTYRQ);
1                            END;
1                    LOCK(MASTERLOCK);
1                    LOCK(CLOCKLOCK);
1                    IF ( RQHEAD <> RQTAIL )
1                       AND (MEMREQ[RQLIST[RQHEAD]] <= MEMSWAPABLE) AND((CLOCK-LASTSWAP) >=500)
1                      THEN BEGIN
1                             CREGION;
1                               WRITELN('                              SWAPPING  ');
1                             CEND;
1                             LASTSWAP := CLOCK;
1
1                             WHILE (RQTAIL <> RQHEAD) AND
```

```
1                (MEMREQ[BQLIST[BQHEAD]] >= MEMUNUSED)
1               DO BEGIN
1                     LRQ := ( 20+RQTAIL-RQHEAD ) MOD 20;
1                     MAXWAIT := RQWAIT[RQLIST[RQHEAD]]; J := RQHEAD;
1                     IF LRQ > 1
1                       THEN BEGIN
1                               FOR I:=1 TO (LRQ-1) DO
1                                       BEGIN;
1                                          K :=(RQHEAD+I) MOD 20;
1                                          IF MAXWAIT > RQWAIT[RQLIST[ K ]]
1                                            THEN BEGIN
1                                                 MAXWAIT := RQWAIT[RQLIST[ K ]];
1                                                 J := K;
1                                                 END;
1                                        END;
1                             END;
1                      MEMUNUSED:=MEMUNUSED+MEMREQ[RQLIST[J]];
1                      MEMSWAPABLE:=MEMSWAPABLE-MEMREQ[RQLIST[J]];
1                      BQLIST[ BQTAIL ]:= RQLIST[ J ];
1                      BQTAIL :=(BQTAIL+1) MOD 20;
1                      LOCK(ARRANGELOCK);
1                      LOCK(ARRFLAG);
1                      ARRANGENTRY := ARRGLIST ;
1                      FORK WITH TASKNAME(AD1) ARRANGE(ARRANGENTRY,BQLIST,BQHEAD,BQTAIL,QUANTUM);
1                      WAIT(ARRFLAG);
1                      AWAIT(AD1);
1                      UNLOCK(ARRANGELOCK);
1                      SHIFT :=(RQTAIL - J +19) MOD 20 ;
1                      IF SHIFT > 0
1                        THEN BEGIN
1                               FOR I:=1 TO SHIFT DO
1                                   BEGIN;
1                                      K := I+J-1;
1                                      RQLIST[K MOD 20]:=RQLIST[(K+1) MOD 20];
1                                    END;
1                               END;
1
1                      RQTAIL :=(RQTAIL+20-1) MOD 20;
1                     END;
1
1           WHILE (MEMREQ[BQLIST[BQHEAD]] <= MEMUNUSED)
1            AND (BQHEAD <> BQTAIL)
1            DO BEGIN
1                  RQLIST[RQTAIL] := BQLIST[BQHEAD];
1                  RQWAIT[RQLIST[RQTAIL]] := CLOCK;
1                  RQTAIL :=(RQTAIL+1) MOD 20;
1                  LOCK(ARRANGELOCK);
1                  LOCK(ARRFLAG);
1                  ARRANGENTRY := ARRGLIST ;
1                  FORK WITH TASKNAME(AD6) ARRANGE(ARRANGENTRY,RQLIST,RQHEAD,RQTAIL,QUANTUM);
1                  WAIT(ARRFLAG);
```

```
1                AWAIT(AQ6);
1                UNLOCK(ARRANGELOCK);
1                MEMUNUSED:=MEMUNUSED-MEMREQ[BQLIST[BQHEAD]];
1                MEMSWAPABLE:=MEMSWAPABLE+MEMREQ[BQLIST[BQHEAD]];
1                BQLIST[BQHEAD] := 0;
1                BQHEAD :=(BQHEAD+1) MOD 20;
1             END;
1          END;
1          IF ((CLOCK-TIMEDECREMENT)>= 50) OR(TIMEDECREMENT=0) THEN
1             BEGIN
1              TIMEDECREMENT := CLOCK;
1              WITH CONTROLTABLE
1                  DO BEGIN
1                      IF CCU <> 0  THEN QUANTUM[ CCU ] :=  QUANTUM[ CCU ] + 1 ;
1                      IF ( RQTAIL <> RQHEAD )
1                        THEN BEGIN
1                              IF( CCU <> 0 ) AND ((QUANTUM[ CCU ]  MOD QUANTMAX) = 0 )
1                                THEN BEGIN
1                                     DEACTIVATE SLAVETASK(CCU);
1                                     CREGION;
1                                       WRITELN('                                REGULAR INTRPT');
1                                     CEND;
1                                     FETCH STATUS OF SLAVETASKS;
1                                     IF STATUS[ CCU ]
1                                       THEN BEGIN
1                                              RQLIST[RQTAIL]:=CCU;
1                                              RQWAIT[RQLIST[RQTAIL]]:=CLOCK;
1                                              RQTAIL:=(RQTAIL+1) MOD 20;
1                                              LOCK(ARRANGELOCK);
1                                              ARRANGENTRY := ARRGLIST ;
1                                              LOCK(ARRFLAG);
1                                              FORK WITH TASKNAME(AQ2)
1                                                ARRANGE(ARRANGENTRY,RQLIST,RQHEAD,RQTAIL,QUANTUM);
1                                              WAIT(ARRFLAG);
1                                              AWAIT(AQ2);
1                                              UNLOCK(ARRANGELOCK);
1                                            END;
1                                     MEMSWAPABLE:=MEMSWAPABLE+MEMREQ[CCU];
1                                     CCU := 0 ;
1                                     IF RQTAIL =RQHEAD THEN CPUIDLE := CLOCK;
1                                    END;
1                             END;
1                      IF(RQTAIL <> RQHEAD) AND ( CCU = 0)
1                        THEN BEGIN
1                                CCU := RQLIST[RQHEAD];
1                                RQLIST[RQHEAD] := 0;
1                                RQHEAD :=(RQHEAD+1) MOD 20;
1                                MEMSWAPABLE:=MEMSWAPABLE-MEMREQ[CCU];
1                                ACTIVATE SLAVETASK(CCU);
1                              END;
1                    END;
```

```
1                               END;
1   /C
1   /C    **  DUMPING  SECTION  **
1   /C
1      II := II+1;
1      IF  II <= 100
1       THEN BEGIN
1              TIMEC II]:= CLOCK; CPUUSEREII]:= CONTROLTABLE.CCU;
1              DIOJOBEII]:= CONTROLTABLE.CIOJ;
1              FOR I:= 0 TO 19 DO BEGIN
1                                  READYQUEEII,I]:= RQLISTEI];
1                                  BLOCKEDQUEEII,I]:= BQLISTEI];
1                                  DIOQUEEII,I]:= DIOQLISTEI];
1                                  MEMIDLEEII]:= MEMUNUSED;
1                                 END;
1             IF II>1 THEN MEMIDLECUM := MEMIDLECUM+MEMUNUSED*(TIMEEII] TIMEEI-1]);
1            END
1       ELSE BEGIN
1              CPUIDLECUM := 0; MEMIDLECUM:= 0;
1              FOR II:= 1 TO 100 DO BEGIN
1                   CREGION;
1                     WRITELN;
1                     WRITELN(' CLOCK ',TIMEEII],' CCU ',CPUUSEREII],' DIOJ ',DIOJOBEII],' IDLE STORE ',MEMIDLEEII]);
1                     WRITELN; WRITE(' RQUEUE  ');
1                   CEND;
1                   FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(READYQUEEII,I]:3); CEND;  END;
1                   CREGION;  WRITELN;  WRITE(' BQUEUE  '); CEND;
1                   FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(BLOCKEDQUEEII,I]:3); CEND; END;
1                   CREGION; WRITELN; WRITE(' DIOQUE  '); CEND;
1                   FOR I :=0 TO 19 DO BEGIN  CPEGION; WRITE(DIOQUEEII,I]:3);CEND; END;
1                   CREGION; WRITELN; CEND;
1                 END;
1              II := 0;
1            END;
1   /C
1   /C    **  END OF DUMPING  SECTION  **
1   /C
1                  UNLOCK(CLOCKLOCK);
1                  UNLOCK(MASTERLOCK);
1                 END;
1            END;
1         IOINITIATE:
1            BEGIN
1              LOCK(MOSLOCK);
1              SIGNAL(MOSLOCK);
1              WHILE TRUE
1                DO BEGIN
1                   WAIT(IOINIT);
1                   LOCK(IOINIT);
1                   CREGION;
1                     WRITELN('                              I/O STARTED');
```

