Real-Time Multiprocessor Programming Language (RTMPL)

Users Manual

Dale J. Arpasi
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Summary

The NASA Lewis Research Center is developing and evaluating experimental hardware and software systems to help meet future needs for real-time, high-fidelity simulations of dynamic systems. Specifically, the Real-Time Multiprocessor Simulator (RTMPS) project focuses on the use of multiple microcomputers to achieve the required computing speed and accuracy at relatively low cost. A real-time multiprocessor programming language (RTMPL) has been developed to provide high-order language (HOL) programming of RTMPS systems. The RTMPL programming utility (translator) supports a variety of multiprocessor configurations and microcomputer types. The utility serves as an assembly language programmer. It translates the HOL source program for each RTMPS computer to a time-efficient assembler source program and sets up all data communication between the computers.

This manual describes the RTMPL from a user’s viewpoint. A programming example is presented to illustrate the use of the RTMPL utility to program an RTMPS system consisting of six MC68000-based computers. The RTMPL source programs and translator listings are described, as well as the utility output files, including the assembler source code programs for each computer in the simulator, and a comprehensive data base that describes the simulation. The use of the data base in conjunction with a NASA-developed real-time multiprocessor operating system (RTMPOS) for interactive execution of the simulator is discussed. Finally, the unique features of RTMPL are summarized.

Introduction

A real-time multiprocessor simulator (RTMPS) is being developed at the NASA Lewis Research Center (ref. 1). It is used to develop and evaluate experimental hardware and software systems that will allow real-time, interactive simulation of dynamic systems. The RTMPS project is focusing on the use of multiple microcomputers to achieve the required computing speed and accuracy at low cost (relative to mainframe digital and hybrid computers). A related goal is to devise a programming methodology that will permit engineering-level personnel to easily generate time-efficient code for the simulator and to conveniently operate the simulator.

A real-time multiprocessor programmers language (RTMPL) has been developed to provide high-order language (HOL) programming of RTMPS systems. The RTMPL programming utility (translator) supports a variety of multiprocessor configurations and microprocessors. The utility acts as an assembly language programmer. It translates the RTMPL source program for each RTMPS computer to a time-efficient assembler source program and sets up all data communication between the computers. The RTMPL utility is written in Pascal and is designed to run on a host computer under a disk operating system.

The NASA Lewis implementation of RTMPL runs on a Motorola EXORmacs development system under the VERSAdos operating system. The user generates RTMPL source files describing the simulation. The utility translates these source files into assembly language program files for the simulator computers. The utility generates an extensive listing file to aid the user in debugging the simulation and minimizing its execution time. The RTMPL language is macro based. Therefore only the macros have to be rewritten for different processors (typically done by system programmers). The current versions of the macros have been written for the Motorola MC68000 processor. The RTMPL utility also generates data-base files that describe the simulation to a real-time multiprocessor operating system (RTMPOS) (refs. 2 and 3). The RTMPOS and RTMPL complement each other, providing a unique environment for programming and engineering-level, interactive execution of the simulation.

Reference 4 describes the RTMPL concept, design philosophy, general features, and relationships to the simulator hardware and operating system. It also provides a general orientation and discussion of the language. The intent of this manual is to familiarize the RTMPL user with the language constructs and the functions, capabilities, and limitations of the RTMPL utility.

This users manual is organized so as to provide a top-down introduction to RTMPL programming. Since

1Motorola trademark.
the RTMPL was developed to program a general multiprocessor simulator configuration, that general configuration and the methods used to target the RTMPL utility to subsets of that configuration are described. That description is followed by a discussion of interprocessor information transfer. The RTMPL input/output file structure is then presented, and the function and interrelationships of these files are described in the context of interactive, real-time simulation. Each input file is then syntactically defined in terms of language constructs. Having established the language definition, a simple simulation example is developed in detail and used to illustrate the use of the RTMPL utility, the resultant listings, and the output files. Methods of using the listings to develop optimized simulations are also discussed.
Chapter 1: Application to Multiprocessor Configurations

Generally a multiprocessor system consists of a number of individual computers communicating with each other. To be solved on a multiprocessor system, a problem must be segmented. Each segment is assigned to a separate computer so that the problem may be solved in parallel, providing answers in less time than possible with a single computer. Generally this improvement in performance is gained at the cost of greater programming complexity since the transmission and reception of data on the individual computers must be handled by the programmer. To make the programming of a multiprocessor system attractive to engineering-level users, a high-order language (HOL) is needed that can automate these communications. Ideally the HOL will allow the user to program the system as a whole rather than on a computer-by-computer basis.

A multiprocessor system can be configured with a wide variety of communication paths (architecture) and computer hardware. To avoid obsolescence and to improve simulation transportability, the HOL must be conveniently targetable in terms of both simulator architecture and hardware. That is, the utility that translates the HOL should do so according to information describing the specifics of the target simulator so as to avoid the necessity of generating a new utility for each simulator. Further the HOL should allow the user to select the number of computers and communication paths (within the limits of the target simulator) to be used to solve a particular problem. Finally the HOL should automate information transfer and synchronization within the simulator on the basis of information contained in the problem statement.

This section describes the multiprocessor configurations that are programmable in RTMPL. It also presents an overview of the targeting methods used by the RTMPL utility to generate code for specific configurations and components. Also included is a discussion of the information transfer and past-value retention features of RTMPL, which allow the user to structure simulations for the shortest execution time.

General Simulator Configuration

RTMPL was developed to program the general multiprocessor simulator configuration shown in figure 1. Subsets of this configuration are also supported. The primary elements in the general configuration are the front-end processor (FEP), a real-time interface, and a number of simulation channels. Data are transferred between the simulation channels via the interactive information bus and the real-time information bus.

The FEP serves as the simulation controller and user interface. The FEP and its resident disk operating system provide for simulator run-time operations such as program loading, simulator mode control, data handling, and data display. The FEP also services the simulator peripherals (terminals, disks, printers, etc.). File-handling services are provided by the disk operating

![Figure 1. General simulator configuration.](image-url)
system. The FEP is the bus controller for the interactive information bus. All communications between the FEP and the simulation channels are via this bus. In the Lewis RTMPS a real-time multiprocessor operating system (RTMPOS) (refs. 2 and 3) works in conjunction with the FEP manufacturer’s disk operating system to perform the required functions.

The real-time interface serves as the communication path between the simulator and the real-time world. Using digital-to-analog and analog-to-digital converters, it allows the simulation to be coupled to external analog components such as controllers, actuators, and display devices. Data to and from the real-time interface are transferred from and to the simulation channels via the real-time information bus.

The simulation channels are programmed to execute the user’s simulation. For noninteractive simulations, those that do not require communication to or from the FEP during execution, both buses can be used for real-time, interchannel communications. However, for interactive simulation, the interactive information bus might be tied up servicing user requests and might not be available for real-time data transfer when required. RTMPL allows the user to assign data communication paths to meet specific simulation requirements.

Each simulation channel, in the general configuration, consists of two processors: a computation processor (COMP) tied directly to the interactive bus, and a preprocessor (PREP) tied directly to the real-time bus. These processors communicate through shared memory. The general configuration allows a simulation program to be segmented into 1 to 2N parts, where N is the number of available simulation channels. One of these channels can be assigned to perform real-time functions necessary to support the actual real-time simulation. This channel is designated as the “RTX” (real-time extension of the FEP). Depending on the specific implementation of the general configuration, the RTX may have to perform functions such as control of the real-time information bus, sequencing and control of simulation execution, and support of RTMPOS functions. The user should be aware that using the RTX functions available on the target simulator may require significant execution time overhead. This overhead may result in a limit on the time available for executing a user’s program on the RTX. The other simulator channels are designated as “DSC” (digital simulation computers). The DSC channels should generally be used for the simulation computations since they require the least overhead. The RTX should be limited to performing nonessential functions (e.g., analytical) since they might have to be sacrificed to execute the simulation within a prescribed update interval.

The general configuration in figure 1 indicates the broad scope of multiprocessor simulators that may be programmed in RTMPL. Any subset of this general configuration may also be programmed in RTMPL. Subsets are obtained by eliminating elements from the general configuration. These subsets therefore include

1. Single processor
2. Single channel
3. Multiprocessor, single bus
4. Multichannel, single bus
5. Multiprocessor, dual bus
6. Multichannel, dual bus
7. Multiprocessor, shared memory (no data transfer required)

Note that the general configuration assumes no specific hardware for any of its elements. RTMPL is hardware independent.

Targeting

The RTMPL utility contains features that allow the user to target a simulation to a particular simulator configuration, type of computational processor, and simulation purpose. The target configurations are specified in relation to the general configuration and include (1) the number of channels and processors to be used, (2) the location (COMP or PREP) and function (RTX or DSC) of each processor, and (3) the data transfer paths to be used. Processor type is specified by furnishing the utility with information that describes (1) the hardware characteristics of the processor, (2) the assembly language code for RTMPL operations, functions and commands, and (3) the format of the RTMPL utility’s output (i.e., assembly language programs) as required for the further development of executable code for the processor. More than one set of assembly language code may exist for a processor. Simulation purpose is specified by selecting the set of codes that best meets this purpose. For example, to verify the execution of the simulation, the user might select a set of operation and function coding that contains calculation overflow tests. After verification, the user would reduce the computation time by selecting a set of operation and function coding without the overflow tests. The following paragraphs describe the methods to be used in supplying targeting information to the utility.

Configuration targeting is done within the RTMPL simulation programs. The utility requires the user to construct an RTMPL program for every processor to be used in the simulation. Each program must be assigned a unique identifier (i.e., RTX, RTXPREP, DSC, or DSCPREP) that indicates the function and location of the processor. (The specific formats for these identifiers are provided in Chapter 9.) These identifiers implicitly define the configuration of the target simulator to the utility. Additionally, an RTMPL construct is available (see the section Variables, Chapter 4) to allow the user to...
specify the data path for transferring variables from one processor to another. This implicit definition of the data paths in the target simulator requires that the RTMPL user be familiar with the available hardware and with these data paths.

The user targets the utility to processor type and simulation purpose by specifying a set of target definition files (Control Segment and File, Chapter 3) that govern the translation function of the utility. The RTMPL utility translates RTMPL source programs into assembly language macro statements according to information contained in this set of files. These files describe the target processors, the target assembler, and the assembly language macros to the utility. They are normally developed by systems programmers during installation of the RTMPL utility. More than one set may be available for a particular simulator to allow for optimum code generation for different applications or simulation objectives. The use of the target definition files makes for easy transportation of RTMPL simulations between simulators containing different processors. It also allows a single source program to be translated differently for different purposes. For example, different target definitions may be used to produce both efficient noninteractive code and code that permits maximum interaction of the user with the simulation at run time. Other information contained in the target definition files will be covered in the discussion of RTMPL constructs and utility functions.

Information Transfer

The RTMPL utility translates RTMPL programs into assembly language programs by breaking them down into a sequence of macro operations and arguments. The target assembler then substitutes assembly language code for each macro in the sequence and assembles this code into machine language for execution on the target processors. The utility selects the macro operations from a standard set on the basis of targeting information and program requirements. Arguments are specified to meet program requirements. The assembly language code used for macro substitution is obtained from the target definition files. This code is usually formulated by systems programmers during installation of the RTMPL utility to provide time-efficient execution of the RTMPL macro set on the target processors.

The RTMPL user need not be concerned with most aspects of this translation process. However, knowledge of how the utility mechanizes information transfer may be important since the information transfer may significantly affect the execution time of the simulation.

Three types of information transfer can be mechanized by the utility: control, analytical, and data. Control information regulates the computational sequencing of the simulation computations. Analytical information conveys simulation results to the user. Data information is passed between the various processors as required to compute the simulation. Control and analytical information transfer requirements are specified explicitly by the user in the RTMPL source programs (Commands, Chapter 5). Data information transfer is specified implicitly (Argument Specification, Chapter 4).

At this point a description of the data transfer mechanism employed by the RTMPL utility is appropriate. Figure 2 shows the data paths in a single channel of the general configuration. One segment of shared memory is shown and it contains the channel’s transfer and external variables. A transfer variable is one whose value is computed in one processor in a channel and referenced either by the other processor in the channel or by a processor in another channel. An external variable is one whose value is used in a processor but is computed in another processor. Data information transfer between processors is implemented on the PREP and the COMP by using the macros shown above and below the segment of shared memory in figure 2. Their functions are defined as follows:

STX$ stores value of a transfer variable into shared memory and sends value to other channels via bus external to processor in which value is computed

STV$ as above, but sends value via bus local to processor in which value is computed

TSTXVX$ tests currency of value of an external variable sent via bus external to receiving processor; repeated until value becomes current

Figure 2. Information transfer.
TSTXVLS as above, but used for values sent via bus local to receiving processor
TSTXVAS as above, but used for values sent via shared memory from alternative processor in channel

The local bus for a PREP is the real-time information bus. The interactive information bus is local to a COMP.

When the RTMPL utility encounters a reference to the current value of an external variable in one of the user's programs (Argument Specification, Chapter 4), it inserts either a STXS or STVS macro directly after the macro sequence used to compute the value in the source program. It also inserts either a TSTXVXS, TSTXVLS, or TSTXVSA macro before the reference in the receiving program. The exact selection of these macros is made according to the location of the source and receiving processors in the general configuration and the data path specified for the variable by the user (Variables, Chapter 4). For example, if a variable were to be transferred from a COMP to another channel via the real-time information bus, STXS would be inserted after the variable was computed on the COMP. If it were to be received by a PREP in the other channel, TSTXVLS would be used to test currency. If it were to be received only by a COMP, TSTXVXS would be used. If it were to be received only by the PREP in the same channel as the source processor, TSTXVSA would be used in the PREP.

To accommodate transfers of variables to multiple destinations, the RTMPL utility generates a transfer map for each transfer variable. When a variable is selected for transfer, it is assigned a location in channel-shared transfer memory. This becomes a global assignment for all channels used in the simulation. Therefore this is the destination location (or external variable location) for that variable in all channels receiving the transferred value. The transfer map for a variable consists of a list of channels that reference the variable externally. The STXS/STVS macros consult this map to implement transfers from a specified location in the local-shared transfer memory to identical locations in the memory of the mapped channels. If a variable is externally referenced only on the alternate processor in the local channel, the transfer map for this variable contains no entries. Similarly in a multiprocessor configuration communicating only by shared memory the STXS/STVS macros would not be required to consult the transfer map at all.

The exact functions of the data information transfer macros and their use of the transfer maps depend on the specific configuration of the target simulation. Their general functions, as described, permit data transfer to be implemented for any subset of the general configuration. This is done during generation of the target definition files. Again, the RTMPL user need not be concerned with the specifics as to how data are transferred. It is important, however, that the user realize that the time required to transmit and receive these data depends on the data path and specific configuration of the simulator. Proper structuring of the simulation to minimize these times may make the difference in realizing real-time execution.

Past-Value Control

Dynamics are incorporated into simulations by manipulating the past values of variables. Integration algorithms, for example, require the retention of one or more past values of a variable. The RTMPL utility automates the retention of past values.

Figure 3 illustrates the memory configuration and macros used to control past values in a single channel of the general configuration. Local memory is shown on each processor in the channel. All variables whose values are calculated on a processor have local memory assigned to them to store their current value and all required past values (Variables, Chapter 4). After the macros that calculate a variable's current value the RTMPL utility inserts SVLS macros, which roll the past values down one calculation interval. That is,

\[ \text{VALUE} (T - i) = \text{VALUE} (T - i - 1) \]

where T represents the current calculation and i goes from 1 to the number of past values to be retained. The oldest past value is discarded. The SLVS macro is then inserted to store the current value in VALUE(T). It is at this point that the RTMPL utility would insert the data transfer macros STXS/STVS if external transfer of the variable's value were necessary.

The RTMPL utility also automates the retention of a single past value of an external variable. As indicated in the section INFORMATION TRANSFER, referencing the current value of an external variable causes the TSTXVXS/TSTXVLS/TSTXVAS macros to be used to test the currency of the value on the receiving processor. If only the past value of an external variable is referenced, these macros are not used since currency is not a consideration. Certain actions are necessary, however, to accommodate the retention of the past value.

Two segments of shared memory are shown in figure 3. One segment is used to receive the current values of external variables as described in figure 2. The second segment is identical to the first but is used to retain the past values of the external variables. The XFERSV$ macro is used to test the currency of values of external variables that are referenced only in terms of past values and to transfer these current values into the past-value segment of shared memory for use in the next calculation interval. The XFERSV$ macros are inserted after all
other calculations are completed. On a PREP this macro operates only on values transferred on the real-time information bus, and on a COMP it operates only on values transferred on the interactive information bus.

The TSTXVS$ macro is inserted into the calculation sequence prior to any use of the referenced external past value. Its function is to implement the access of the external past value to local processor computation. Unlike the TSTXVX$/TSTXVL$/TSTXVAS macros, currency testing is not required before implementing this access.

Note that the precise functions of the data-transfer and past-value control macros depend on the target simulator configuration. The preceding descriptions apply to their functions in the general multiprocessor configuration. Although these functions are required in any configuration, they may be performed in whole or in part by the target simulator's hardware. By allowing these macros to be structured to suit the target hardware, RTMPL can be applied to the various subsets of the general configuration.
Chapter 2: RTMPL Environment

The RTMPL utility functions under a disk operating system (DOS). It was initially implemented under Motorola's VERSAdos on an EXORmacs development system. The utility is specific to a particular DOS only in the file identification format. In this manual, files are identified by using the following VERSAdos format:

VOLUME:USERNAME.CATALOG.
FILENAME.EXTENSION

where the field widths (i.e., maximum number of characters) are

(4):(4):(8):(8):(2)

The user should become familiar with the file identification format required by the DOS used in the specific installation of RTMPL.

The RTMPL utility processes and produces files of information. It operates in conjunction with other DOS utilities to develop user simulations. This section places the RTMPL utility in context with the overall simulation effort and familiarizes the user with its major functions.

Simulation Development System

Figure 4 shows the RTMPS software utilities used in the development and execution of real-time multiprocessor simulations. The SYSDEF utility is used to generate target definition files. This is normally done by qualified systems programmers and need not concern the general user. Simulation development begins with the DOS editor, which is used to develop RTMPL source files. These files define the simulation problem and contain programs for each simulator processor to be used in its execution. The RTMPL utility translates the RTMPL source into assembly language source files according to information contained in the target definition files. The target assembler and linker utilities are used to create load modules for execution on the target processors. The RTMPL utility also produces simulation-descriptive data-base files. The RTMPOS utility accepts the load modules and loads them into the simulator at run time. Also at run time RTMPOS reads the data-base files to establish a simulation data base that will allow engineering-level interactive execution of the simulation. In addition to the object files (assembler source and data base) the RTMPL utility produces an extensive listing file that provides messages and source interpretations to aid the user in developing error-free, time-efficient simulations. The RTMPL source, object, and listing files are discussed more completely in later sections of this manual.

Source Translation

The RTMPL utility is, in effect, an assembly language programmer. From the simulation description supplied in
the source files the utility develops assembly language programs according to information supplied in the specified target definition files. Although the translation process is essentially transparent to the user, the major functions of the utility in performing this translation are described here to provide a background for the source and object file descriptions that follow.

The utility parses each executable source statement into a list of operations and associated arguments. While doing this, it tests each statement syntactically for correctness. (Parsing is the breaking down of complex statements into an ordered sequence of primitive operations.) It also tests each statement semantically against source argument definitions. Arguments are defined in terms of data type and precision. RTMPL supports the Boolean data type and three arithmetic data types (integer, scaled fraction, and floating point), as well as three arithmetic precisions (single, double, and triple). The required data type of the operation is determined from the data type of the statement result. As part of the semantics test the utility compares the required data type with the data type associated with the arguments of the operation.

If the statement is found to be syntactically and semantically correct, the operation/argument list is translated into a list of assembly language macros. The utility supports three argument sources (register, memory, and immediate). An arithmetic addition operation, for example, could be supported by up to 81 addition macros in the target definition files (considering all possible combinations of data type, precision, and argument sources). Having already determined the required data type, the required precision is determined based on look-aheads and look-backs at the other operations in the list. The minimum precision necessary to provide the required accuracy of the statement result is selected as the desired precision of the macro. The target definition files are consulted to see if this precision is supported. If it is not, the next best macro is determined. The user is advised if accuracy will be impaired because the proper macro is not available. The required precision of the arguments is obtained from the target information once the precision of the macro has been determined. Precision conversion macros are inserted automatically by the utility to provide the proper precision of the arguments.

At this point the macro options have been reduced to those that support the required operation, data type, and precision. It now remains for the utility to select the macro, from this set, that best supports the available argument sources. The values of the arguments may reside in memory or in register (if they are the results of previous calculations). If the argument is a constant, it may be expedient to use an immediate data source (where the value exists only within the code of the operation). Desired sources are determined so as to minimize the loading and storing of data from and to memory. The target macro set is consulted to see if the desired sources are supported. If they are not, the best available source is selected and appropriate load and store macros are inserted to conform the arguments to the required sources. The use of scratch pad memory (temporary storage) is fully automated by the utility.

When the macro set for the source statement has been formed, it is edited by the utility (i.e., scaling macros are inserted) if the scaled-fraction data type has been specified by the user. Past-value control and data transfer macros are also inserted as required.

The user is advised of all precision and scale factor adjustments by means of warnings in the listing file. If adjustments to constant arguments are necessary, a new constant with the proper attributes is created by the utility. Definitions of variables are not modified. Using the warnings, however, the user may opt to incorporate the redefinitions in the source programs to eliminate superfluous adjustment macros and thereby reduce simulation execution time.

The final steps in the translation process are the assignment of registers and the generation of assembly language source files.
Chapter 3: Simulation Structure

RTMPL is a structured, high-order language designed to facilitate the development of error-free, time-efficient simulations. The user constructs an RTMPL simulation by creating RTMPL source files as shown in figure 5. The source files define the four segments: control, global data, local data, and execution of an RTMPL simulation. There is one control segment and, at most, one global data segment for each simulation. There is one local data segment and one execution segment for each processor to be used in the simulation. The combination of local data and execution segments for a processor is referred to as a program.

Separate source files are used to contain the control and global data segments. A separate source file is needed for each program. These files are text files, but they must conform to RTMPL constructs. In the following sections the format of RTMPL constructs and the structure of the RTMPL source files are described.

Syntax Diagram and Basic Constructs

RTMPL constructs can be best illustrated by using syntax diagrams. Syntax diagrams for the basic RTMPL constructs, shown in figure 6, define these constructs and show how to use them in writing source code.

In general a syntax diagram contains one or more programming elements linked together by curved paths that are terminated with arrowheads to show the direction of travel. A rectangular element is used to indicate where a named construct is to be inserted. Parenthetical remarks are used within some syntax diagram rectangles for clarification and generally to denote a special application of the referenced construct. They do not modify the construct in any way. A circular or oval element contains a symbol or string of symbols that must be exactly replicated. The basic construct, NAME (fig. 6(a)), consists of the LETTER construct followed by a series of LETTER or DIGIT constructs (figs. 6(b) and (c), respectively). Note the use of the "..." sequence in these figures to show the inclusions of all symbols from "A" to "Z" and from "0" to "9."

A basic problem with syntax diagrams is in the definition of limits. In the NAME construct the LETTER/DIGIT choice is contained in an infinite loop. In reality this construct is limited to eight symbols. To get around this problem, notes are used in the diagrams to indicate the limitations imposed.

The INTEGER and SIGNED-INTEGER constructs are shown in figures 6(d) and (e). The number of digits allowed in an integer depends on the Pascal compiler used to generate the RTMPL utility. Sufficient digits will generally be available for all applications. There is no need to burden the user with precise specifications on these limits since violations will be rare and flagged as errors by the utility.

The VALUE construct (fig. 6(f)) is used to specify real numbers in RTMPL. A versatile E-format is used. An additional syntax diagram element, the hexagon, is shown in the construct. The hexagon denotes that only one path may follow from it, depending on the value of a
representation of whole numbers (following section). Some examples of real numbers using the VALUE construct are

3479., .3479E + 4, 1.7048

or, if #DECPT is set in the control segment,

7048, 7048E − 4

Boolean values are defined by the LOGIC construct in figure 6(g).

RTMPL allows the user to program in a free form. That is, although the syntax diagrams must be followed exactly, the user is free to insert spaces and line feeds anywhere. This feature allows the user to structure source programs that are personally readable. The semicolon is used in RTMPL to denote the end of a statement or entry. To further enhance readability, the user may insert comments anywhere after a semicolon or at the start of a source file. Comments are structured by using the COMMENT and STRING constructs (figs. 6(h) and (i)). An example of a comment is

*THE*COMPRESSOR*HAS*STALLED*;

Note that asterisks are used in lieu of spaces in strings. All statements, entries, and comments are limited to 3200 nonspace characters (i.e., semicolons may not be separated by more than 3200 nonspace characters).

Control Segment and File

The control segment describes the nature of the simulation to the RTMPL utility and regulates its actions in processing the other segments of the simulation. The file containing this segment has no identification restrictions (as do other RTMPL source files). It is referenced as an argument in the DOS command line that invokes the utility (see Chapter 7). This single-record segment (file) is generated by using the CONTROL construct (fig. 7). The file (fig. 7(a)) consists of up to 11 + N entries, where N is the number of simulator channels to be used for the simulation. Each entry must be terminated with a semicolon. An example of a control file for a simulation called T700SIM is shown here.

DECEPT,FLOPPY; (entry 1)
T700SIM; (entry 2)
TRANSIENT*TEST*CASE; (entry 3)
FLO*T*BLADE; (entry 4)
FLOP; (entry 5)
FLOP; (entry 6)
FLOP; (entry 7)
l; (entry 8)
The first entry contains user-specified options that govern the operation of the utility. One or more options must be specified from the defined set. Multiple options are separated by commas. These options are defined in figure 7(b) and summarized in table I for easy reference.

When the utility encounters the NONE option, any previously specified options are ignored, but any options following NONE are enforced.

The FLOPPY option results in the utility pausing prior to accessing an RTMPL source file. The message

(FILE ID) READY? (Y/N)

is displayed and the utility waits for a "Y" response. This option is useful if all RTMPL sources files cannot be contained on a single physical volume such as a floppy disk. Note the use of angular brackets. The convention will be used in this manual to denote user-supplied or, in this case, utility-supplied information of the type specified within the brackets.

The DECPT option requires the utility to insert warnings in the listing file if a decimal point is not contained within an engineering unit value. This option should be used by those wishing to differentiate between real and integer values or those worried about decimal point omissions. The DEBUG option will not normally be selected by the user. It requires the utility to provide functional information in the listing file to verify the validity of the utility's operation. The NOGLF option, if used, advises the utility that the simulation contains no global data file. The global data segment is optional in RTMPL.

Entry 2 contains a user-assigned simulation name. It is used by the utility whenever reference to the entire simulation is required. It is used in developing listing headers, in certain diagnostic messages, and in file identification for non-program-specific database file assignments. Entries 3 and 4 allow further user descriptions of the simulation for use in listing headers. They are limited to 64 and 32 characters, respectively.

Entries 5, 6, and 7 specify logical volume names (designating the disk or medium containing the files) for the RTMPL source, object (assembler source), and database files ownership. Entry 8 is the user number for file identification. The constructs for these entries and entry 2 are defined not in RTMPL but by the resident DOS and are installation dependent. The volume names and user number are used by the utility in accessing source files and in generating object files.

Entry 9 defines the number of simulator channels (N) to be used in the simulation. Entries 10 through 9+N
TABLE 1.—UTILITY CONTROL OPTIONS

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECPT</td>
<td>Causes a listing file warning if a decimal point is not encountered in a real number</td>
<td>NOT DECPT</td>
</tr>
<tr>
<td>NOGLF</td>
<td>Advises that the simulation does not have a global segment</td>
<td>NOT NOGLF</td>
</tr>
<tr>
<td>SCAN</td>
<td>Causes the object files not to be generated and the listing file and special macro files to be generated</td>
<td>NOT SCAN</td>
</tr>
<tr>
<td>FLOPPY</td>
<td>Causes a pause for disk insertion before files are accessed</td>
<td>NOT FLOPPY</td>
</tr>
<tr>
<td>DEBUG</td>
<td>Not for general use; causes expanded listing containing RTMPL diagnostic information</td>
<td>NOT DEBUG</td>
</tr>
<tr>
<td>NONE</td>
<td>Causes all previously specified options to be set to default value</td>
<td>-----------</td>
</tr>
</tbody>
</table>

contain the channel identifiers in terms of type and logical name. Entry 10+N must be included if the NOGLF option was not selected. Entry 11+N specifies the target simulator characteristics and forms the basis for the utility's referencing of all target definition files.