```
1                   CEND;
1                   LOCK(CLOCKLOCK);
1                   WITH CONTROLTABLE
1                     DO BEGIN
1                          DIOQLIST[DIOQTAIL] := CCU;
1                          DIOQTAIL :=(DIOQTAIL+1) MOD 20;
1                          IF RQHEAD <> RQTAIL
1                            THEN BEGIN
1                                  CCU := RQLIST[ RQHEAD ];
1                                  RQLIST[ RQHEAD ] := 0;
1                                  RQHEAD :=(RQHEAD+1) MOD 20;
1                                  ACTIVATE SLAVETASK(CCU);
1                                 END
1                            ELSE BEGIN
1                                    CCU := 0 ;
1                                    CPUIDLE := CLOCK ;
1                                 END;
1                          IF CIOJ = 0
1                           THEN BEGIN
1                                 CIOJ := DIOQLIST[DIOQHEAD];
1                                 DIOQLIST[DIOQHEAD] := 0;
1                                 DIOQHEAD := (DIOQHEAD +1) MOD 20;
1                                 ACTIVATE SLAVETASK(CIOJ);
1                                END;
1                        END;
1   /C
1   /C    **  DUMPING  SECTION  **
1   /C
1      II := II+1;
1      IF  II <= 100
1       THEN BEGIN
1              TIME[II]:= CLOCK; CPUUSER[II]:= CONTROLTABLE.CCU;
1              DIOJOB[II]:= CONTROLTABLE.CIOJ;
1              FOR I:= 0 TO 19 DO BEGIN
1                                  READYQUE[II,I]:= RQLIST[I];
1                                  BLOCKEDQUE[II,I]:= BQLIST[I];
1                                  DIOQUE[II,I]:= DIOQLIST[I];
1                                  MEMIDLE[II]:= MEMUNUSED;
1                                 END;
1              IF II>1 THEN MEMIDLECUM := MEMIDLECUM+MEMUNUSED*(TIME[II]-TIME[II-1]);
1            END
1       ELSE BEGIN
1               CPUIDLECUM := 0; MEMIDLECUM:= 0;
1               FOR II:= 1 TO 100 DO BEGIN
1                    CREGION;
1                      WRITELN;
1                      WRITELN(' CLOCK ',TIME[II],' CCU ',CPUUSER[II],' DIOJ ',DIOJOB[II],' IDLE STORE ',MEMIDLE[II]);
1                      WRITELN; WRITE(' RQUEUE  ');
1                    CEND;
1                    FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(READYQUE[I,II]:3); CEND;  END;
1                    CREGION;  WRITELN;  WRITE(' BQUEUE  '); CEND;
```

```
1                   FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(BLOCKEDQUE[II,I]:3); CEND; END;
1                   CREGION; WRITELN; WRITE(' DIOQUE  '); CEND;
1                   FOR I :=0 TO 19 DO BEGIN  CREGION; WRITE(DIOQUE[II,I]:3);CEND; END;
1                   CREGION; WRITELN; CEND;
1                 END;
1               II := 0;
1             END;
1   /C
1   /C    **  END OF DUMPING  SECTION  **
1   /C
1                 UNLOCK(CLOCKLOCK);
1                 UNLOCK(MASTERLOCK);
1                 END;
1           END;
1         IOTERMINATE:
1           BEGIN
1             LOCK(MOSLOCK);
1             SIGNAL(MOSLOCK);
1             WHILE TRUE
1               DO BEGIN
1                   WAIT(IOTERM);
1                   LOCK(IOTERM);
1                   CREGION;
1                     WRITELN('                              I/O FINISHED');
1                   CEND;
1                   LOCK(CLOCKLOCK);
1                   WITH CONTROLTABLE
1                     DO BEGIN
1                         LOCK(MASTERLOCK);
1                         RQLIST[RQTAIL] := CIOJ;
1                         RQWAIT[RQLIST[RQTAIL]]:=CLOCK;
1                         RQTAIL :=(RQTAIL +1) MOD 20;
1                         LOCK(ARRANGELOCK);
1                         ARRANGENTRY := ARRGLIST ;
1                         LOCK(ARRFLAG);
1                         FORK WITH TASKNAME(A03) ARRANGE(ARRANGENTRY,RQLIST,RQHEAD,RQTAIL,QUANTUM);
1                         WAIT(ARRFLAG);
1                         AWAIT(A03);
1                         UNLOCK(ARRANGELOCK);
1                         IF RQHEAD<>RQTAIL THEN BEGIN
1                                               LOCK(EMPTYRQ);
1                                               SIGNAL(EMPTYRQ);
1                                               CPUIDLECUM := CPUIDLECUM + (CLOCK - CPUIDLE );
1                                             END;
1                                             MEMSWAPABLE:=MEMSWAPABLE+MEMREQ[CIOJ];
1                         IF DIOQHEAD = DIOQTAIL THEN CIOJ := 0
1                                                ELSE BEGIN
1                                                       CIOJ := DIOQLIST[DIOQHEAD];
1                                                     DIOQLIST[DIOQHEAD] := 0;
1                                                       DIOQHEAD := (DIOQHEAD +1) MOD 20;
1                                                       ACTIVATE SLAVETASK(CIOJ);
```

```
1                                                                   END;
1   /C
1   /C    **  DUMPING  SECTION  **
1   /C
1      II := II+1;
1      IF  II <= 100
1       THEN BEGIN
1              TIMEC II]:= CLOCK; CPUUSERC II]:= CONTROLTABLE.CCU;
1              DIOJOBC II]:= CONTROLTABLE.CIOJ;
1              FOR I:= 0 TO 19 DO BEGIN
1                                  READYQUEC II,I]:= RQLISTC I];
1                                  BLOCKEDQUEC II,I]:= BQLISTC I];
1                                  DIOQUEC II,I]:= DIOQLISTC I];
1                                  MEMIDLEC II]:= MEMUNUSED;
1                                 END;
1              IF II>1 THEN MEMIDLECUM := MEMIDLECUM+MEMUNUSED*(TIMEC II]-TIMEC II-1]);
1            END
1       ELSE BEGIN
1              CPUIDLECUM := 0; MEMIDLECUM:= 0;
1              FOR II:= 1 TO 100 DO BEGIN
1                   CREGION;
1                     WRITELN;
1                     WRITELN(' CLOCK ',TIMEC II],' CCU ',CPUUSERC II],' DIOJ ',DIOJOBC II],' IDLE STORE ',MEMIDLEC II]);
1                     WRITELN; WRITE(' RQUEUE  ');
1                   CEND;
1                   FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(READYQUEC II,I]:3); CEND;  END;
1                   CREGION;  WRITELN;  WRITE(' BQUEUE  '); CEND;
1                   FOR I :=0 TO 19 DO BEGIN CREGION; WRITE(BLOCKEDQUEC II,I]:3); CEND; END;
1                   CREGION; WRITELN; WRITE(' DIOQUE  '); CEND;
1                   FOR I :=0 TO 19 DO BEGIN  CREGION; WRITE(DIOQUEC II,I]:3);CEND: END;
1                   CREGION; WRITELN; CEND;
1                 END;
1              II := 0;
1            END;
1   /C
1   /C    **  END OF DUMPING  SECTION  **
1   /C
1                        UNLOCK(CLOCKLOCK);
1                        UNLOCK(MASTEPLOCK);
1                        UNLOCK(TERMLOCK);
1                        END;
1          END;
1       END;
1      MOSINIT:
1         BEGIN
1          CONTROLTABLE.CCU  := 0;
1          CONTROLTABLE.CIOJ := 0;
1          LASTINTRPT        := 0;
1          LASTSWAP          := 0;
1          CLOCK             := 0;
1          RQHEAD            := 0;
```