**Program Files**

A program file contains the local data and execution segments for each processor to be used in the simulation. The program file for a VERSAdos installation must be named as follows:

- **VOLUME ID** must be consistent with that specified in control file (entry 5)
- **USER NUM** must be consistent with that specified in control file (entry 8)
- **CATALOG ID** must be "RTX" or "DSC" to identify program function. (If program is for a PREP, "PREP" must be appended (e.g., DSCPREP).)
- **FILE NAME** must be logical name assigned to a channel in control file (entries 9 through 8+N)
- **EXTENSION** "SA," indicating a text file

Examples of program file names based on the previous control file examples are

- FLOP:1.RTXPREP.INPRC.SA
- FLOP:1.RTX.INPRC.SA
- FLOP:1.DSCPREP.CMPSIM.SA
- FLOP:1.DSC.CMPSIM.SA
- FLOP:1.DSCPREP.BNRSIM.SA
- FLOP:1.DSC.BNRSIM.SA
- FLOP:1.DSCPREP.TRBSIM.SA
- FLOP:1.DSC.TRBSIM.SA

The program file construct is shown in figure 8. Each program file is made up of records. There are five types of record, denoted by the record identifiers VARIABLE, CONSTANT, ARGGROUP, EXEC, and TASK. The identifier is separated from the record content by the colon character. Records are terminated by the end-of-record statement "EOR;". Record types may appear more than once in a file and their order in the file is up to the user. All statements and definitions within the records must be terminated with a semicolon.
The EXEC and TASK records define the execution segment of a processor program. VARIABLE, CONSTANT, and ARGGROUP records define the local data segments for the EXEC and TASK records. Constructs for these records are described in the sections of this manual that discuss the segments. At least one EXEC record is required in each program. The other records are used as necessary to describe the program function. Program files containing the various record types will be shown in detail for the example problem.

Global Data Segment and File

The global data file contains data that may be referenced as execution segment arguments in any or all of the program files. The file for a VERSAdos installation must be named as follows:

- **VOLUME ID**: must be consistent with that specified in control file (entry 5)
- **USER NUM**: must be consistent with that specified in control file (entry 8)
- **CATALOG ID**: must be “GLOBAL”
- **FILE NAME**: user selected
- **EXTENSION**: “SA,” indicating a text file

An example of a name for the global data file corresponding to the control file example is

```
FLOP:1.GLOBAL.INT700.SA
```

The construct to be followed in generating the global data file is shown in figure 9(a). The file consists of records. There are two different record types, denoted by the identifiers MESSAGE and GLCNST. The record identifier is separated from the record content by the colon character. Records are terminated by the end-of-record statement “EOR;”. These records are used as required to define the global data segment. Remember, if no data segment is required, the NOGLF option must be selected in the control segment. Records may appear more than once in a file, and their order in the file is up to the user. All definitions within records must be terminated with a semicolon. Constructs for these records and their functions are described in the following section.
Chapter 4: Data Segments

The local and global data segments are used to define simulation variables, constants, argument groups, and run-time messages. These definitions are used to verify semantics and to build assembly language macros when these items are referenced as arguments in the execution segments. Variables are defined as those items that are subject to change as a result of executing the simulation. Constants are those items that do not change as a result of simulation execution. Argument groups are lists of variables and constants. They can be used by RTMPOS for run-time data gathering and display. They may also be used within the simulation to pass arguments and data between the user’s programs and target library procedures. Messages are displayed to the user during simulation execution when user-programmed conditions are met.

This section describes the constructs used to define data items. The data attributes are discussed, as are special properties that are useful for simulation.

Data Attributes

All local and global data are assigned names to identify the data item (fig. 6(a)). All names within a local data segment must be unique within the segment. All names of constants within the global data segment must not only be unique within the global data segment but also different from any name assigned in any local data segment in the simulation.

Along with names, RTMPL requires certain other attributes to be specified. The VALUE construct (fig. 6(f)) is used to specify data values. Other attributes are size (SIZE), data type and precision (DTP), and scale factor (SF). Constructs for the specification of these attributes are given in figure 10. SIZE (fig. 10(a)) is used to define the number of elements associated with a data name. Its meaning is data-construct dependent and is described in the discussion of these constructs. DTP (fig. 10(b)) is used to specify the data type and precision of constants, variables, and argument groups. RTMPL allows assignments of four data types:

1. Integer (I): integers
2. Scaled fraction (S): real numbers
3. Floating point (F): real numbers
4. Boolean (B): logical (true or false)

The arithmetic data types—I, S, and F—must be assigned a precision. RTMPL supports single-, double-, and triple-precision data of these types (1, 2, and 3). The selected precision dictates the number of bytes used in the target processor to represent the data and is directly proportional to accuracy and generally inversely proportional to computational speed. Usually single-precision integer data provide two bytes of accuracy, with another two bytes of accuracy added for each increase in precision. The exact implementation of precision by the target processor is specified in the target definition files.
The choice of data type assigned to integer or logical variables and constants is obvious. However, in assigning real variables and constants, the user must decide between the \( S \) and \( F \) data types. This choice is dictated primarily by the computational speed requirements of the simulation and the computational speed capability of the target processor in performing operations on the data types. Generally scaled-fraction computations are faster but are slightly more difficult to generate since they require scaling of all variables and constants. Since scaled-fraction values must fall between \(-1\) and \(+1\), the maximum absolute value of each variable or constant must be determined and specified in its RTMPL definition. RTMPL uses binary scaling. The maximum absolute value must therefore be specified in terms of the minimum power of 2 that exceeds the maximum absolute value. The specification is made by using the construct in figure 10(c). For example, if the maximum absolute value is 31.9, \( SF \) becomes \( 5 \) \((2^5 = 32)\); if the value is 0.1239, \( SF \) becomes \(-3 \) \((2^{-3} = 0.125)\).

While processing equations involving scaled fractions, the RTMPL utility will perform all necessary scale factor manipulations, thereby relieving the user of this chore. The user-assigned scale factor \( (SF) \) is referred to as the “nominal” scale factor of a variable or constant. When a operation is performed on the variable or constant, a “required” scale factor is then determined by the utility on the basis of subsequent operations (required to compute the equation) and information concerning the operations obtained from the target definition files. The difference between the “nominal” and “required” scale factors is reconciled by inserting a scaling macro (shift operation) before or after the operation as appropriate. The result of the operation is assigned the “nominal” scale factor for use when the result is an argument of a subsequent operation. The utility will list recommended adjustments in \( SF \) or precision specifications that will minimize the computation time (see Chapter 8). Through these and other advisories the user can adjust the variable and constant definitions to eliminate time-consuming scale factor adjustments and potential overflow or underflow problems.

Variables

Variables are defined by using the construct in figure 11. Each variable is assigned a name and set of attributes. DTP and \( SF \) were described previously. The \( SIZE \) attribute, in this case, determines how many current and past values of a variable are to be kept. For example, if the simulation requires the current and last value of a variable (e.g., if a second-order integration scheme is used), its size would be specified as 2. The minimum variable size is 1 (i.e., only the current value is saved to provide one past value). The RTMPL utility provides for automatically adjusting the variable’s past-value array after its solution in an equivalence statement. All variables must appear on the left of an equivalence statement.

Two values must be assigned to each variable in the variable definition. The hold value is reserved for special operating system (RTMPOS) applications. The initial-condition (IC) value is the starting value of the variable when the program is loaded and whenever the RTMPOS IC mode command is executed (ref. 4). Both are specified in engineering units even if the variable is designated as a scaled fraction.

Note the various default paths through the VARIABLE DEFINITION construct. All or any attributes of a variable may be defaulted (as long as the required default values exist). DTP and \( SF \) may be defaulted to those attributes of the last defined variable.

Consider the following examples of variable definitions based on the figure 11 construct:

1. Variable \( \text{SPEED} \) is to have the value 5000 rpm in hold and IC. It is a single-precision, scaled-fraction variable and is to be transferred on the interactive bus. Since scale factors \( 2^{12} = 4096 \) and \( 2^{13} = 8196 \), speed would be defined as

\[
\text{SPEED} = \text{S1/13}, 1 \text{ [5000./5000.];}
\]

or, using defaults,

\[
\text{SPEED} = \text{S1/13} \text{ [5000./5000];}
\]

2. Variable \( \text{SPEEDDOT} \) is to have the value 0.0 in hold and IC. It is a single-precision, scaled-fraction variable and is to be transferred on the real-time bus. Two past values are required for the numerical integration scheme. Therefore \( \text{SPEEDDOT} \) would be defined as
SPEEDOT = S1/10, 2 [0.0/0.0];

or, using defaults,

SPEEDOT = S1/10, 2;

(3) Variable READOT is to have the same attributes as SPEEDOT. Therefore all defaults are used to define READOT after the definition of SPEEDOT.

SPEEDOT = S1/10, 3; READOT;

Two types of processor memory are reserved for the variable values—local memory and transfer memory (fig. 3). Variable values can only be transferred to other programs if they are stored in transfer memory. The RTMPL utility will automatically assign transfer memory if a variable is referenced in another program. Otherwise the variable is assigned to local memory. The user specifies the transfer path for a variable by inserting or omitting a period before the name specification. Omission causes real-time bus transfer; insertion forces interactive bus transfer.

Certain variables are implicitly defined for every program by the target definition files. Called target Boolean variables, their values are generated by the processor's hardware and firmware. They are always local and may not be referenced directly in another program. They are always Boolean (i.e., DTP = B). Examples of target Boolean variables are OVERFLOW, POSITIVE, ZERO, and NEGATIVE, which may be generated by the processor in its status register. Since these variables are processor dependent, the user must refer to the system description of the target definition file to see what variables are available.

**Constants**

Constants are defined by using the construct in figure 12. As with variables, constants have DPT, SF, and SIZE attributes. SIZE for constants specifies the number of elements in a multivalued constant array. The minimum constant array size is 1. The construct definition allows a string of N identical values to be extended as N @ value. Therefore three sequential values of 1.25 could be entered as 3 @ 1.25. The number of values entered must correspond to the specified size. No value defaults exist.

RTMPL allows the use of four types of constant:

1. Local constants
2. Local parameters
3. Global constants
4. Global parameters

Parameters are constants that are adjustable through RTMPOS at run time. They are specified during the constant definition by preceding the constant name with a period. Local constants and parameters are those defined within the program file. Global constants and parameters are those defined within the global definition file, and their use is described in the discussion of that file.

RTMPL does not allow user definition of Boolean constants. The Boolean constants TRUE and FALSE are predefined by the utility and available implicitly to the user.

**Global Constants**

The GLCNST records in the global data file are used to specify constants and parameters that are global to the simulation. The record content is specified by using the construct of figure 12. Global constants may be referenced as arguments in any program, without being defined in that program. Upon being referenced, the global constant definition is copied into the program. Apart from the advantage that global constant records relieve the user of the task of defining the same constant in a multitude of programs, the global constant has a special meaning to the operating system. If a global constant is defined as a parameter, modifying its value at run time, by using RTMPOS, will cause it to change globally throughout the simulation.

Some examples of constants (both local and global) are

1. \(.\text{PI} = 3.1416\) (scaled to 4; single precision; parameter; single value)
2. \(.\text{PI} = S1/2, 1 [3.1416]\);
3. or \(.\text{PI} = S1/2 [3.1416]\); (using the SIZE default)
(2) \( K1 = 1 \) (integer; double precision; not parameter; single value)
\( K1 = 12 \[1\];

(3) \( PRXVALS = 1.25, 1.25, 1.25, 4.0, 5.0 \) (floating point; single precision; not parameter; five values)
\( PRXVALS = F1, 5 \ [3@1.25, 4.0, 5.1; \)

Messages

Messages can be relayed to the user at run time via the ADVISE command. These messages are defined in the global data file. Figure 9(b) defines the MESSAGE DEFINITION construct. A message is assigned a name, which is used to reference the message in an advisory. A message containing up to 64 characters will be displayed on the user’s terminal upon execution of the advisory. A message is global and may be referenced in any program. Note that spaces are ignored in the message format, but asterisks are interpreted as spaces.

Argument Specification

To understand argument groups, it will help to understand how arguments are defined. When a variable or constant is referenced in a statement as an operand or in an argument group, it is called an argument. RTMPL allows any variable or constant, defined within the scope of the simulation (including global constants), to be referenced as an argument. The ARGUMENT construct is defined in figure 13.

Global constants are referenced only by name. Program-defined constants and variables can have their source program file explicitly specified. This is done by specifying the source channel name and processor type. Thus

TURBINE.C.FLOW

specifies the variable FLOW defined in the COMP program in channel TURBINE. Examples of other source specifications are

FLOW

source of variable FLOW is local program file

.P.FLOW

source of variable FLOW is PREP program in logical channel assigned to local program

TURBINE.FLOW

source of variable FLOW is program for local processor type assigned to logical channel TURBINE

If a constant is specified as an external argument (defined in another program) in the local program and has not been defined in the local program, the RTMPL utility will create a local constant with the name and attributes of the argument specification. This constant will be used as the argument. However, if a constant of the same name has been defined locally, a program error will result. This mechanism can be used to identify identical constants in different programs that should be handled via global constants.

If a variable not defined in the local program (but defined in another program) is specified as an argument, the utility will create an external variable in the local program and assign it a location in external memory. Its value will be transferred to the local program after it has been computed in the external program. The external variable will then be used as the argument (Information Transfer, Chapter 1).

The ARGUMENT construct provides a means for specifying a particular past value of a variable or a particular element within a multivalued constant array. This is done by appending \( n \) to the name, where \( n \) is the variable past-value number or constant-element number. For example,

FLOW \( 2 \) (second past value of flow)

TABLE \( 10 \) (tenth element in constant array TABLE)

Note that the term "past value" refers to the results of computations. When a variable is recomputed, the old
value is assigned as the first past value of the variable. The RTMPL utility will issue a warning if a local variable is referenced as an argument before it has been assigned a value through computation.

**Argument Groups**

An argument group is a set of arguments grouped together under a single name. It can be used to pass arguments to or from target library procedures (see the CALL command). Argument groups also provide for large-volume data transfers between the FEP and the simulator channels. Argument groups are specified in a program file by using the ARGGROUP construct defined in figure 14.

ARGGROUP attributes consist of a data type and precision (DTP) assigned to the group, the maximum number of arguments to be contained in the group (SIZE), and an optional initial set of arguments. Argument groups can be edited at run time by using RTMPOS. Therefore arguments need not be specified in the program. However, since only variables and constants that are available on the argument group's processor can be inserted at run time into the argument group, the user should include, in the ARGGROUP specification, any external variables and constants that may eventually be required in the ARGGROUP. This will allow the RTMPL utility to form these constants and external variables.

All arguments within an argument group must conform to the specified DTP for that group. For examples of argument groups and their uses, see Chapter 6.
Chapter 5: Execution Segment

The execution segment of a program (fig. 15) is made up of two types of records—executives and tasks. Executives are used to provide program control and to perform major simulation functions. Tasks are used to perform services for executives. Two types of executives may be specified by the user: background and foreground (see the section Executives, Chapter 5). Executive and task records are made up of statements that define the required simulation execution.

This chapter discusses the definition and use of executives and tasks. The user should refer to figure 15 in these discussions. The variations of the STATEMENT construct and the use of the EXPRESSION construct are explained.

Executives

An executive is defined by using the construct in figure 15. It is assigned a name and a priority level. The first seven characters of the name must be unique within the set of program executive and task names. The priority level is an integer, limited in magnitude to 8, that

Figure 16. - Executive record specification.

Figure 15. - RTMPL source records - execution segment.
specifies the computational priority of the executive within the program. Lower priority executives may be interrupted for execution of higher priority executives. Priority assignments greater than zero must be unique within the program.

The RTMPL utility modifies the user-specified name, to ensure its uniqueness. (Future versions of the utility will eliminate this annoyance.) A special assembler character (".") is inserted following the name, if the name is seven characters or less. If an eight-character name is specified, the last character is replaced with the special assembler character (e.g., "TURBINES" would become "TURBINE."). (Two special assembler characters are defined in the target definition files. These are used whenever the utility must generate a name. In this manual the period and dollar sign are used.)

Executive execution is governed by two processor firmware programs: the sequencer and the channel interrupter (ref. 1). The sequencer is controlled by the FEP with information provided by the user at run time through RTMPOS. The channel interrupter firmware services user-programmed interrupts between COMP and PREP processors in the same channel.

The user may specify background executives at run time that will control the execution of the simulation programs through the sequencer. RTMPL requires at least one background executive in each program, but more than one is permitted. By using multiple background executives the user may change the simulation subtly or completely at run time (i.e., more than one simulation may be programmed within a single set of RTMPL source files). All background executives must have priority levels of zero.

Executives that are assigned priority levels greater than zero are considered to be foreground executives. Their execution is governed by the local processor's channel interrupter firmware. This firmware functions during program execution and allows user-programmed interrupts between COMP and PREP processors in the same channel. Obviously foreground executives may only be implemented on simulators having both COMP and PREP programs in a channel.

Typically the function of a foreground executive in a particular program will be to service exceptions occurring in the alternate processor in the channel. These exceptions would be generated in the alternate processor by using the ACTIVATE command (see the section Commands) and would be the result of conditional testing in that processor's program. This eliminates duplication of code and data transfer when both processors must respond to the same event. Any number of foreground executives may be activated simultaneously, with the order of execution controlled by the channel interrupter according to predefined priority levels. Upon completion of all activated foreground executives, program control returns to the background executive. If a foreground executive is reactivated while it is still active, the second activation request is ignored.

**Tasks**

Tasks are defined by using the construct in figure 17. The construct consists merely of identifying the task by name. The first seven characters of the name must be unique within the set of executive and task names used in the program. As with the executive definition the task name is modified by using the special assembler character "."

Tasks consist of statements structured to do a particular job within a program. They are reenterable and therefore may be initiated in any background or foreground executive (see ENTER and DISPATCH commands). A task can never be initiated by another task.

To enhance their flexibility, tasks may be enabled or disabled at run time by the user through RTMPOS. They may also be enabled or disabled by any executive or task in the program (see ENABLE and DISABLE commands). A task may disable itself. If a task is disabled, it cannot be initiated.

**Statements**

As shown in figure 15 the functions of executives and tasks are defined in terms of statements. The STATEMENT construct is shown in figure 18. The executive and task statements are processed by the RTMPL utility to formulate the executable part of programs. Three types of statement are defined in RTMPL—assignment, conditional, and command. Assignment statements are used to establish values for local variables (those defined in the program containing the statement). Conditional statements are used to test values and to take specified actions depending on the result of the test. Command statements are used to provide simulation control, sequencing, and linkage to

![Task definition](image)
simulator hardware and software components. These statement types are described in detail in the sections Assignments, Conditionals, and Commands.

Statements may be labeled by the user. Labels are names and are enclosed by the underscore character "_". If a statement is not labeled by the user, the utility will supply a label based on the order of the statement in the program. The special assembler character "$" is used to generate this label. For example, the first statement in the program would be labeled by the utility as $S1 if it were not assigned a label by the user. User-assigned labels must be unique names within the program.

Statements are limited to 3200 characters, excluding spaces, returns, and line feeds. These three characters are ignored by the utility, providing flexibility for the user in formatting the source program. The number and complexity of statements are essentially unlimited by the utility. However, they are limited by the amount of user memory available in the host computer and the amount of program memory available in the target computer.

Assignments

The ASSIGNMENT construct is defined in figure 19. The "=" character is used to denote the assignment of the computed value of an expression to a local variable. Although many languages (e.g., Pascal and Ada) denote assignments by the ":=" combination (to differentiate an assignment from an equality), RTMPL depends on the user to properly apply the "=" character. All local variables should appear as the result of assignment. The utility will flag those that do not (Data-Base Files, Chapter 9). Data type (I, S, F, or B) must be maintained within an assignment (see the section Expressions). The expression must result in a value whose data type is the same as that of the local variable.

Conditionals

The CONDITIONAL construct is defined in figure 20. A conditional statement consists of the key word "IF" followed by an underscore character (all RTMPL key words are terminated by an underscore character in source programs), a Boolean expression (true or false value), the key word "THEN" (and its underscore character), a series of statements to be executed if the expression's value is true, and optionally, the key word "ELSE" (and its underscore character) and a series of statements to be executed if the expression's value is false. Note that a Boolean expression may be formed from arithmetic expressions (data type I, S, or F) through conjunction with conditional operators (<, #<, =, #=, >, #>). The conditional operators are defined in table 11. For example, for integer expressions A, B, and C, the Boolean expression

A < B = C

will be true if the value of A is arithmetically less than B and the value of B is equal to the value of C; otherwise the Boolean expression will be false. The Boolean
The "A" character in RTMPL is interpreted as a logical NOT.

Expressions

An RTMPL expression is an ordered string of operation/operand pairs that is logically formulated by the user to produce a value. Two types of EXPRESSION constructs are available: the arithmetic expression (fig. 21(a)) and the Boolean expression (fig. 21(b)). They differ in the type of value they produce and in the set of operations available. A Boolean expression can contain only Boolean operands (DTP = B). An arithmetic expression can contain only arithmetic operands of the
same data type (integer (I), scaled fraction (S), and floating point (F)).

The data type of the value produced by the expression must be consistent with the data type requirement of the statement containing the expression. The required data type of an assignment statement is always the data type of the local variable receiving the assignment. The required data type of a conditional statement is always Boolean. Arithmetic expressions that are compared, by using conditional operators, must have consistent data types across those operators. For example, an integer value cannot be compared with a scaled-fraction value.

The available RTMPL arithmetic and Boolean operators are given in table III. Both sets contain unary and binary operators. Unary operators have a single operand and must appear only at the beginning of an expression. The "null" unary operator is contained in each set to indicate that a unary operator is not necessary unless a "negate" or "logical not" operation is required. Binary operators have two operands and must always be preceded and followed by an expression.

Each operation is assigned the corresponding parsing value listed in table III. These values are used by the RTMPL utility to establish the order of calculation in the expression. Generally an expression is parsed from right to left. An operator (and associated operands) is placed in the sequence when a subsequent operator has a parsing value not greater than its own. For example, the expression

\((- A \cdot B/C + D - E)\)

would be parsed as

\[\text{SAVE} = D - E \quad \text{RESULT} = - A \quad \text{RESULT} = \text{RESULT} \cdot B \quad \text{RESULT} = \text{RESULT} / C \quad \text{RESULT} = \text{RESULT} + \text{SAVE}\]

This parsing rule should be followed by the user in writing an expression.

Operands for arithmetic and Boolean expressions are defined in figure 22. Four operand types are common to both:

1. Argument
2. Multivariable function
3. Unary function
4. Parenthetical expression

Boolean expression operands include the implicitly defined Boolean constants TRUE and FALSE and target Boolean variable names.

The basic operand type is the ARGUMENT construct (fig. 13). This allows any constant or variable defined in the simulation to be specified as an operand as long as its data type is consistent with the required data type of the

![Operand diagram](a) Arithmetic expression.

### Table III. — RTMPL Operators

#### (a) Arithmetic expression

<table>
<thead>
<tr>
<th>Operator</th>
<th>Type</th>
<th>Interpretation</th>
<th>Parsing value</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Unary</td>
<td>Negate</td>
<td>0</td>
</tr>
<tr>
<td>+</td>
<td>Unary</td>
<td>No operation</td>
<td>0</td>
</tr>
<tr>
<td>Null</td>
<td>Unary</td>
<td>No operation</td>
<td>0</td>
</tr>
<tr>
<td>+</td>
<td>Binary</td>
<td>Add</td>
<td>1</td>
</tr>
<tr>
<td>-</td>
<td>Binary</td>
<td>Subtract</td>
<td>2</td>
</tr>
<tr>
<td>/</td>
<td>Binary</td>
<td>Divide</td>
<td>3</td>
</tr>
<tr>
<td>*</td>
<td>Binary</td>
<td>Multiply</td>
<td>4</td>
</tr>
</tbody>
</table>

#### (b) Boolean expression

<table>
<thead>
<tr>
<th>Operator</th>
<th>Type</th>
<th>Interpretation</th>
<th>Parsing value</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Unary</td>
<td>Logical NOT</td>
<td>0</td>
</tr>
<tr>
<td>Null</td>
<td>Unary</td>
<td>No operation</td>
<td>0</td>
</tr>
<tr>
<td>$</td>
<td>Binary</td>
<td>Logical AND</td>
<td>1</td>
</tr>
<tr>
<td>#$</td>
<td>Binary</td>
<td>Logical NAND</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>Binary</td>
<td>Logical OR</td>
<td></td>
</tr>
<tr>
<td>#%</td>
<td>Binary</td>
<td>Logical NOR</td>
<td></td>
</tr>
</tbody>
</table>

Figure 22. - Operand specification.
expression. Specifying an external variable as an operand will cause that variable's value to be transferred to the local program during execution; specification of an external constant as an operand will cause that constant to be defined in the local program file.

An operand may be a parenthetical expression (i.e., an expression enclosed within parentheses). This definition does not preclude nested parentheses. For example, the complex expression

\[-((A/(B + C) + D)*E)\]

contains the following parenthetical expressions as operands:

Operand 1: \((B + C)\)
Operand 2: \((A/\text{OPERAND 1} + D)\)
Operand 3: \((\text{OPERAND 2} \times E)\)

Since each parenthetical expression produces a value, the use of parenthetical expressions as operands dictates the parsing sequence of the complex expression. Parenthetical expressions are always parsed from the inside out.

RTMPL supports two types of functional operands: (1) unary functions, which are functions of a single variable (e.g., \(\text{SINE}(\text{ANGLE})\)) and (2) multivariable functions, which may have eight variables (e.g., \(\text{INTEGRAL}([\text{RESULT}, \text{GAIN}, \text{DERIVATIVE}]\)). RTMPL does not contain any inherent functions of either type. That is, the specific functions available to the user are those that have been established during the RTMPL utility implementation on the host computer. These functions are implemented as assembly language macros and are defined in the target definition files. The user should become familiar with those functions that are available for the target simulator.

Functions produce values of specified data type. The user must select functions that are compatible with the required data type of the expression. For example, an implementation of the utility might support the sine function for both scaled-fraction and floating-point numbers (named \(\text{SINSF}\) and \(\text{SINFP}\), respectively). Use of \(\text{SINSF}\) in an expression that is required to produce a floating-point value would be flagged as an error by the utility.

All unary function names must be immediately followed by an expression in parentheses. This expression provides the value of the function argument. The unary function argument must always be of the same data type as the function. For computational sequencing the parsing value of any unary function is assumed by the utility to be zero. The computational sequence of

\((A + \text{SINE}(B + D))\)

would be

\[\text{RESULT} = B + D\]
\[\text{RESULT} = \text{SINE} (\text{RESULT})\]
\[\text{RESULT} = A + \text{RESULT}\]

The arguments of multivariable functions are enclosed in brackets and separated by commas. The arguments may be any expression with the following restrictions:

1. The functional arguments must not contain other multivariable function operands. Therefore multivariable functions may not be nested within expressions.
2. The data types of the function arguments must correspond to those specified in the target definition of the function. Unlike unary functions the data types of the function arguments have no required relationship to the data type of the expression containing the function.

For computational sequencing the parsing value of any multivariable function is assumed by the utility to be zero. The computational sequence of

\((A + \text{INTEGRAL}([\text{STATE1}, \text{K/J}, \text{B*C}]\))\)

would be

\[\text{ARG1} = \text{B*C}\]
\[\text{ARG2} = \text{K/J}\]
\[\text{RESULT} = \text{INTEGRAL}([\text{STATE1}, \text{ARG2}, \text{ARG1}]\)
\[\text{RESULT} = A + \text{RESULT}\]

Note that the value of each functional argument is determined in sequence from right to left.