```
1          RQTAIL              := 0;
1          DIOQHEAD            := 0;
1          DIOQTAIL            := 0;
1          BQHEAD              := 0;
1          BQTAIL              := 0;
1          MAXRQLEN            :=18;
1          II                  := 0;
1          MEMUNUSED           := 4000;
1          MEMSWAPABLE         := 0;
1          TIMEINCREMENT       := 0;
1          TIMEDECREMENT       := 0;
1          QUANTMAX            := 4;
1          CPUIDLECUM          := 0;
1          MEMIDLECUM          := 0;
1          LOCK(IOINTT);  LOCK(IOTERM);
1          I := 0;
1          WHILE I<= 19  DO  BEGIN
1                             RQLIST[ I ] := 0;
1                             BQLIST[ I ] := 0;
1                             RQWAIT[ I+1 ] := 0;
1                             DIOQLIST[ I ] := 0;
1                             PRIORITY[ I+1 ] := 0;
1                             STARTTIME[ I+1 ] := 0;
1                             QUANTUM[ I+1 ] := 0;
1                             I := I+1;
1                            END;
1         RESET(INFOTABLE);
1         READLN(INFOTABLE);
1         FOR I := 1 TO 18 DO BEGIN
1                               READ(INFOTABLE,MEMREQ[I],PRIORITY[I],STARTTIME[I]);
1                              END;
1       FOR I:= 1 TO 18
1          DO BEGIN
1              FOR J := (I+1) TO 18
1                 DO BEGIN
1                      IF  STARTTIME[ I ] > STARTTIME[ J ]
1                         THEN BEGIN
1                               TEMP := STARTTIME[J]; STARTTIME[J]:=STARTTIME[I]; STARTTIME[I]:=TEMP;
1                               TEMP := MEMREQ[J]; MEMREQ[J]:=MEMREQ[I]; MEMREQ[I]:=TEMP;
1                               TEMP := PRIORITY[J]; PRIORITY[J]:=PRIORITY[I]; PRIORITY[I]:=TEMP;
1                              END;
1                    END;
1             END;
1       I := 1;
1       WHILE  ( I <= MAXPQLEN ) AND
1         ( MEMUNUSED > MEMREQ[I] ) DO BEGIN
1                                      RQLIST[I-1]:= I;
1                                      RQWAIT[ I ]:= STARTTIME[ I ];
1                                      MEMUNUSED:=MEMUNUSED-MEMREQ[I];
1                                       MEMSWAPABLE:=MEMSWAPABLE+MEMREQ[I];
1                                      RQTAIL := RQTAIL+1;
```

```
1                                       I := I+1;
1                                       END;
1       K := 18-1;
1       FOR J:=0 TO K   DO BEGIN
1                           BOLIST[J]:=I;
1                           BOTAIL := BOTAIL +1;
1                           I := I+1;
1                          END;
1        LOCK(FINISH);
1        RELEASE(MOS);
1        LOCK(FINISH);
1        WAIT(FINISH);
1        QUIT;
1      END;
1    END;
1  END;
1  *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER1,USER=BIR,SIZE=330,PRIORITY=2,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C : REAL  ;
1       BEGIN
1          B:= 1;
1          WHILE  TRUE
1            DO BEGIN
1                FOR J :=1 TO 999999
1                  DO BEGIN
1                       A := B ; C:=5*1.23*14/(3.3*99.0/2.0) ;
1                       IF (J MOD 333)=0
1                         THEN BEGIN
1                                WRITELN(A,C);
1                              END;
1                       B := A;
1                     END;
1              END;
1
1       END.
1  *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER2,USER=IKI,SIZE=420,PRIORITY=1,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  : REAL ;
1       BEGIN
1          B:= 2;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                  DO BEGIN
1                       A := B ; C := 4.3*7.7*0.24/(12.3*14.8*1.2);
1                       B := A;
1                     END;
1              END;
1
1       END.
1  *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER3,USER=UC,SIZE=140,PRIORITY=5,STARTTIME=0000
```

```
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1       BEGIN
1          B:= 3;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO  BEGIN
1                         A := B ; C := 5.23*18.2*0.03/(3.8*8.8*0.44);
1                         IF (J MOD 444)=0
1                          THEN BEGIN
1                                 WRITELN(A,C);
1                               END;
1                         B := A;
1                       END;
1              END;
1
1       END.
1   *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER4,USER=DRT,SIZE=435,PRIORITY=3,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;   C  : REAL ;
1       BEGIN
1          B:= 4;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO  BEGIN
1                         A := B ; C := 6.4*8.1*0.005/(3.3*8.3*0.7);
1                         B := A;
1                       END;
1              END;
1
1       END.
1   *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER5,USER=BES,SIZE=200,PRIORITY=1,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1       BEGIN
1          B:= 5;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
1                         A := B ; C:= 0.44*1.5*9.99*9.2/(3.7*0.99);
1                         IF (J MOD 555)=0
1                          THEN BEGIN
1                                 WRITELN(A,C);
1                               END;
1                         B := A;
1                       END;
1              END;
1
```

```
1        END.
1    *COMPILE   OPTIONS=IPNLMV,FLTNAME=TPF$~USER6,USER=ALT,SIZE=290,PRIORITY=3,STARTTIME=0000
1        PROGRAM MAIN;
1        VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1        BEGIN
1           B:= 6;
1           WHILE  TRUE
1             DO BEGIN
1                  FOR J :=1 TO 999999
1                    DO BEGIN
1                         A := B ;  C:=0~91*3,5*9,4/(5~3*8~2*0~45);
1                         B := A;
1                       END;
1                END;
1
1        END.
1    *COMPILE   OPTIONS=IPNLMV,FLTNAME=TPF$~USER7,USER=YED,SIZE=400,PRIORITY=1,STARTTIME=0000
1        PROGRAM MAIN;
1        VAR  A,B,J  :  INTEGER ;   C  : REAL ;
1        BEGIN
1           B:= 7;
1           WHILE  TRUE
1             DO BEGIN
1                  FOR J :=1 TO 999999
1                    DO BEGIN
1                         A := B ; C:= 7~2*7~1*0~03/(5~3*9~9*0~02);
1                         IF (J MOD 400)=0
1                          THEN BEGIN
1                                 WRITELN(A,C);
1                               END;
1                         B := A;
1                       END;
1                END;
1
1        END.
1    *COMPILE   OPTIONS=IPNLMV,FLTNAME=TPF$~USER8,USER=SEK,SIZE=350,PRIORITY=4,STARTTIME=0000
1        PROGRAM MAIN;
1        VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1        BEGIN
1           B:= 8;
1           WHILE  TRUE
1             DO BEGIN
1                  FOR J :=1 TO 999999
1                    DO BEGIN
1                         A := B ; C := 7,1*0,92*0~65/(8~1*9~3*0~56);
1                         B := A;
1                       END;
1                END;
1
1        END.
1    *COMPILE   OPTIONS=IPNLMV,FLTNAME=TPF$~USER9,USER=DOK,SIZE=360,PRIORITY=3,STARTTIME=0000
```