The RTMPL utility translates operators and functions into target-defined macro operations that are assembly language equivalents to the operator/function for the required data type. If an operator/function does not have a macro equivalent for the required data type, the utility will flag an error in the listing. To produce the desired precision of operator values and to accommodate particular sources of operands (e.g., register and memory), the target definition files can contain more than one macro equivalent for an operator for the required data type. For example, the \(\text{"+"}\) binary operator for integer data types might be supported by the macro's named

\[\text{ADDSI1RR ADDS11RM ADDS11RI}\]
\[\text{ADDSI2RR ADDS12RM}\]
\[\text{ADDSI3RR ADDS13RM}\]

where \(\text{ADDS}\) denotes the operation, \(I\) denotes integer data type, the numbers \((1,2,3)\) denote the precision of the result value, and the trailing letters specify the source of the operands. The operand source letters—R, M, and I—specify register, memory, and immediate data sources, respectively. A function can have only a single macro equivalent. The precision of its result and the source of its operands are inherent in its name.
For operators the utility may choose a macro equivalent. In those cases the utility will first look for a macro that provides the maximum precision of the operands. If a macro equivalent providing this required precision does not exist, the required precision will be reduced until one is found. If the precision of the selected macro equivalent is less than the required precision of the expression, a warning is issued in the listing. After the precision-based search is completed, the utility next tries to find a suitable macro equivalent that corresponds to the operand sources.

Once the “best” macro equivalent has been selected, the operands are adjusted accordingly by inserting housekeeping macros into the computational sequence. These housekeeping macros consist of precision conversions, loading registers from memory, loading registers with immediate data, and storing registers into scratch pad memory. These operations, of course, result in less accuracy and longer execution times. To aid the user in reformulating the program to improve accuracy and shorten execution time, a warning is issued each time a precision conversion macro is inserted into the computational sequence. This allows the user to reconsider the precision specified for the constants or variables identified in the warnings.

After the parsing of scaled-fraction expressions the RTMPL utility will scale the computational sequence. Since only binary scale factors are allowed in specifying RTMPL variables and constants, a scaling macro is inserted where required in the computational sequence. This macro shifts the result of the preceding operation to produce the required scaling. Whenever a scaling macro is inserted, a warning is issued in the listing file. The user may use these warnings to improve the accuracy and shorten the execution time of the simulation. Initially the user may specify the scale factors of variables and constants to be just large enough to handle the expected maximum values. Using the scaling warnings from successive passes of the source files through the utility, the user may then adjust the scale factors according to the warning messages. Minimizing the number of warning messages shortens the execution time of the simulation. Special warnings are issued by the utility whenever a scale factor of a variable or constant is required to be larger than that specified by the user. This warning implies a potential overflow and should be given special attention. Underflows may also result from improper scale factor or precision assignments, but these are not detected by the RTMPL utility.

Commands

RTMPL provides 13 command statements to allow the user to implement program control, to interface to target-defined states, to utilize target library procedures, and to communicate between the various processors in the simulator. The availability of these commands to the user requires the generation and definition of the corresponding target macros for the RTMPL utility during system implementation. Since many of the commands depend on the configuration, firmware, and data paths in the simulator, the user should refer to simulator targeting information for command availability and description. Use of undefined command statements in user programs will be flagged as errors by the RTMPL utility.

The COMMAND construct is defined in figure 23. Commands consist of key words (always followed by an underscore) and a command-dependent extension.

REDO and EXIT Commands

The REDO and EXIT commands are provided to enhance the flexibility of conditionals. RTMPL does not provide loop execution constructs such as

FOR ... DO ...
REPEAT ... UNTIL ...
WHILE ... DO ...

The REDO and EXIT commands, when properly used within a conditional structure, can provide the same effect. For example, to raise a variable A to its Nth power (N ≥ 1), a Pascal programmer could write

B := A;
FOR I := 2 TO N DO B := B*A; A := B;

An RTMPL equivalent is

I = ONE;
MULTIPLY_ B = B*A;
I = I + ONE;
IF_ I < N THEN_ REDO_ MULTIPLY;! A = B;

In general, an RTMPL requires more statements. However, the RTMPL program statements more closely reflect the actual machine operations and usually result in more time-efficient codes. This is important in developing real-time simulations, where minimization of computation time can mean the difference between success and failure.

As an example of the use of the EXIT command, consider the programming of Newton’s method for determining the square root of a positive number. In Pascal

ROOT := 1;
WHILE ABS(NUMBER/SQR(ROOT) - 1) > EPSILON DO
ROOT := (NUMBER/ROOT + ROOT)/2;

The RTMPL equivalent is
EXIT command, execution of the EXIT command will transfer program control to the statement following the exclamation point associated with the current conditional level. By supplying an operand, one can specify the conditional level to be exited. The statement

`EXIT_TESTROOT;`  

would result in the same branching as the previous example.

To program the complex conditional logic contained in the Pascal statement

```pascal
IF ((A < B) AND ((C < D) OR (E < F))) THEN G := H;
```

the RTMPL user could write

```rtmpl
_DOLOGIC_IF_A < B THEN_IF_C# < D THEN_IF_E# < F THEN_EXIT_DOLOGIC;!!
G := H;!!
```

The double exclamation point terminates the C# < D and E# < F conditionals so that G := H will be computed if either conditional is false. Otherwise the conditional labeled "DOLOGIC" will be terminated and program control will be passed to the statement following the last conditional terminator(!!).

The redo command allows the user to specify any previously defined label as the operand and thus permits backward jumps only. REDO may be used only within a conditional statement. EXIT also may be used only within a conditional statement to terminate the execution of that or a higher level conditional statement.

**ENABLE and DISABLE Commands**

The ENABLE and DISABLE commands allow the user to enable or disable the execution of any task defined in the program file. A task is executed only if the task is enabled (see ENTER and DISPATCH commands). Tasks may also be enabled or disabled at run time by using RTMPOS.

**ENTER Command**

The ENTER command causes program control to pass from an executive to a specified task if that task is enabled. It is valid only if used in an EXEC record. That is, a task cannot enter another task. The statements

```rtmpl
ENTER_TASKA;
ENTER_TASKB;
```

cause sequential execution of TASKA and TASKB. Upon completion of TASKA (see RETURN command)
program control would revert to the executive, which would then transfer control to TASKB.

To minimize execution time, the ENTER command, by itself, does not preserve data registers. However, if executives of different priorities can execute a task, the RTMPL utility will change the ENTER command to a REENTER command. This will cause data registers to be preserved for reentry. The REENTER command is not available to the user but will appear on listings when generated by the utility. Scratch-pad memory conflicts are avoided by having a task scratch pad contained within executive memory space.

**DISPATCH Command**

The DISPATCH command is used to restrict execution of a task until all of the external variables required by that task are available. It is valid only when used in an EXEC record. The target processor can sense through firmware when variables have been transferred to its memory from another processor. The statement

```
DISPATCH TASKA, TASKB, TASKC;
```

will cause the local PREP to cyclicly test required variables for each task. If the variables for a task have arrived, the task is executed and marked complete. If a task is disabled, it is marked complete without variable testing. Upon completion of TASKB, for example, the processor would continue cyclic testing of TASKC and TASKA until they have also been marked complete. When all tasks are completed, they are remarked incomplete and the statement following DISPATCH is executed.

The RTMPL utility determines what external variables are necessary for DISPATCH. The utility does not provide for task reenterability when executed under DISPATCH. To avoid the problem, the user should only dispatch tasks from background executives.

**SET and RESET Commands**

The SET and RESET commands are used to manipulate the values of target Boolean variables. For example, the target processor may contain a bit in its status register that is a target Boolean variable called OVERFLOW. If the bit is automatically set when an arithmetic operation results in a register overflow condition, the statements

```
A = B + C
IF_ OVERFLOW THEN_
A = AMAX;
RESET_ OVERFLOW ;!
```

will test the bit for an overflow in the computation of A. If an overflow occurs, A will be limited and the bit reset in the status register. RESET assigns the Boolean value FALSE to a target state variable; SET assigns the Boolean value TRUE to a target state variable.

**EXECUTE Command**

The EXECUTE command is a general-purpose command that permits the user to execute any target-defined macro. Uses for this command depend strictly on the simulator definition. For example, a simulator macro could be defined that copies the value of the program counter into a preassigned location and terminates simulation processing. The macro could be called HALT. Then the statement

```
EXECUTE_HALT;
```

would cause execution of that macro. The present version of the utility does not permit the use of the EXECUTE command for macros requiring arguments.

**CALL Command**

The CALL command is used to invoke target library procedures. These procedures are prewritten during system installation and are, as needed, linked to the user's program during generation of the assembly language program. Target library procedures communicate with calling programs via argument groups (Argument Groups, Chapter 4). Argument groups contain constants and variables of the same data type and precision. The RTMPL utility structures the assembly language representations of the argument groups and the CALL command to pass the number of items in the group, the address of each item, and a processed value for each item to the procedure (Assembler Source Files, Chapter 9). The processed value may be used as an input argument to the procedure (formulated by other procedures or by RTMPOS) or as an output argument (formulated by the procedure itself). Processed values should not be confused with assigned values, which are results of assignment statements (variables) or defined values (constants). Assigned values may be used as input arguments for procedures. These are obtained from the specified item address. RTMPL assumes that an assigned value will never be an output argument of a procedure, although this is possible.

Target library procedures are useful for processing large volumes of data for display or analysis. Since their execution will normally be time consuming, they are usually not called from simulation programs but rather from RTX programs. For example, assume a procedure called SAMPLE exists in the target library and that its purpose is to obtain current values of single-precision, scale-fraction variables for output to data files. The user would first define an ARGGROUP to specify those variables:
ARGGROUP: SAMPDATA = S1, 25 [A,B,C,D]; EOR;

This example specifies SAMPDATA as an argument group of DTP = S1 with a maximum of 25 items and initialized to contain four variables (A, B, C, and D). The procedure SAMPLE would be invoked as

CALL_SAMPLE[SAMPDATA];

When executed, SAMPLE would obtain current assigned values of A, B, C, and D and would store these values in their respective processed-value locations for use by the calling program. The calling program could then output the data to the disk by using the ADVISE command (see the next section). At run time SAMPDATA could be edited by RTMPOS to add up to 21 additional items of the same DTP to the argument group. Item removal and replacement is also possible.

The CALL construct (fig. 23) allows more than one (up to eight) ARGGROUP's to be specified as procedural arguments. This feature accommodates those procedures that require arguments of multiple data type and precision. Before using this construct the user should become familiar with the procedures contained in the target library and with their argument requirements.

ADVISE Command

ADVISE is used to interface a user program to RTMPOS. It consists of the command name, an action code, and an object. The action code is separated from the object by a decimal point. Table IV defines the function of the various action codes. For example, one could display a message, defined in the global data file as

MESSAGE:
T5LIMIT = STATION*TEMPERATURE*LIMIT*EXCEEDED; EOR;

by using the message advisory command

ADVISE_M.T5LIMIT;

When the command statement is executed, the T5LIMIT message appears on the terminal screen. If the action code were changed to an "H," the simulation would stop. With the "M" action code the simulation continues.

The "R" action code (read advisory) causes the referenced argument group to be read from local memory and processed (filed or displayed) by the operating system (RTMPOS). For example, to send the SAMPDATA argument group to a disk file after sampling, the statements would be

CALL_SAMPLE[SAMPDATA];

ADVISE_R.SAMPDATA;

Because of the multitude of data that can be transferred by using the read advisory, it may only be used in programs that are to reside on processors with direct access to the interactive information bus (COMP's).

Execution of the ADVISE command causes a priority interrupt to be issued from the local processor to the FEP. The FEP stops executing the RTMPOS background executive, obtains the action code and object from the local processor, and takes appropriate action. The RTMPOS background executive is then resumed. This priority processing ensures prompt action when executing the ADVISE command statement. Local processor program execution is delayed, as required, for memory access by the FEP. This delay could be substantial during processing of an "R" action. These delays must be considered by the user when structuring the simulation programs. In most cases it is best to issue advisories from processors intended for the RTX function.

ACTIVATE Command

ACTIVATE provides the mechanism for initiating execution of foreground (priority level > 0) executives on the alternate processor in the local channel (i.e., a PREP may activate a COMP EXEC and vice versa). The operand must be the name of a foreground executive defined in the alternate processor program. For example, suppose that, in the program file DSCPREP.CHANNELA, a foreground EXEC record is defined as

EXEC: DOTASKS [1];
ENTER_TASKA; ENTER_TASKB;
EOR;

and that the companion COMP file (DSC.CHANNELA) contains the statement

ACTIVATE_DOTASKS;

Upon execution of the ACTIVATE command statement, the COMP would issue an interrupt to the PREP. The PREP would respond by reading the desired priority level (1) specified by the operand DOTASKS. From this the
PREP would determine the foreground executive to be executed. If a lower priority executive were active (the background EXEC in this case), its execution would be interrupted, DOTASKS would be executed, and the execution of the interrupted EXEC would be resumed. If a higher priority executive were active, DOTASKS would be placed in a pending queue. It would then be executed when all higher priority EXEC's were completed.

RETURN Command

RETURN is used to terminate the execution of executives and tasks and must always be the last executable statement in each. It may also be contained within the body of a task or executive to allow termination as the result of conditionals. Execution of RETURN in a task restores program control to the executive from which the task was entered. If the task is reenterable, the saved registers will be restored. Execution of RETURN in an executive transfers program control to the next lowest priority executive pending (see ACTIVATE command). If no foreground executive is pending, the background executive is resumed. If the RETURN command is encountered in a background executive, program control returns to the processor's firmware.
Chapter 6: RTMPL Simulation

The programming of a simple multiprocessor simulation will be used to illustrate some major operational aspects of the RTMPL utility and as an example of the object and listing files. In this chapter the simulation is described, the RTMPL source files are generated, and the use of the RTMPL utility to process these files is presented.

Description

A jet engine dual-exhaust-nozzle system is illustrated in figure 24(a). The nozzle system was chosen as the simulation example because the mathematical model of the nozzle (also shown) is fairly simple and lends itself to straight-forward partitioning into multiprocessor programs. The nozzle is modeled as two separate nozzles fed by separate core (CN) and duct (DN) sections of a turbofan engine (not simulated). It is assumed that the inlet conditions for the core and duct nozzles are known. They are pressures (PCN, PDN), temperatures (TCN, TDN), and weight flow rates (WCN, WDN). Both gas flows exit at the ambient pressure, PO. In the simulation the flow areas of both nozzles (ACN, ADN) are to be calculated with the constraint that the sum of the physical areas for the two nozzles is equal to the actual physical area (AN).

For the purpose of the example it is assumed that AN is specified as an input to the simulation and is read at the start of each computation interval through an analog-to-digital converter (ADC). For this simulation PCN, PDN, TCN, TDN, WCN, and P0 will be parameters. These parameters can be adjusted by the user at run time by using RTMPOS. The duct weight flow (WDN) and the core and duct nozzle areas (ACN, ADN) will be calculated variables. Finally it is assumed that the variables ACN and ADN will be output from the simulation through a digital-to-analog converter (DAC).

Mathematical Model

For the dual-exhaust-nozzle system the given values are P0, PCN, KCN, WCT, TCN, AN, PDN, KDN, and TDN. All variables are expressed as computer variables to avoid dual definitions and are presented in table V. The equations used to model the system are
**TABLE V.—SIMULATION VARIABLES AND PARAMETERS**

<table>
<thead>
<tr>
<th>Identification</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>Total nozzle physical area</td>
<td>Variable</td>
</tr>
<tr>
<td>ANF</td>
<td>Total nozzle flow area</td>
<td>Variable</td>
</tr>
<tr>
<td>CFLC</td>
<td>Flow coefficient (core)</td>
<td>Variable</td>
</tr>
<tr>
<td>CFFN</td>
<td>Flow function (core)</td>
<td>Variable</td>
</tr>
<tr>
<td>CFFNA</td>
<td>CFFN intermediate calculation (core)</td>
<td>Variable</td>
</tr>
<tr>
<td>CFFNB</td>
<td>CFFN intermediate calculation (core)</td>
<td>Variable</td>
</tr>
<tr>
<td>DFLC</td>
<td>Flow coefficient (duct)</td>
<td>Variable</td>
</tr>
<tr>
<td>DFFN</td>
<td>Flow function (duct)</td>
<td>Variable</td>
</tr>
<tr>
<td>DFFNA</td>
<td>DFFN intermediate calculation (duct)</td>
<td>Variable</td>
</tr>
<tr>
<td>DFFNB</td>
<td>DFFN intermediate calculation (duct)</td>
<td>Variable</td>
</tr>
<tr>
<td>P0</td>
<td>Ambient exhaust pressure</td>
<td>Parameter</td>
</tr>
<tr>
<td>PRC</td>
<td>Core nozzle pressure ratio</td>
<td>Variable</td>
</tr>
<tr>
<td>PCN</td>
<td>Core nozzle inlet pressure</td>
<td>Parameter</td>
</tr>
<tr>
<td>TCN</td>
<td>Core nozzle inlet temperature</td>
<td>Parameter</td>
</tr>
<tr>
<td>WCN</td>
<td>Core nozzle inlet weight flow</td>
<td>Parameter</td>
</tr>
<tr>
<td>ACN</td>
<td>Core nozzle flow area</td>
<td>Variable</td>
</tr>
<tr>
<td>ACNA</td>
<td>ACN intermediate calculation</td>
<td>Variable</td>
</tr>
<tr>
<td>PRD</td>
<td>Duct nozzle pressure ratio</td>
<td>Variable</td>
</tr>
<tr>
<td>PDN</td>
<td>Duct nozzle inlet pressure</td>
<td>Parameter</td>
</tr>
<tr>
<td>TDN</td>
<td>Duct nozzle inlet temperature</td>
<td>Parameter</td>
</tr>
<tr>
<td>WDN</td>
<td>Duct nozzle inlet weight flow</td>
<td>Parameter</td>
</tr>
<tr>
<td>WDNB</td>
<td>WDN intermediate calculation</td>
<td>Variable</td>
</tr>
<tr>
<td>WDNRC</td>
<td>WDN intermediate calculation</td>
<td>Variable</td>
</tr>
<tr>
<td>ADN</td>
<td>Duct nozzle flow area</td>
<td>Variable</td>
</tr>
<tr>
<td>PREPDONE</td>
<td>Interchannel logic variable</td>
<td>Variable</td>
</tr>
<tr>
<td>DUCTDONE</td>
<td>Interchannel logic variable</td>
<td>Variable</td>
</tr>
<tr>
<td>JOBDONE</td>
<td>Program-complete logic variable</td>
<td>Variable</td>
</tr>
</tbody>
</table>

\[
\text{AN} = \text{AN} + 800, \quad \text{where} \quad 50 \leq \text{AN} \leq 1600. \quad (1)
\]

\[
\text{ANF} = 1.049 - 1.622E - 4 \times \text{AN} \quad (2)
\]

\[
\text{PRC} = \frac{\text{P0}}{\text{PCN}} \quad (3)
\]

\[
0.825 \quad \text{if CFLC} \leq 0.825
\]

\[
\text{CFLC} = 1.3635 - 0.7158 \times \text{PRC} \quad (4)
\]

\[
1.0 \quad \text{if CFLC} \geq 1.0
\]

\[
\text{CFFNA} = \text{PRC}^{0.7143} \quad (5)
\]

\[
\text{CFFNB} = [1.0 - \text{PRC}^{0.2857}]^{1/2} \quad (6)
\]

\[
\text{CFFN} = \begin{cases} 
0.2588 & \text{if PRC} \leq 0.53 \\
\text{CFFNA} \times \text{CFFNB} & \text{if PRC} > 0.53 
\end{cases} \quad (7)
\]

\[
\text{PRD} = \frac{\text{P0}}{\text{PDN}} \quad (8)
\]

\[
\text{ACNA} = \text{KCN} \times \text{WCN} \times \text{TCN}^{1/2} \quad (9)
\]

\[
\text{ACN} = \begin{cases} 
0.0 & \text{if CFFN} \leq 0.0 \\
\text{ACNA} \times \text{CFFN} \times \text{CFLC/PC} & \text{if CFFN} > 0.0 
\end{cases} \quad (10)
\]

\[
\text{ADN} = \begin{cases} 
0.0 & \text{if ACN} = 0.0 \\
\text{ANF} - \text{ACN} \quad (11)
\end{cases}
\]

\[
\text{DFLC} = \begin{cases} 
1.575 - \text{PRD} & \text{DFLC} \leq 0.825 \\
1.0 & \text{DFLC} \geq 1.0
\end{cases} \quad (12)
\]

\[
\text{DFFNB} = \text{PRD}^{0.7143} \quad (13)
\]

\[
\text{DFFNB} = [1.0 - \text{PRD}^{0.2857}]^{1/2} \quad (14)
\]

\[
\text{WDNA} = \text{KDN} \times \text{TDN}^{1/2} \quad (15)
\]

\[
\text{DDFN} = \begin{cases} 
0.2588 & \text{if PRD} \leq 0.53 \\
\text{DFFNA} \times \text{DFFNB} & \text{if PRD} > 0.53
\end{cases} \quad (16)
\]

\[
\text{WDNB} = \text{DFFN} \times \text{DFLC} / \text{WDNA} \quad (17)
\]

\[
\text{WDNC} = \text{PDN} \times \text{WDNB} \quad (18)
\]

\[
\text{WDN} = \text{ADN} \times \text{WDNC} \quad (19)
\]

**Model Partitioning and Allocation**

Before the model can be described in RTMPL, it must be partitioned and the resulting segments allocated to the processors in a selected configuration. The partitioning and allocation will depend on the number of channels in the simulator and the availability of COMP and PREP processors in the channels. Although the actual partitioning of mathematical models is not a primary topic of this report, it will be helpful to understand how the example problem was partitioned and how data were transferred between the channels. Figure 24(b) shows a data flow diagram of the equations in the nozzle model. Note from the structure of the diagram that the model naturally breaks up into parallel segments, as indicated by the dashed line. The only "crosstalk" between the segments is the WDN calculation, which needs ADN from segment 1 and WDCN from segment 2. However, to demonstrate the transfer of data in RTMPL, the diagram was broken up into two segments, as indicated by the solid line. The calculations of both WDCN and WDN were put into segment 1.

Since the model breaks up into two segments, three channels were used: two channels for the model calculations (the DSC channels) and one for the input/output and user interaction (the RTX channel). Since it is assumed that there is a COMP and a PREP in each channel, the problem was further broken up into six segments as shown in figure 25, which was derived from...
the data flow chart (fig. 24(b)). In figure 25, variables within the oval elements represent the equations used to calculate the variables. Other program functions are shown in rectangles. In general, the segments were partitioned and allocated to demonstrate RTMPL rather than the solution of the problem. For a time-critical problem care must be taken in allocating calculations. The philosophy used for the example problem allocation is as follows:

1. Channel 1 was selected as the RTX channel.
   (a) It was assumed that the PREP processor in channel 1 is connected to the outside world through ADC and DAC. Since it is desired to read AN from an ADC, the calculation of ANF was assigned to that channel.
   (b) The COMP processor in channel 1 was used for the input and adjustment of PCN, PO, etc., and for user interaction with the simulation.

2. Channel 2 was designated as the segment 1 channel. In general, calculations were distributed between the COMP and the PREP to demonstrate data transfers. For example, variables CFFNA and WDNC must be transferred from the channel 2 PREP to the channel 2 COMP. Also ANF must be transferred from the channel 1 PREP to the channel 2 COMP.

3. Channel 3 was used as the segment 2 channel. Here also calculations were distributed between the COMP and the PREP to demonstrate data transfers. For example, DFLC and DFFNA must be transferred from the channel 3 PREP to the channel 3 COMP. Note also that WDNB must be transferred from the channel 3 COMP to the channel 2 PREP.

Thus the arbitrary breakup of the model has variables transferred from (1) a PREP to a COMP in the same channel, (2) a PREP in one channel to a COMP in another channel, and (3) a COMP in one channel to a PREP in another channel.

Channel and processor assignments are shown on the left side in the computational flow diagram (fig. 25). The string of calculations/operations assigned to each processor is shown on the right side. Data transfer between processors is also indicated. Boolean variables PREPDONE, DUCTDONE, and JOBDONE were added to the simulation simply as a mechanism to demonstrate the ADVISE command. Although providing
some data transfer synchronization, they are unnecessary since the RTMPL utility automates this synchronization (Information Transfer, Chapter 1).

Depending on the application of a simulation it is often desirable to include certain analytical computations to permit the gathering of data, the monitoring of simulator performance, and the control of the simulation execution. Under RTMPOS many analytical functions can be performed. Many of the RTMPL constructs are designed to support analytical functions. As discussed earlier, advisories allow the user to display messages and to stop execution on the basis of simulation performance. They also support the gathering of data structured in terms of argument groups. The CALL command allows analytical routines from the target library to be incorporated into the simulation. Task enabling and disabling may be used to control the execution of the analytical functions (as well as the mathematical model). The ACTIVATE command may be used to trigger analytical functions on the alternate processor in a channel on the basis of occurrences in the local processor's calculations. The example simulation incorporates many of these constructs.

At run time the user specifies the parametric values and sets the simulation calculation update interval by using RTMPOS. During execution the simulation is repetitively calculated, once each update interval. The calculations on each processor proceed sequentially, as diagrammed in figure 25. The following paragraphs describe the desired sequence of operations.

The PREP in the RTX channel (channel 1) reads the ADC for AN, and computes the flow area, ANF, for use on the COMP in channel 2. Its task is then complete until the mathematical model has been computed. This is determined by the Boolean variable JOBDONE, calculated on the COMP in channel 2. When JOBDONE becomes true, the channel 1 PREP writes ACN, ADN, CFFNB, and DFFNB to DAC's and advises the operator of the completion of the calculation sequence.

The DSC PREP in channel 2 controls the Boolean variables PREPDONE and DUCTDONE. They are used on the channel 2 COMP to advise the operator of calculation delays if the channel 2 PREP or channel 3 data (respectively) have not arrived when required to complete the channel 2 COMP calculations. Note that CFLC and CFFNA are required for calculating ACN. PREPDONE is set after their calculation. The channel 2 PREP then computes WDNC on the basis of WDNB computed in channel 3. When this calculation is complete, DUCTDONE is set. The channel 2 COMP then completes its calculation sequence by computing ADN and WDN and then setting JOBDONE true.

The channel 3 processors work in tandem to calculate WDNB. Another PREPDONE variable is used to signal the operator of calculation delay due to PREP data (DFFNA) not arriving on time to complete the calculation of WDNB on the COMP.

The COMP processor in the RTX channel (channel 1) is assigned the task of sampling simulation data and transferring these data to the FEP for analysis. Argument groups are used in developing the RTX COMP to present the run-time selection of the data items to be sampled.

**Model Translation to RTMPL**

RTMPL contains both a programming language for the mathematical model on the parallel processors and a set of commands for coordinating execution and obtaining data and for interaction of the simulation with the user and the real-time world. The different aspects of the language will be covered in the context of the sample problem.

Equations (1) to (19) must be converted to RTMPL by using the constructs defined in figures 10 to 12 and 18 to 22. This will be done for each channel and processor according to the variable distribution in figure 25. Note that no simulation equations are assigned to channel 1 COMP, which is reserved for analysis functions.