```
1         PROGRAM MAIN;
1         VAR  A,B,J  :  INTEGER ;  C :  REAL ;
1         BEGIN
1            B:= 9;
1            WHILE  TRUE
1              DO BEGIN
1                  FOR J :=1 TO 999999
1                    DO  BEGIN
1                           A := B ; C:= 9.9*0.2*0.7/(0,67*0.89);
1                           B := A;
1                        END;
1                END;
1
1         END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER10,USER=ON,SIZE=220,PRIORITY=3,STARTTIME=0000
1         PROGRAM MAIN;
1         VAR  A,B,J  : INTEGER ; C  : REAL ;
1         BEGIN
1            B:= 10;
1            WHILE  TRUE
1              DO BEGIN
1                   FOR J :=1 TO 99999
1                     DO  BEGIN
1                           A := B ; C := 1,1*2,2*3,3/(6.4*0.7*8.1);
1                            B := A;
1                        END;
1                END;
1
1         END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER11,USER=ONB,SIZE=300,PRIORITY=2,STARTTIME=0000
1         PROGRAM MAIN;
1         VAR  A,B,J  : INTEGER ; C : REAL;
1         BEGIN
1            B:= 11;
1            WHILE  TRUE
1              DO BEGIN
1                   FOR J :=1 TO 999999
1                     DO  BEGIN
1                           A := B ; C := 8,1*8,8*0,5/(7.4*0.1*0.6);
1                           B := A;
1                        END;
1                END;
1
1         END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER12,USER=ONI,SIZE=270,PRIORITY=1,STARTTIME=0000
1         PROGRAM MAIN;
1         VAR  A,B,J  :  INTEGER ;  C : REAL ;
1         BEGIN
1            B:= 12;
1            WHILE  TRUE
1              DO BEGIN
```

```
1                  FOR J :=1 TO 999999
1                    DO BEGIN
1                         A := B ; C:= 7.3*9.3*0.04/(4.3*9.1*0.03);
1                         B := A;
1                       END;
1                END;
1
1       END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER13,USER=ONU,SIZE=420,PRIORITY=2,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1       BEGIN
1          B:= 13;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J :=1 TO 999999
1                   DO BEGIN
1                         A := B ; C := 4,1*0,044*9.1/(4.2*0.8*9.3);
1                         B := A;
1                       END;
1                END;
1
1       END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER14,USER=ONO,SIZE=300,PRIORITY=3,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C : REAL ;
1       BEGIN
1          B:= 14;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
1                         A := B ; C := 8,2*9,1*0,055/(4.3*0.94*0,56);
1                         IF (J MOD 500)=0
1                          THEN BEGIN
1                                 WRITELN(A,C);
1                               END;
1                         B := A;
1                       END;
1                END;
1
1       END.
1    *COMPILE   OPTIONS=IRNLMV,ELTNAME=TPF$.USER15,USER=OBS,SIZE=490,PRIORITY=2,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL;
1       BEGIN
1          B:= 15;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
```

```
1                       A := B ; C:= 0.45*0.91*8.34/(5.3*0.99);
1                       B := A;
1                     END;
1             END;
1
1       END.
1   *COMPILE   OPTIONS=IRNLMV,FLTNAME=TPF$.USER16,USER=ONA,SIZE=360,PRIORITY=2,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  : REAL ;
1       BEGIN
1          B:= 16;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
1                        A := B ; C := 9.2*0.06*0.45/(0.23*9.6);
1                        B := A;
1                     END;
1              END;
1
1       END.
1   *COMPILE   OPTIONS=IRNLMV,FLTNAME=TPF$.USER17,USER=ONY,SIZE=210,PRIORITY=5,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1       BEGIN
1          B:= 17;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
1                        A := B ; C := 0.05*8.4*0.76/(0.3*7.8*0.4);
1                        IF (J MOD 999)=0
1                         THEN BEGIN
1                                WRITELN(A,C);
1                              END;
1                        B := A;
1                     END;
1              END;
1
1       END.
1   *COMPILE   OPTIONS=IRNLMV,FLTNAME=TPF$.USER18,USER=ONS,SIZE=145,PRIORITY=1,STARTTIME=0000
1       PROGRAM MAIN;
1       VAR  A,B,J  :  INTEGER ;  C  :  REAL ;
1       BEGIN
1          B:= 18;
1          WHILE  TRUE
1            DO BEGIN
1                 FOR J := 1 TO 999999
1                   DO BEGIN
1                        A := B ; C:= 9.5*9.3*0.56/(5.5*0.3*0.7);
1                         B := A;
```

```
    1                       END;
    1                   END;
    1
    1           END.
@CPS.S,N    SCRATCH$,SCRATCH1,CPS.S/1,SCRATCH$,SCRATCH2
MACRO INTERPPETER LEVEL 7R1 07/31/83 19:51:27
@CPS.S,N    SCRATCH$,SCRATCH2,CPS.S/2,
MACRO INTERPRETER LEVEL 7R1 07/31/83 19:53:07
@CPS.X
@BU*PASCAL.S,IRSLMG
PASCAL 8R1A PLIB  SUNDAY, 1983 JULY 31, 19:57:27
                1


                2   PROGRAM MAIN(INPUT,OUTPUT);
                3   TYPE    ARRTYP1 = ARRAY [ 0 .. 19 ] OF INTEGER ;
                4           ARRTYP2 = ARRAY [ 1 .. 20 ] OF INTEGER ;
                5           MOSENTRIES =(MOSINIT,CLOCKSTART,REGULARINT,IOINITIATE,IOTERMINATE);
                6           ARRGENTRIES =( ARRGINIT , ARRGLIST) ;
                7   PROCEDURE MOS(VAR MOSENTRY : MOSENTRIES);EXTERNAL ;
                8   PROCEDURE ARRANGE(VAR ARRANGENTRY : ARRGENTRIES ; VAR LIST : ARRTYP1;
                9                     LISHEAD : INTEGER;LISTAIL : INTEGER ;VAR SORTKEY : ARRTYP2);E
               10     VAR GLOBALS : ARRAY (.1 .. 1880.) OF INTEGER ;
               11       ARRANGENTRY : ARRGENTRIES ;
               12       DUMARR1 : ARRTYP1 ;
               13       DUMARR2 : ARRTYP2 ;
               14       DUMINT : INTEGER ;
               15       I : INTEGER ;
               16       MOSENTRY : MOSENTRIES ;
               17 $CODE RSCELL*       T$CELL
               18 $CODE CBGNST*       T$CELL
               19 $CODE SYSTEMHOLD*   T$CELL
               20 $CODE ACTIVATOR*     T$CELL
               21 $CODE ARRANGELOCK*   T$CELL
               22 $CODE ARRFLAG*       T$CELL
               23 $CODE CLOCKINTRPT*   T$CELL
               24 $CODE CLOCKLOCK*     T$CELL
               25 $CODE EMPTYRQ*       T$CELL
               26 $CODE FINISH*        T$CELL
               27 $CODE IOINIT*        T$CELL
               28 $CODE IOTERM*        T$CELL
               29 $CODE MASTERLOCK*    T$CELL
               30 $CODE MOSLOCK*       T$CELL
               31 $CODE STARTER*       T$CELL
               32 $CODE TERMLOCK*      T$CELL
               33 $CODE T$ARRANGE*       T$CELL
               34 $CODE T$MAIN*          T$CELL
               35 $CODE T$MOS*           T$CELL
               36 $CODE XS$ARRANGE*       RES     1
               37 $CODE XS$MAIN*          RES     1
               38 $CODE XS$MOS*           RES     1
```

```
1                    0  135
1
1
1
2                    0    5
2                    0    4
2                    5    9
1                  136 2015
1                 2016 2016
1                 2017 2036
1                 2037 2056
1                 2057 2057
1                 2058 2058
1                 2059 2059
1          0    0
1          1    1
1          2    2
1          3    3
1          4    4
1          5    5
1          6    6
1          7    7
1          8    8
1          9    9
1         10   10
1         11   11
1         12   12
1         13   13
1         14   14
1         15   15
1         16   16
1         17   17
1         18   18
1         19   19
1         20   20
1         21   21
```

```
                    $(3)    012704 013106
USER18              $(1)    013107 013177   $(0)    040426 040427       31 JUL 83   20:10:12
                    $(3)    013200 013214
USER17              $(1)    013215 013344   $(0)    040430 040431       31 JUL 83   20:09:59
                    $(3)    013345 013361
USER16              $(1)    013362 013451   $(0)    040432 040433       31 JUL 83   20:09:43
                    $(3)    013452 013464
USER15              $(1)    013465 013554   $(0)    040434 040435       31 JUL 83   20:09:30
                    $(3)    013555 013567
USER14              $(1)    013570 013717   $(0)    040436 040437       31 JUL 83   20:09:18
                    $(3)    013720 013734
USER13              $(1)    013735 014025   $(0)    040440 040441       31 JUL 83   20:09:04
                    $(3)    014026 014042
USER12              $(1)    014043 014133   $(0)    040442 040443       31 JUL 83   20:08:49
                    $(3)    014134 014150
USER11              $(1)    014151 014241   $(0)    040444 040445       31 JUL 83   20:08:37
                    $(3)    014242 014256
USER10              $(1)    014257 014347   $(0)    040446 040447       31 JUL 83   20:08:25
                    $(3)    014350 014364
USER9               $(1)    014365 014454   $(0)    040450 040451       31 JUL 83   20:08:13
                    $(3)    014455 014467
USER8               $(1)    014470 014560   $(0)    040452 040453       31 JUL 83   20:08:01
                    $(3)    014561 014575
USER7               $(1)    014576 014725   $(0)    040454 040455       31 JUL 83   20:07:49
                    $(3)    014726 014742
USER6               $(1)    014743 015033   $(0)    040456 040457       31 JUL 83   20:07:36
                    $(3)    015034 015050
USER5               $(1)    015051 015200   $(0)    040460 040461       31 JUL 83   20:07:22
                    $(3)    015201 015215
USER4               $(1)    015216 015306   $(0)    040462 040463       31 JUL 83   20:07:09
                    $(3)    015307 015323
USER3               $(1)    015324 015453   $(0)    040464 040465       31 JUL 83   20:06:57
                    $(3)    015454 015470
USER2               $(1)    015471 015561   $(0)    040466 040467       31 JUL 83   20:06:42
                    $(3)    015562 015576
USER1               $(1)    015577 015732   $(0)    040470 040471       31 JUL 83   20:06:31
                    $(3)    015733 015745
MODELOS             $(1)    015746 024251   $(0)    040472 040503       31 JUL 83   20:06:18
                    $(3)    024252 024351
ARRANG              $(1)    024352 024567   $(0)    040504 040505       31 JUL 83   20:02:09
MAIN                $(1)    024570 025516   $(0)    040506 040536       31 JUL 83   20:01:54
                                            $(036)  040537 040541

SYS$*RLIB$: LEVEL
END MAP,  ERRORS: 0  TIME: 22,421  STORAGE: 18816/5/040777/075777
@USE    INFOTABLE,INFO$.
@USE    DA%000000,INFO$.
@SETC,D
@XQT   TPF$.MAIN
                    I/O STARTED
                    REGULAR INTRPT
                    I/O STARTED
```

```
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT
                    I/O STARTED
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT
                    REGULAR INTRPT
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT
                    I/O STARTED
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT
1       0.527089    I/O FINISHED
                    SWAPPING
                    REGULAR INTRPT
                    I/O STARTED
                    REGULAR INTRPT
3       0.194078    I/O FINISHED
                    I/O STARTED
7       1.461407    I/O FINISHED
                    SWAPPING
                    I/O STARTED
                    I/O STARTED
14      1.813149    I/O FINISHED
                    I/O STARTED
17      0.341026    I/O FINISHED
                    I/O STARTED
1       0.527089    I/O FINISHED
                    REGULAR INTRPT
3       0.194078    I/O FINISHED
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT
5      16.560000    I/O FINISHED
                    REGULAR INTRPT
7       1.461407    I/O FINISHED
                    REGULAR INTRPT
14      1.813149    I/O FINISHED
                    REGULAR INTRPT
                    SWAPPING
                    REGULAR INTRPT
                    REGULAR INTRPT

 CLOCK SP CCU 1 DIOJ 0 IDLE STORE 295

 ROJEUE    0  2  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
 BOJEUE   13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 DIOOUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 100 CCU 1 DIOJ 0 IDLE STOPL 295

RQJEUE     0  2  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 100 CCU 2 DIOJ 1 IDLE STOPL 295

RQJEUE     0  0  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 150 CCU 2 DIOJ 1 IDLE STORE 295

RQUEUE     0  0  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 200 CCU 2 DIOJ 1 IDLE STOPE 295

RQJEUE     0  0  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 250 CCU 2 DIOJ 1 IDLE STORE 295

RQJEUE     0  0  3  4  5  6  7  8  9 10 11 12  0  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 300 CCU 3 DIOJ 1 IDLE STORE 295

RQJEUE     0  0  0  4  5  6  7  8  9 10 11 12  2  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 350 CCU 3 DIOJ 1 IDLE STOPE 295

RQJEUE     0  0  0  4  5  6  7  8  9 10 11 12  2  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 350 CCU 4 DIOJ 1 IDLE STOPE 295

RQJEUE     0  0  0  0  5  6  7  8  9 10 11 12  2  0  0  0  0  0  0  0
BQJEUE    13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE     0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 400 CCU 4 DIOJ 1 IDLE STOPL 295
```

```
RQUEUE    0  0  0  0  5  6  7  8  9 10 11 12  2  0  0  0  0  0  0  0
BQUEUE   13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 450 CCU 4 DIOJ 1 IDLE STORE 295

RQUEUE    0  0  0  0  5  6  7  8  9 10 11 12  2  0  0  0  0  0  0  0
BQUEUE   13 14 15 16 17 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 500 CCU 4 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  6  7  8  9 10 11 12 13  2  0  0  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 550 CCU 6 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  7  8  9 10 11 12 13  2  4  0  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 600 CCU 6 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  7  8  9 10 11 12 13  2  4  0  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 650 CCU 6 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  7  8  9 10 11 12 13  2  4  0  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 700 CCU 6 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  7  8  9 10 11 12 13  2  4  0  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 750 CCU 7 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  0  8  9 10 11 12 13  2  4  6  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 800 CCU 7 DIOJ 1 IDLE STORE 75

RQUEUE    0  0  0  0  0  0  8  9 10 11 12 13  2  4  6  0  0  0  0  0
BQUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 800 CCU 8 DIOJ 1 IDLE STORE 75

ROUEUE    0  0  0  0  0  0  0  9 10 11 12 13  2  4  6  0  0  0  0  0
BOUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 850 CCU 8 DIOJ 1 IDLE STORE 75

ROUEUE    0  0  0  0  0  0  0  9 10 11 12 13  2  4  6  0  0  0  0  0
BOUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 900 CCU 8 DIOJ 1 IDLE STORE 75

ROUEUE    0  0  0  0  0  0  0  9 10 11 12 13  2  4  6  0  0  0  0  0
BOUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 950 CCU 8 DIOJ 1 IDLE STORE 75

ROUEUE    0  0  0  0  0  0  0  9 10 11 12 13  2  4  6  0  0  0  0  0
BOUEUE    0 14 15 16 17 18  5  0  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1000 CCU 10 DIOJ 1 IDLE STORE 135

ROUEUE    0  0  0  0  0  0  0  0 11 12 13 14  2  4  6  8  0  0  0  0
BOUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1050 CCU 10 DIOJ 1 IDLE STORE 135

ROUEUE    0  0  0  0  0  0  0  0 11 12 13 14  2  4  6  8  0  0  0  0
BOUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1100 CCU 10 DIOJ 1 IDLE STORE 135

ROUEUE    0  0  0  0  0  0  0  0 11 12 13 14  2  4  6  8  0  0  0  0
BOUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1150 CCU 10 DIOJ 1 IDLE STORE 135

ROUEUE    0  0  0  0  0  0  0  0 11 12 13 14  2  4  6  8  0  0  0  0
BOUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1200 CCU 11 DIOJ 1 IDLE STORE 135
```

```
RQUEUE    0  0  0  0  0  0  0  0  0 12 13 14  2  4  6  8 10  0  0  0
BQUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1300 CCU 11 DIOJ 1 IDLE STORE 135

RQUEUE    0  0  0  0  0  0  0  0  0 12 13 14  2  4  6  8 10  0  0  0
BQUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1350 CCU 11 DIOJ 1 IDLE STORE 135