**Channel 1 PREP**

The only two equations solved on the channel 1 PREP are equations (1) and (2). The constants in these equations are 1.049, 1.622E-4, 50., 800., and 1600. From the definitions of figure 12

\[
\begin{align*}
K1P049 &= S1/1[1.049]; \\
K1P622M4 &= S1/1[1.622E-4]; \\
MINAREA &= S1/1[50.]; \\
MAXAREA &= S1/1[1600]; \\
K2 &= S1/1[800.];
\end{align*}
\]

The variables are AN and ANF. From the variable definition of figure 11

\[
\begin{align*}
AN &= S1/1[1600.]; \\
ANF &= S1/1[1263.168.]
\end{align*}
\]

From figures 19 to 21(a) equation (1) becomes

\[
\begin{align*}
AN &= AN + K2; \\
\text{IF} \_ AN < \text{MINAREA} & \text{THEN} \_ AN = \text{MINAREA}; \\
\text{ELSE} \_ & \text{IF} \_ AN > \text{MAXAREA} \text{THEN} \_ AN = \text{MAXAREA}; \!
\end{align*}
\]

Equation (2) becomes
ANF = K1P049 - K1P622M4 * AN; \quad (21)

**Channel 2 PREP**

The equations solved on the channel 2 PREP are (3) to (5) and (18). The constants are \( P0, \) \( PCN, 1.3635, 0.7158, 0.825, 1.0, \) and \( PDN. \) From the construct of figure 12

\[
\begin{align*}
K1P3625 & = S1/1[1.3625]; \\
KP7158 & = S1/0[.7158]; \\
KP825 & = S1/0[.825]; \\
K1P & = S1/1[1.0]; \\
P0 & = S1/6[14.7]; \\
PCN & = S1/7[14.7]; \\
PDN & = S1/7[14.7];
\end{align*}
\]

The variables are \( PRC, \) \( CFLC, \) \( CFFNA, \) \( WDNC, \) and \( WDNB. \) From the construct in figure 11

\[
\begin{align*}
PRC & = S1/1[1./1.]; \\
CFFNA & = S1/1[1./1.]; \\
CFLC & = S1/1[.825/.825]; \\
WDNC & = S1/2[.825/.825];
\end{align*}
\]

\( WDNB \) comes from channel 3 COMP, and from the figure 13 construct it is referenced as

\[
\langle \text{channel 3 name}. \rangle . C. WDNB
\]

The equations are translated to RTMPL. From figures 19 and 21(a) equation (3) becomes

\[
PRC = P0/PCN; \quad (22)
\]

and equation (4), from figures 19 to 21(a), becomes

\[
CFLC = K1P3625 - K1P7158 * PRC; \quad (23)
\]

\[
\begin{align*}
\text{IF} & \quad \text{CFLC} > K1P \\
\text{THEN} & \quad \text{CFLC} = K1P; \\
\text{ELSE} & \quad \text{IF} \quad \text{CFLC} < KP825 \\
\text{THEN} & \quad \text{CFLC} = KP825; !!
\end{align*}
\]

Equation (5) is an exponential and can be solved by using a univariate function. The function will be defined as \( \text{FUN1} \) with the construct

\[
CFFNA = \text{FUN1}[\text{PRXVALS}, \text{PRNVALS}, \text{XT07143}, \text{PRC}]; \quad (24)
\]

where

\[
\text{PRNVALS} = 11[21];
\]

\[
\text{PRXVALS} = S1/1,21[0., .05, .10, .15, .20, .25, .30, .35, .40, .45, .50, .55, .60, .65, .70, .75, .80, .85, .90, .95, 1.0];
\]

\[
\text{XT07143} = S1/1,21[0.000, .1177, .1931, .2579, .3166, .3820, .4232, .4724, .5197, .5653, .6095, .6524, .6943, .7351, .7751, .8142, .8527, .8904, .9275, .9640, 1.000];
\]

The method is to calculate \( PRC, \) search the range of \( \text{PRXVALS}, \) find the corresponding values in \( \text{XT07143}, \) and interpolate.

Equation (18) involves a transfer variable \( WDNB: \)

\[
WDCN = PDN * \langle \text{channel 3 name}. \rangle . C. WDNB; \quad (25)
\]

**Channel 2 COMP**

The equations solved on the channel 2 COMP are (3), (6), (7), (9) to (11), and (19). The constants are \( P0, \) \( PCN, 1.0, \) \( KCN, 0.2588, \) \( WCN, TCN, 0.53, \) and \( 0.0. \) From the constructs of figure 12

\[
\begin{align*}
P0 & = S1/6[14.7]; \\
PCN & = S1/7[14.7]; \\
K1P & = S1/1[1.0]; \\
KCN & = S1/0[.5124]; \\
KP2588 & = S1/1/- 1[.2588]; \\
KP53 & = S1/0[.53]; \\
ZERO & = S1/0[0.]; \\
WCN & = S1/8[0.]; \\
TCN & = S1/13[900.];
\end{align*}
\]

The variables are \( PRC, \) \( CFFNB, \) \( ACNA, \) \( CFFN, \) \( ACN, \) \( CFLC, \) \( CFFNA, \) \( ADN, \) \( WDN, \) \( ANF, \) and \( WDNC. \) From the construct of figure 11

\[
\begin{align*}
PRC & = S1/1[1./1.]; \\
CFFNB & = S1/1[1./1.]; \\
ACNA & = S1/11[0., 0.]; \\
CFFN & = S1/2[0., 0.]; \\
ACN & = S1/10[0., 0.]; \\
ADN & = S1/10[0., 0.]; \\
WDN & = S1/9[0., 0.];
\end{align*}
\]

\( \text{CFLC, CFFNA, and WDNB are variables transferred from the channel 2 PREP. Thus from the construct of figure 13 these variables are referenced as } \langle \text{channel 2 name}. \rangle . \text{P.CFLC, } \langle \text{channel 2 name}. \rangle . \text{P.CFFNA, and } \langle \text{channel 2 name}. \rangle . \text{P.WDNB, respectively.} \)

\( \text{ANF is transferred from the channel 1 PREP and referenced as} \)

\[
\langle \text{channel 1 name}. \rangle . \text{P.ANF}
\]
From figures 19 and 21(a), equation (3) becomes

\[
PRC = P0/PCN; \quad (26)
\]

Note that this equation was also implemented on channel 2 PREP to avoid data transfer delays. Equation (6) uses the FUN1 function and a square root univariate function (SQRT):

\[
FFNB = SQRT(KP5 - FUN1(PRXVALS, PRNVALS, \\ XT02857, PRC)); \quad (27)
\]

where

\[
PRNVALS = 11[21]; \\
PRXVALS = S1/1,2[etc.]; \\
XT02857 = S1/1,2[etc.];
\]

Equation (9) becomes

\[
ACNA = KCN * WCN * SQRT(TCN); \quad (28)
\]

From figures 19 to 21(a) equation (7) becomes

\[
IF\_PRC > KP53 \\
THEN\_CFFN = KP2588; \\
ELSE\_CFFN = CFFNB * P.CFFNA; ! \quad (29)
\]

Equation (10) becomes

\[
IF\_CFFN > ZERO \\
THEN\_ACN = ACNA * CFFN * P.CFLC/PCN; \\
ELSE\_ACN = ZERO; ! \quad (30)
\]

Equation (11) becomes

\[
IF\_ACN = ZERO \\
THEN\_ADN = ZERO; \\
ELSE\_ADN = (CHANNEL 1 name).P.ANF - ACN; ! \quad (31)
\]

Equation (19) becomes

\[
WDN = ADN * P.WDNC; \quad (32)
\]

**Channel 3 PREP**

Equations (8), (12), and (13) are solved on the channel 3 PREP. The constants are P0, PDN, 1.575, 0.825, and 1.0. From the construct in figure 12

\[
P0 = S1/6[14.7]; \\
PDN = S1/7[14.7]; \\
KP575 = S1/1[1.575]; \\
KP825 = S1/0[.825]; \\
K1P = S1/1[1.]
\]

The variables are PRD, DFLC, and DFFNA. From the construct in figure 11

\[
PRD = S1/1[1./1.]; \\
DFLC = S1/1 [.825/.825]; \\
DFFNA = S1/1[1./1.];
\]

From figures 19 and 21(a) equation (8) becomes

\[
PRD = P0/PDN; \quad (33)
\]

and equation (12) becomes

\[
DFLC = KP575 - PRD; \\
IF\_DFLC > KP575 \\
THEN\_DFLC = KP575; \\
ELSE\_ \\
IF\_DFLC < KP825 \\
THEN\_DFLC = KP825; !! \quad (34)
\]

Equation (13) becomes

\[
DFFNA = FUN1(PRXVALS, PRNVALS, XT07143, \\ PRD); \quad (35)
\]

**Channel 3 COMP**

The equations solved on the channel 3 COMP are (8) and (14) to (17). The constants are P0, PDN, 1.0, KDN, TDN, 0.2588, and 0.53. From the constructs in figure 12

\[
P0 = S1/6[14.7]; \\
PDN = S1/7[14.7]; \\
TDN = S1/13[900.]; \\
KDN = S1/0[.50655]; \\
K1P = S1/1[1.]; \\
KP2588 = S1/0[.2588]; \\
KP53 = S1/0[.53];
\]

The variables are PRD, DFFNB, WDNA, DFFNA, DFFN, WDNB, and DFLC. From figure 11

\[
PRD = S1/1[1./1.]; \\
DFFNB = S1/1[1./1.]; \\
WDNA = S1/8[151.665/151.665]; \\
DFFN = S1/2[0./0.]; \\
WDNB = S1/5[0./0.];
\]

DFFNA and DFLC are transfer variables from the channel 3 PREP; thus from figure 13, they are referenced.
as .P.DFFNA and .P.DFLC, respectively. From figures 19 and 21(a) equation (8) becomes

\[ \text{PRD} = \frac{P_0}{PDN}; \]  

(36)

Using the SQRT and FUN1 functions we get equation (14) as

\[ \text{DFFNB} = \text{SQRT}(K1P - \text{FUN1}[PRXVALS,PRNVALS,XT02857,PRD]); \]  

(37)

Equation (15) becomes

\[ \text{WDNA} = KDN \times \text{SQRT(TDN)}; \]  

(38)

Equation (17) becomes

\[ \text{WDNB} = \text{DFFN} \times \frac{.P.DFLC}{\text{WDNA}}; \]  

(39)

From figures 19 to 21(a) equation (16) becomes

\[ \text{IF}_- \text{PRD} > KP53 \]  

THEN

\[ \text{DFFN} = KP2588; \]  

ELSE

\[ \text{DFFN} = \text{DFFNB} \times \text{.P.DFFNA}; \]  

(40)

**Example Source Files**

The required RTMPL source files are a control file, a global data file, and program source files for the various processors. The files are shown in figure 26 and will be described in detail for the example problem.

**Control Segment Source File**

The control file for the simulation is arbitrarily named "DUALSIM" and is shown in figure 26(a). The construct for the file is given in figure 7. In the file the...
Figure 26. - Continued.

(c) DATAPROC channel, PREP program.

(d) DATAPROC channel, COMP program.

Figure 26. - Continued.
name of the simulation is DUALNOZZ; the volume (or disk) for the source, object, and data base is DEV1; the user number is 0; the number of channels is three. The first channel is RTX.DATAPROC; the second is DSC.CORESIM; the third is DSC.DUCTSIM. There will be global data, so GLOBAL.DUALNOZZ is specified, and the target file catalog name is MC68000. The global file name and the program file names—one for each of the six processors—must be the same as specified in the control file. The file names are

Channel 1 program file:
DEV1:0.RTXPREP.DATAPROC.SA
DEV1:0.RTX.DATAPROC.SA

Channel 2 program file:
DEV1:0.DSCPREP.CORESIM.SA
DEV1:0.DSC.CORESIM.SA

Channel 3 program file:
DEV1:0.DSCPREP.DUCTSIM.SA
DEV1:0.DSC.DUCTSIM.SA

Global file:
DEV1:0.GLOBAL.DUALNOZZ.SA

This is a VERSAdos format.
Global Data Segment Source File

The global data file format (fig. 9) consists of global constant (GLCNST) and message (MESSAGE) records. For the dual-nozzle simulation the file is shown in figure 26(b). Note that the MESSAGE record contains eight messages that can be invoked at different parts of the simulation to advise the user of the simulation progress. The GLCNST record consists of all constants to be distributed to all channels. The dot in front of the constant means that the constant is a parameter. Note that the vectors needed for the FUN1 function are also included in the global data.

Program Source Files

RTMPL program files consist of at least one EXEC record and can include VARIABLE, CONSTANT, ARGGROUP, and TASK records. The construct for the program file is shown in figure 8. The construct, along with the computational flow diagram of figure 25, was used to create the program files for the six processors.

Channel 1 PREP.—Channel 1, the RTX channel, is given the name DATAPROC. The file name for the PREP is DEV1:0.RTXPREP.DATAPROC.SA. The file (fig. 26(c)) consists of one EXEC, three TASK, two ARGGROUP, one CONSTANT, and one VARIABLE record. The EXEC record is

EXEC:GETAN[O];

Since the first part of the diagram in figure 25 says to read an ADC for variable AN, the executive was arbitrarily named GETAN and given a zero priority level (fig. 7), which is a background or lowest priority (fig. 15) job.

The actual reading of the ADC is done with the CALL... command (fig. 23):
CALL_ READ[ADCVAR,ADCCHN];

where READ is the target procedure, ADCVAR is an argument group containing the variable AN, and ADCCHN is an argument group containing the ADC channel number. ANF is then calculated by using equations (20) and (21). Note that the ACTIVATE command is used (fig. 23) if AN>MAXAREA or AN<MINAREA. This sends an interrupt to the DATPROC COMP and the corresponding EXEC (BADADC) is activated there. Next a Boolean variable is checked to see if the simulation has completed the calculation of WDN in the channel 2 COMP. The ENTER command (fig. 23)

ENTER_ JOBDONE;

is used, where JOBDONE is a task that does the actual testing and must be defined in this source file.

After execution of the JOBDONE task, ACN and ADN are written to DAC's by using the DISPATCH_command from figure 23:

DISPATCH_ WRTACN,WRTADN;

where WRTACN and WRTADN are tasks that must be records written in this source file. The RETURN_command from figure 23 terminates execution of the EXEC. Finally an EOR completes the record.

The WRTACN task record is then defined:

.TK1 =I1[1];

where the ‘‘[’’ indicates that it is a parameter, adjustable at run time.

Argument groups are then defined for the read procedure. The construct is shown in figures 8 and 14.

ADCVAR =S1/32[AN];
ADCCHN =I1/32[K1];

For illustration the size of these argument groups is greater than one. Size 32 indicates that 32 variables can be read on 32 channels by adding items to these groups at run time.

Channel 1 COMP.—The file name for the COMP processor is DEV1:0.RTX.DATPROC.SA. The file (fig. 26(d)) consists of two EXEC'S, one TASK, and one ARGGROUP. The constructs for the records are given in figures 16 and 18 to 22.

The first executive is defined as

EXEC:MAIN[0];

This EXEC is given the name MAIN with priority 0 (fig. 17), meaning it is a background EXEC (fig. 15). Its purpose is to sample the values of variables at each cycle of computation. The ENTER command (fig. 23) is used to begin execution of GETDATA, which is a task to be defined later. GETDATA will do the actual sampling and transfer the data to RTMPOS.