RQUEUE    0  0  0  0  0  0  0  0  0 12 13 14  2  4  6  8 10  0  0  0
BQUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1400 CCU 11 DIOJ 1 IDLE STORE 135

RQUEUE    0  0  0  0  0  0  0  0  0 12 13 14  2  4  6  8 10  0  0  0
BQUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1450 CCU 12 DIOJ 1 IDLE STORE 135

RQUEUE    0  0  0  0  0  0  0  0  0  0 13 14  2  4  6  8 10 11  0  0
BQUEUE    0  0 15 16 17 18  5  9  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1500 CCU 12 DIOJ 1 IDLE STORE 65

RQUEUE    0  0  0  0  0  0  0  0  0  0  0 13 14 15  4  6  8 10 11  0  0
BQUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1550 CCU 12 DIOJ 1 IDLE STORE 65

RQUEUE    0  0  0  0  0  0  0  0  0  0 13 14 15  4  6  8 10 11  0  0
BQUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1600 CCU 12 DIOJ 1 IDLE STORE 65

RQUEUE    0  0  0  0  0  0  0  0  0  0 13 14 15  4  6  8 10 11  0  0
BQUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1650 CCU 13 DIOJ 1 IDLE STORE 65

RQUEUE    0  0  0  0  0  0  0  0  0  0  0 14 15  4  6  8 10 11 12  0
BQUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 1700 CCU 13 DIOJ 1 IDLE STORE 65

ROJEUE    0  0  0  0  0  0  0  0  0  0  0 14 15  4  6  8 10 11 12  0
BOJEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1750 CCU 13 DIOJ 1 IDLE STORE 65

ROUEUE    0  0  0  0  0  0  0  0  0  0  0 14 15  4  6  8 10 11 12  0
BOUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1800 CCU 13 DIOJ 1 IDLE STORE 65

ROJEUE    0  0  0  0  0  0  0  0  0  0  0 14 15  4  6  8 10 11 12  0
BOUEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1850 CCU 14 DIOJ 1 IDLE STORE 65

ROJEUE    0  0  0  0  0  0  0  0  0  0  0  0 15  4  6  8 10 11 12 13
BOJEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1900 CCU 14 DIOJ 1 IDLE STORE 65

ROJEUE    0  0  0  0  0  0  0  0  0  0  0  0 15  4  6  8 10 11 12 13
BOJEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1900 CCU 15 DIOJ 1 IDLE STORE 65

ROJEUE    0  0  0  0  0  0  0  0  0  0  0  0  0  4  6  8 10 11 12 13
BOJEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 1950 CCU 15 DIOJ 1 IDLE STORE 65

ROUEUE    0  0  0  0  0  0  0  0  0  0  0  0  0  4  6  8 10 11 12 13
BOJEUE    0  0  0 16 17 18  5  9  2  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2000 CCU 15 DIOJ 1 IDLE STORE 140

ROJEUE    0  0  0  0  0  0  0  0  0  0  0  0  0 16  6  8 10 11 12 13
BOUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2050 CCU 15 DIOJ 1 IDLE STORE 140
```

```
ROUEUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0 16  6  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2100 CCU 16 DIOJ 1 IDLE STORE 140

RQUEUE   15  0  0  0  0  0  0  0  0  0  0  0  0  0  6  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2150 CCU 16 DIOJ 1 IDLE STORE 140

RQUEUE   15  0  0  0  0  0  0  0  0  0  0  0  0  0  6  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2200 CCU 16 DIOJ 1 IDLE STORE 140

RQUEUE   15  0  0  0  0  0  0  0  0  0  0  0  0  0  6  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2250 CCU 16 DIOJ 1 IDLE STORE 140

RQUEUE   15  0  0  0  0  0  0  0  0  0  0  0  0  0  6  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2300 CCU 6 DIOJ 1 IDLE STORE 140

RQUEUE   15 16  0  0  0  0  0  0  0  0  0  0  0  0  8 10 11 12 13
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0
DIOQUE    0  3  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2300 CCU 6 DIOJ 3 IDLE STORE 140

RQUEUE   13 15 16  0  0  0  0  0  0  0  0  0  0  0  1  8 10 11 12
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2350 CCU 6 DIOJ 3 IDLE STORE 140

RQUEUE   13 15 16  0  0  0  0  0  0  0  0  0  0  0  1  8 10 11 12
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2400 CCU 6 DIOJ 3 IDLE STORE 140

RQUEUE   13 15 16  0  0  0  0  0  0  0  0  0  0  0  1  8 10 11 12
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 2450 CCU 6 DIOJ 3 IDLE STORE 140

RQUEUE   13 15 16  0  0  0  0  0  0  0  0  0  0  0  0  1  8 10 11 12
BQUEUE    0  0  0  0 17 18  5  9  2  4  0  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2500 CCU 17 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0 18  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2400 CCU 17 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0 18  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2650 CCU 17 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0 18  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2650 CCU 18 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0  0  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2700 CCU 18 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0  0  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2750 CCU 18 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0  0  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2800 CCU 18 DIOJ 3 IDLE STORE 135

RQUEUE   12 13 15 16  6  0  0  0  0  0  0  0  0  0  0  0  0  1 10 11
BQUEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2850 CCU 1 DIOJ 3 IDLE STORE 135
```

```
ROJEUE   12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  0 10 11
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  7 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2850 CCU 1 DIOJ 7 IDLE STORE 135

ROJEUE   11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  3 10
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  0 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2900 CCU 1 DIOJ 7 IDLE STORE 135

ROJEUE   11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  3 10
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  0 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2950 CCU 1 DIOJ 7 IDLE STORE 135

ROJEUE   11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  3 10
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  0 14 17  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2950 CCU 3 DIOJ 7 IDLE STORE 135

ROJEUE   11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  3 10
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  0 14 17  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 2950 CCU 3 DIOJ 14 IDLE STORE 136

ROJEUE   10 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  7
BOJEUE    0  0  0  0  0  0  5  9  2  4  8  0  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3000 CCU 3 DIOJ 14 IDLE STORE 155

ROJEUE    7 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  5
BOJEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3050 CCU 3 DIOJ 14 IDLE STORE 155

ROJEUE    7 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  5
BOJEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3050 CCU 5 DIOJ 14 IDLE STORE 155

ROJEUE    7 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  0
BOJEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  3  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 3100 CCU 5 DIOJ 14 IDLE STORE 155

ROUEUE    7 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  3  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3150 CCU 5 DIOJ 14 IDLE STORE 155

ROUEUE    7 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  3  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3150 CCU 7 DIOJ 14 IDLE STORE 155

ROUEUE    0 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0 17  1  3  5  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3150 CCU 7 DIOJ 17 IDLE STORE 155

ROUEUE    0 14 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  1  3  5  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3200 CCU 7 DIOJ 17 IDLE STORE 155

ROUEUE    0 14 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  1  3  5  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3250 CCU 7 DIOJ 17 IDLE STORE 155

ROUEUE    0 14 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  1  3  5  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3250 CCU 14 DIOJ 17 IDLE STORE 155

ROUEUE    0  0 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  1  3  5  7  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3250 CCU 14 DIOJ 1 IDLE STORE 155

ROUEUE    0  0 17 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  3  5  7  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3300 CCU 14 DIOJ 1 IDLE STORE 155
```

```
ROUEUE    0  0 17 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  3  5  7  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3350 CCU 14 DIOJ 1 IDLE STORE 155

ROUEUE    0  0 17 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  3  5  7  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3350 CCU 17 DIOJ 1 IDLE STORE 155

ROUEUE    0  0  0 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  3  5  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3350 CCU 17 DIOJ 3 IDLE STORE 155

ROUEUE    0  0  0  1 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  5  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3400 CCU 17 DIOJ 3 IDLE STORE 155

ROUEUE    0  0  0  1 11 12 13 15 16 18  6  0  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  5  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3450 CCU 1 DIOJ 3 IDLE STORE 155

ROUEUE    0  0  0  0 11 12 13 15 16 18 17  6  0  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  5  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3450 CCU 1 DIOJ 5 IDLE STORE 155

ROUEUE    0  0  0  0  3 11 12 13 15 16 18 17  6  0  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  9  2  4  8 10  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3500 CCU 9 DIOJ 5 IDLE STORE 95

ROUEUE    0  0  0  0  0  3 12 13 15 16 18 17  1  6  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3600 CCU 9 DIOJ 5 IDLE STORE 95

ROUEUE    0  0  0  0  0  3 12 13 15 16 18 17  1  6  0  0  0  0  0  0
BOUEUE    0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0
```

```
CLOCK 3650 CCU 9 DIOJ 5 IDLE STORE 95

RQUEUE   0  0  0  0  0  3 12 13 15 16 18 17  1  6  0  0  0  0  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3700 CCU 9 DIOJ 5 IDLE STORE 95

RQUEUE   0  0  0  0  0  3 12 13 15 16 18 17  1  6  0  0  0  0  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3750 CCU 3 DIOJ 5 IDLE STORE 95

RQUEUE   0  0  0  0  0  0 12 13 15 16 18 17  1  9  6  0  0  0  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  7 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3750 CCU 3 DIOJ 7 IDLE STORE 95

RQUEUE   0  0  0  0  0  0  5 12 13 15 16 18 17  1  9  6  0  0  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  0 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3800 CCU 5 DIOJ 7 IDLE STORE 95

RQUEUE   0  0  0  0  0  0  0 12 13 15 16 18 17  1  9  3  6  0  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  0 14  0  0  0  0  0  0  0  0  0  0

CLOCK 3800 CCU 5 DIOJ 14 IDLE STORE 95

RQUEUE   0  0  0  0  0  0  0  7 12 13 15 16 18 17  1  9  3  6  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3850 CCU 5 DIOJ 14 IDLE STORE 95

RQUEUE   0  0  0  0  0  0  0  7 12 13 15 16 18 17  1  9  3  6  0  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3900 CCU 7 DIOJ 14 IDLE STORE 95

RQUEUE   0  0  0  0  0  0  0  0 12 13 15 16 18 17  1  9  3  5  6  0
BQUEUE   0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3900 CCU 7 DIOJ 0 IDLE STORE 95
```

```
RQUEUE    0  0  0  0  0  0  0  0 14 12 13 15 16 18 17  1  9  3  5  6
BQUEUE    0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 3950 CCU 14 DIOJ 0 IDLE STORE 95

RQUEUE    6  0  0  0  0  0  0  0  0  0 12 13 15 16 18 17  1  9  3  5  7
BQUEUE    0  0  0  0  0  0  0  0  2  4  8 10 11  0  0  0  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 4000 CCU 15 DIOJ 0 IDLE STORE 365

RQUEUE    6  0  0  0  0  0  0  0  0  0 16 18 17  1  9  3  5  7  2 14
BQUEUE    0  0  0  0  0  0  0  0  0  4  8 10 11 12 13  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 4100 CCU 15 DIOJ 0 IDLE STORE 365

RQUEUE    6  0  0  0  0  0  0  0  0  0 16 18 17  1  9  3  5  7  2 14
BQUEUE    0  0  0  0  0  0  0  0  0  4  8 10 11 12 13  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 4150 CCU 15 DIOJ 0 IDLE STORE 365

RQUEUE    6  0  0  0  0  0  0  0  0  0 16 18 17  1  9  3  5  7  2 14
BQUEUE    0  0  0  0  0  0  0  0  0  4  8 10 11 12 13  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

CLOCK 4200 CCU 15 DIOJ 0 IDLE STORE 365

RQUEUE    6  0  0  0  0  0  0  0  0  0 16 18 17  1  9  3  5  7  2 14
BQUEUE    0  0  0  0  0  0  0  0  0  4  8 10 11 12 13  0  0  0  0  0
DIOQUE    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                        SWAPPING
                        SWAPPING
                        SWAPPING
                        SWAPPING
                        REGULAR INTRPT
                        I/O STARTED
3       0.194078        I/O FINISHED
                        I/O STARTED
5      16.560000        I/O FINISHED
                        I/O STARTED
7       1.461407        I/O FINISHED
                        SWAPPING
                        SWAPPING
                        SWAPPING
                        REGULAR INTRPT
                        SWAPPING
                        SWAPPING
                        SWAPPING
```

```
                    SWAPPING
                    REGULAR INTRPT
                    SWAPPING
                    SWAPPING
                    SWAPPING
                    SWAPPING
                    REGULAR INTRPT
                    SWAPPING
                    SWAPPING
                    SWAPPING
                    SWAPPING
                    REGULAR INTRPT
                    SWAPPING
                    SWAPPING
                    SWAPPING
ER ABORT$    ABORT ADR: 016017  BDI:000004
  ID: 000003
ER ABORT$    ABORT ADR: 024557  BDI:000004
  ID: 000001
ER ABORT$    ABORT ADR: 025512  BDI:000004
ER ABORT$    ABORT ADR: 022054  BDI:000004
  ID: 000006
ER ABORT$    ABORT ADR: 020620  BDI:000004
  ID: 000005
ER ABORT$    ABORT ADR: 024232  BDI:000004
  ID: 000002
ER ABORT$    ABORT ADR: 014222  BDI:000004
  NAME 242307
ER ABORT$    ABORT ADR: 020602  BDI:000004
  ID: 000004
ER ABORT$    ABORT ADR: 025052  BDI:000004
  NAME 242330
ER ABORT$    ABORT ADR: 025040  BDI:000004
  NAME 242336
ER ABORT$    ABORT ADR: 025026  BDI:000004
  NAME 242306
ER ABORT$    ABORT ADR: 025014  BDI:000004
  NAME 240730
ER ABORT$    ABORT ADR: 025002  BDI:000004
  NAME 242311
ER ABORT$    ABORT ADR: 024770  BDI:000004
  NAME 242332
ER ABORT$    ABORT ADR: 024756  BDI:000004
  NAME 242316
ER ABORT$    ABORT ADR: 024732  BDI:000004
  NAME 002423
ER ABORT$    ABORT ADR: 024720  BDI:000004
  NAME 112420
ER ABORT$    ABORT ADR: 024706  BDI:000004
  NAME 301220
ER ABORT$    ABORT ADR: 014712  BDI:000004
```

```
 NAME 361211
ER ABORT%     ABORT ADR: 024662  PDI:000004
 NAME 062131
ER ABORT%     ABORT ADR: 015465  PDI:000004
 NAME 071230
ER ABORT%     ABORT ADR: 024636  PDI:000004
 NAME 112731
ER ABORT%     ABORT ADR: 015440  PDI:000004
 NAME 003210
ER ABORT%     ABORT ADR: 024612  PDI:000004
 NAME 162016
ER ABORT%     ABORT ADR: 024600  PDI:000004
 NAME 071627
DUNSTREAM ANALYSIS TERMINATED
```

APPENDIX F - PROGRAM TRACE AND DUMP OUTPUTS

F.1 - Program Tracing

F.2 - Snapdump Output

```
    TYPE LABELS=(RECEIVE,SEND,INIT);
    PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);MONITOR;
    PROCEDURE PRINTPROC;
    VAR ENTRY :  LABELS ;
        INP   :  INTEGER;
        OUTP  :  INTEGER;
    BEGIN
      RELEASE(PRINTPROC);
      AWAIT(STARTER);
      WHILE TRUE DO
       BEGIN
        SNOOPY ON;
        LOCK(LOCKV);
        ENTRY:= RECEIVE;
        FORK WITH TASKNAME(P1) BUFFER(ENTRY,INP FORWARD ,OUTP);
        AWAIT(P1);
        SNOOPY OFF;
        CREGION; WRITELN(OUTP); CEND;
        NO;
    END;
*COMPILE     OPTIONS=IRSLMV,ELTNAME=TPFS$BUFFER
    PROGRAM DEFINE(BUFFER);
    TYPE LABELS =(RECEIVE,SEND,INIT);
    PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);
    VAR     FULL     : BOOLEAN ;
            CONTENTS: INTEGER ;
    BEGIN
       CASE ENTRY OF
        RECEIVE:
          BEGIN
            NLOCK(LOCKV);
           LOCK(RECEIVER);
           IF NOT FULL THEN WAIT(RECEIVER)
                       ELSE UNLOCK(RECEIVER);
           OUTP := CONTENTS ;
            OCK(SEN ER);
           FULL  := FALSE ;
           SIGNAL(SENDER);
           QUIT;
          END;
        SEND:
          BEGIN
           UNLOCK(LOCKV);
           LOCK(SENDER);
           IF FULL THEN WAIT(SENDER)
                   ELSE UNLOCK(SENDER);
           CONTENTS:= INP;
           LOCK(RECEIVER);
           FULL := TRUE;
           SIGNAL(RECEIVER);
           QUIT;
```

```
QUARTER WORD MODE
STARTING ADDRESS:  022627=000031,$(1),PRINT
MAIN* IBANK:001000-024776   DBANK:040000-054776
DUMP OF PROGRAM STATUS
ACTIVE BANKS:  $IBANK,$DBANK,,
ACTIVE SEGS:   0
   CARRY TOGGLE:  SET      OVERFLOW TOGGLE:     CLEAR
REGISTER CONTENTS
X                  000000051431  000000000000  000000000000  000000000000  000000000000  000000000000  000000000000
      000000000000  000000045566  000000051460  000000017616

A     000000000003  000001022605  000000045566  000001017754  000000003702  000000023710  000000000000  000000000000
      000000001231  000000000000  000000000000  000000000000  000000000000  000000000000  000000000000  000000000000
      000000000000  000000000000  000000000000  000000000000

R                  000000000000  020324123175  000003051200  000000000000  000000000000  000000000000  000000000000
      000000000000  000000000000  000000000000  000000000000  000000444444  000000000004  050505050505  000000000034
PRINT,$(T)
    000031        TS       046001                046001=005700000000/015700000000
    000032        LR,U     R15,051               R15=000000000034/000000000051
    000033        SZ       5,X10                 X10=000000051460  051465=444444444444/000000000000
    000034        LR,U     R15,054               R15=000000000051/000000000054
    000035        LX       A0,046010             A0=000000000003/000000051435  046010=000000051435
    000036        LX,U     X7,5,X10              X7=000000051431/000000051465  X10=000000051460
    000037        SX       X7,5,A0               X7=000000051465  A0=000000051435  051442=000000051454/000000051465
    000040        LX,U     X7,7,X10              X7=000000051465/000000051467  X10=000000051460
    000041        SX       X7,7,A0               X7=000000051467  A0=000000051435  051444=000000000000/000000051467
    000042        LX,U     X9,045566             X9=000000045566
    000043        LR,U     R15,6                 R15=000000000054/000000000006
    000044        SR       R15,,A0               R15=000000000006  A0=000000051435  051435=000000000005/000000000006
    000045        LR       R15,A0                R15=000000000006/000000051435  A0=000000051435
    000046        LX       A0,045554             A0=000000051435/000601022447  045554=000601022447
    000047        ER       FORKS                 A0=000601022447  A1=000001022605
    000050        LX       A0,R15                A0=000601022447/000000051435  R15=000000051435
    000051        LR       R15,A0                R15=000000051435  A0=000000051435
    000052        LA       A0,045555             A0=000000051435/000000000100  045555=000000000100
    000053        ER       0134                  A0=000000000100  A1=000001022605
    000054        LX       A0,R15                A0=000000000100/000000051435  R15=000000051435
    000055J       SLJ      TOFFS                 006012=743000000000/743000022654
***   LEAVE TRACE MODE   ***
INSTRUCTION CYCLE COUNT:      21          , PRINTED:  21
DUMP OF PROGRAM STATUS
ACTIVE BANKS:  $IBANK,$DBANK,,
ACTIVE SEGS:   0
   CARRY TOGGLE:  SET      OVERFLOW TOGGLE:     CLEAR
REGISTER CONTENTS
X                  000000051467  000000000000  000000000000  000000000000  000000000000  000000000000  000000000000
      000000000000  000000045566  000000051460  000000017616
```

```
    TYPE LABELS=(RECEIVE,SEND,INIT);
    PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);MONITOR;
    PROCEDURE PRINTPROC;
    VAR ENTRY :  LABELS ;
        INP   :  INTEGER;
        OUTP  :  INTEGER;
    BEGIN
      RELEASE(PRINTPROC);
      AWAIT(STARTER);
      WHILE TRUE DO
       BEGIN
        LOCK(LOCKV);
        ENTRY:= RECEIVE;
        FORK WITH TASKNAME(PI) BUFFER(ENTRY,INP FORWARD ,OUTP);
        AWAIT(PI);
        CREGION; WRITELN(OUTP); CEND;
       END;
    END;
  *COMPILE     OPTIONS=IRSLMV,ELTNAME=TPF$BUFFER
    PROGRAM DEFINE(BUFFER);
    TYPE LABELS =(RECEIVE,SEND,INIT);
    PROCEDURE BUFFER(VAR ENTRY:LABELS;VAR INP:INTEGER;VAR OUTP:INTEGER);
    VAR     FULL     : BOOLEAN ;
            CONTENTS: INTEGER ;
    BEG N
       CASE ENTRY OF
        RECEIVE:
          BEGIN
           SNAPDUMP(DUMP1);
           UNLOCK(LOCKV);
           LOCK(RECEIVER);
           IF NOT FULL THEN WAIT(RECEIVER)
                       ELSE UNLOCK(RECEIVER);
           SNAPDUMP(DUMP2);
           OUTP := CONTENTS ;
           LOCK(SENDER);
           FULL  := FALSE ;
           SIGNAL(SENDER);
           QUIT;
          END;
        SEND:
          BEGIN
           UNLOCK(LOCKV);
           LOCK(SENDER);
           IF FULL THEN WAIT(SENDER)
                   ELSE UNLOCK(SENDER);
           CONTENTS:= INP;
           LOCK(RECEIVER);
           FULL := TRUE;
           SIGNAL(RECEIVER);
           QUIT;
```

```
BUFFER                    $(I)    010735 0I1I0I                                    03 FEB 84    1I:59:22
PRINT                     $(I)    01I102 0I1I72     $(0)    040412 040414          03 FEB 84    1I:59:00
CARD                      $(I)    01I173 0I1265     $(0)    040415 040417          03 FEB 84    1I:58:40
MAIN                      $(I)    01I266 0I1434     $(0)    040420 040424          03 FEB 84    1I:58:17
                                                    $(036)  040425 046424

SYS$*RLIB$@ LEVEL
END MAP   ERRORS: 0  TIME: 13724  STORAGE: I7792/4/040777/073777
@USE    INFOTABLE,INFOS
@USE    PAS0000000,INFOS
@SET,0
@XQT   TPFS,MAIN

@DUMP1      010762          010760              11:59:53        02/03/84        1106 TIME-SHARING  EXEC

040630                                                                  0057000000000  0057000000000  0057000000
040640   0I57000000I  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000

@DUMP2      01I006          01I004              11:59:53        02/03/84        1106 TIME-SHARING  EXEC

040630                                                                  0057000000000  0057000000000  0057000000
040640   0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000
I

@DUMP1      010762          010760              11:59:53        02/03/84        1106 TIME-SHARING  EXEC

040630                                                                  0057000000000  0057000000000  0057000000
040640   0I57000000I  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000

@DUMP2      01I006          01I004              11:59:53        02/03/84        1106 TIME-SHARING  EXEC

040630                                                                  0057000000000  0057000000000  0057000000
040640   0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000
2

@DUMP1      010762          010760              11:59:53        02/03/84        1106 TIME-SHARING  EXEC

040630                                                                  0057000000000  0057000000000  0057000000
040640   0I57000000I  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000  0057000000000

@DUMP2      01I006          01I004              11:59:53        02/03/84        1106 TIME-SHARING  EXEC
```

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