The second executive

EXEC:BADADC[1];

is defined to service the ACTIVATE command used in the PREP. The priority 1 indicates that this foreground executive will have priority over the background executive. This executive will halt the simulation if the AN value read from an ADC is outside the MINAREA to MAXAREA range. ADVISE_ prints a message from the MESSAGE record in the global data file. This task can be disabled at run time by RTMPOS to enable continuous simulation.

ACNG and ADNG are needed for the write-to-DAC tasks. They are formed by using figures 8, 13, and 14. An additional constant is defined as the AAC channel number:

Channel 2 PREP.—Channels 2 and 3 are used to simulate the model equations. The channel 2 PREP program file (fig. 26(e)) is called DEV1:0.
DSCPREP.CORESIM.SA. It consists of one EXEC, one CONSTANT, and one VARIABLE record. The executive is defined as

EXEC:PRFCTNS [0];

It is a background executive. The two Boolean variables PREPDONE and DUCTDONE are set false to indicate that calculations have not been completed. Values for PRC, CFLC, and CFFNA are then calculated. These calculations are given in equations (22) to (24). The PREPDONE variable is set true to indicate that the calculations have been completed. WDNC is then calculated from equation (25) (where “channel 3 name” is DUCTSIM). The variable DUCTDONE is set true to indicate that the WDNC calculations have been completed. The Boolean variables are defined, by figure 11, as

PREPDONE = B[TRUE/FALSE];

DUCTDONE = B[TRUE/FALSE]

Channel 2 COMP.—The channel 2 COMP source file is called DEV1:0.DSC.CORESIM.SA. The file (fig. 26(f)) consists of one EXEC, one CONSTANT, and one VARIABLE record. The executive is defined as

EXEC:MAINSIM[0];

The EXEC is given the name MAINSIM with priority 0. The variable JOBDONE is set to false to indicate that calculations for this pass through the model have not begun. PRC is then calculated from equation (26). If the calculation overflows, the ADVISE command is used to halt the simulation and give the CORESIM1 message from the global data file. CFFNB and ACNA are then calculated from equations (27) and (28). A test is then made to see if the channel 2 PREP Boolean variable PREPDONE has been set true. If PREPDONE = TRUE, no data transfer delay has been encountered. Otherwise

_ADVISE_.M.COREMES3;

causes a printout that there is a delay. CFFN and ACN are then calculated from equations (29) and (30). If DUCTDONE is true, calculations can continue; otherwise

ADVISE_.M.COREMES4;

causes a printout of the COREMES4 message from the global data file. The variables ADN and WDN are then calculated from equations (31) and (32). Note that DATAPROC is the name for channel 1. The variable JOBDONE (referenced in channel 1) is set true to indicate that the calculations have been completed. The variable

JOBDONE = B[TRUE/FALSE];

is added to the variables for this processor.

Channel 3 PREP.—The channel 3 PREP source file (fig. 26(g)) is called DEV1:0.DCSROUTE.DUCTSIM.SA. It consists of one EXEC, one CONSTANT, and one VARIABLE record. The executive is defined as

EXEC:PRFCTNS[0];

This is a background executive. The Boolean variable PREPDONE is set false to indicate that the calculations have not been completed. PRD is calculated from equation (33). The target Boolean variable, OVERFLOW, is checked and, if true, command causes the simulation to halt and CORMES2 from the global data file is printed out. DFLC and DFFNA are calculated from equations (34) to (35). PREPDONE is set true to indicate that these calculations have been completed for the channel 3 COMP check. From the construct in figure 11

PREPDONE = B[TRUE/FALSE];

is added to the program variables.

Channel 3 COMP.—The channel 3 COMP program file (fig. 26(h)) consists of three records: one EXEC, one CONSTANT, and one VARIABLE. The name of the file is DEV1:0.DSC.DUCTSIM.SA. The name of the file is DEV1:0.DSC.DUCTSIM.SA. The executive is defined as

EXEC:COPROCES[0];

The EXEC name is COPRESS with priority 0. The variables PRD, DFFNB, and WDNA are calculated from equations (36) to (38). Then if PREPDONE is set true, the calculations can continue; otherwise

ADVISE_.M.DUCTMESS;

causes the DUCTMESS from the global data file to be printed. WDNB and DFFN are calculated from equations (39) and (40).

In this example, it is assumed that the following macros have been written and specified for the appropriate data types in the target definition file:

FUN1 multivariable function that provides table lookup and interpolation according to value of input variable

SQRT unary function that returns square root of operand
Additionally, it is assumed that target library procedures exist for the following:

**READ**  reads specified ADC channels and stores values in specified variables

**SAMPLE** assembles values of specified variables into argument group format

**DAC1, DAC2** writes values to DAC channels

The example source files are intended to illustrate many aspects of RTMPL. However, it was impractical to develop an example that illustrated all aspects. The RTMPL utility is designed to aid the inexperienced user in becoming proficient in the language (e.g., it contains a multitude of warnings and error messages). True competence will come only with hands-on programming experience.
Chapter 7: Using the RTMPL Utility

The RTMPL utility is designed to function under a disk operating system (DOS). The DOS file and input/output handlers are used to read and write the files required by the utility. The utility provides one link in a chain of DOS services necessary to bring a simulation from concept to execution. It is assumed that the initial simulation concept has been developed. That is,

1. The equations describing the system to be simulated have been partitioned and assigned to simulation channels. The equations for each channel have been partitioned (if required) and assigned to the COMP and PREP.
2. The necessary real-time data analysis and input/output computations have been defined for the RTX channel.
3. The complete set of RTMPL source files has been generated.

The source files are then processed by the RTMPL utility, producing data-base files for use by the RTMPOS utility and translated source files for the target assembler. The listing files produced by the RTMPL and assembler utilities and the results from their execution are available to the user for documenting and refining the simulation (if necessary).

The RTMPL utility is invoked by using the DOS command

\[
\text{RTMPL(DEF), (LIST); Z=} \text{(SIZE)}
\]

This invocation is the form used in the VERSAdos disk operating system. The user should refer to specific system documentation if another DOS is used. Although command formats may differ between installations, the information required in the command line is generic (with the possible exception of SIZE). DEF is the identification of the simulation control file and LIST is the name of the file designated to receive the listing. Both of these files may be devices (the former being an input/output device, such as the user’s terminal, and the latter an output device, such as a printer). SIZE is a designation used by the DOS in assigning memory segments for utility use.

The amount of memory required depends on the size of the simulation and must be determined by the user. Generally 500K bytes are sufficient for a typical simulation.

After the command has been invoked, the utility will read the simulation control file. If the file has been assigned a device name (e.g., "#", representing the user's terminal), the utility will prompt the user for the required information. The simulation control file, DUALSIM, for the dual-nozzle example is given in figure 26(a), where the entries correspond to the utility control segment structure in figure 7 and the options listed in table 1.

For the dual-nozzle example the RTMPL invocation

RTMPL DUALSIM, #PR; Z = 100

will process the source files of figure 26 according to the simulation control file, DUALSIM, and will provide a listing file on the printer device (#PR). It reserves 100K bytes of memory for RTMPL use. In this case the input and output files are defaulted to the user’s terminal.

In the resulting user-terminal display (fig. 27) the RTMPL header is followed by the RTMPL interpretation of the simulation control file. The general format for each line is

\[
\text{(PROMPT)} = \text{(TERMINAL ENTRY); (RETURN)***}
\]

(file entry)

If the user terminal, rather than the DUALSIM file, had been identified as the simulation control file in the RTMPL invocation, the display would pause after "=" for user entry at the terminal. After each "****", the RTMPL interpretation of the entry is displayed. Any detected entry errors are displayed after the entry.

After all entries have been processed, the total number of errors detected is displayed. If any errors have been detected, RTMPL processing is aborted. Otherwise utility execution pauses at this point (for 15 sec) to allow the user to review the simulation definition. If the user does not intervene (e.g., to redefine the simulation), the RTMPL utility processes the simulation source files.
As shown in figure 28, each major step in processing the simulation source files is displayed on the terminal. The global data file GLOBAL.DUALNOZZ is processed first. At this point the specified listing file #PR is opened. The global data file is then read. If errors are detected in the file structure, RTMPL processing is aborted. Otherwise each record in the global data file is syntactically tested and transferred to the simulation data base being established by the utility. All messages, tasks, and global constants are thereby established for later reference by the program files. If any syntactical errors are detected, RTMPL processing is aborted. Otherwise the utility processes each program source file. Again, file structure is tested. If the structure is correct, the utility processes
The RTMPL utility provides an extensive listing designed to aid the user in developing accurate time-optimized simulations. The listing also provides the documentation necessary to track simulation development and to allow engineering level interactive execution. The listing is generated concurrently with the processing of the simulation source files. Therefore, if the utility aborts because of source file errors, sufficient information should be available in the listing to aid in correcting the errors.

The listing consists of two major parts—scan and documentation. These parts are further divided into a number of phases. The parts and phases are discussed here in terms of their relationships to simulation development and documentation. The discussion will use the dual-nozzle example listing (appendix A) as illustration. References to that listing include the listing page number, which appears on the the header line on each page. The header line also lists the simulation name (DUALNOZZ) and the date and time of the listing generation.

Scan Listing

This part of the listing provides the user with information obtained during syntactic and semantic verification of the simulation by the utility. It has two phases: the scan of the data segments, and the scan of the execution segments. The second phase is obtained only if no errors are recorded in the first phase.

Listing pages 1 to 3 in appendix A show the results of the dual-nozzle data segment scan. The global messages and constants are scanned first. The listing of global operational tasks is included to service future extensions of RTMPL and should be ignored. After the global data are scanned, the local constants and variables in each program file are processed. (The execution segments (executives and tasks) are also identified although their statements are not processed until the next scan phase.) Finally the argument groups in each source program are processed.

The simulation example contains no errors. If errors were detected, they would be listed in the appropriate segment of the scan in a self-descriptive format. All RTMPL error messages are listed in appendix B. The general error and warning format is:

(SOURCE DEFINITION)

(ERROR!) (MESSAGE) (specifics)

The offending source definition is listed verbatim. The errors are then listed; the designation (ERROR!) is followed by a message and specifics. The message describes the offense in general terms. The specifics relate the message to the specific part of the definition that is causing the problem. For example, the constant definition:

CONSTANT:
ABC?DEF12=S1/07 2 [2., O.L] EOR;

would produce the following error listing in the scan:

ABC?DEF12=S1/07 2 [2., O.L.];

ERROR! NAME EXCEEDS 8 CHARACTERS;
ABC?DEF12
ERROR! NONALPHANUMERIC CHAR(S) IN NAME: ABC?DEF12
ERROR! NUMBER TOO LARGE FOR SCALE FACTOR: 2
ERROR! ILLEGAL CHAR IN INTEGER: L

In this example the constant name exceeds eight characters and contains an nonalphanumeric character. The scale factor (2”) is not large enough to scale the specified value, 2. Finally the use of an alphabetic character (L) in the integer value was flagged as an error.
For the sake of clarity some messages will contain specifics within the message. For example,

ERROR! UNDEFINED FOREGROUND EXEC (FOREEXEC) IN PROGRAM

where "FOREEXEC" and "PROGRAM" would be specific source program names. The second phase of the scan is the processing of the statements that are in the execution segment of each source program. This phase is illustrated on listing pages 4 to 6. The results for each executive and task in each source program are listed. Again no errors were encountered in the example. However, a multitude of warning messages were issued. Their format is similar to that for error messages. All RTMPL warnings are listed in appendix B.

Warnings are included in the listing to advise the user of potential problems or to suggest possible changes to the source programs that could reduce the time or improve the accuracy of the computations. On listing page 4, statement 2 of the GETAN executive causes the warning

WARNING! AN MAY NOT BE COMPUTED YET (PAST VALUE USED)

This occurs because the utility has not detected AN as the result (i.e., appearing on the left) of a previous equivalence statement. In this case, AN was derived by using the target procedure READ and the user would simply ignore the warning. Statement 9 in the GETAN executive causes the following to be issued:

WARNING: CONSTANT RESCALING ENCOUNTERED: K1P049 RSF = 11 NSF = 1

*** CREATED SC$1 FOR RESCALING OF K1P049

The nominal scale factor (NSF) is that assigned to a variable or constant by the user in the data segment. The required scale factor (RSF) is that required to make the resulting scale factor of an expression compatible with the required scale factor of the statement containing the expression. This warning indicates that the constant K1P049 requires a scale factor of $2^{11}$ (scale factor on ANF) instead of the specified 21. No user action on this warning is required since a system constant (SC$1$) is automatically created by the utility with the proper value and scale factor. Note that a similar warning is issued for statement 2 of the MAINSIM executive (listing page 5). In this case, however, a system constant is not created by the utility since P0 has been defined as a global parameter. The utility will scale as required to produce the specified result. The user could, however, improve the computational speed (eliminate an internal scaling operation) by redefining the nominal scale factor assigned to P0.

Statement 2 of the MAINSIM executive also produces the warning

WARNING! CONSTANT PRECISION ADJUSTMENT: P0 RPRC = 2 NPRC = 1

The nominal precision (NPRC) is that assigned to a variable or constant by the user in the data segment. The required precision (RPRC) is that required to make the resulting precision of an expression compatible with the required scale factor of the statement containing the expression. This warning is issued because the divide macro, selected from the target definition files, requires a double-precision operand but P0 was defined as a single-precision parameter. The utility will insert the proper precision conversion macro. However, calculation time will be reduced and perhaps accuracy will be improved if the user redefines P0 as a double-precision parameter.

A final illustration of RTMPL warnings is shown for statement 23 of the MAINSIM executive.

WARNING! MULTIPLE ASSIGNMENT OF JOBDONE

is issued to indicate that the variable JOBDONE has appeared more than once on the left side of an equivalence (statement 1 also). In this case the dual assignment was intentional and the warning would be ignored.

Documentation Listing

Documentation, the second part of the listing, is provided if RTMPL processing has not encountered errors during scan. This part is made up of a number of phases, depending on the number of errors during scan. They are

(1) General simulation information
(2) Global data segment
(3) Local data segment
(4) Executable statement segment

Phases 3 and 4 are repeated for each source program.

In the first phase (listing pages 7 to 9) information contained in the control segment is listed and all files used during utility operation are identified. The source, target, and object files are listed. The object files consist of assembler source files and data-base files. Each assembler source file corresponds to an RTMPL program file. Two types of data-base files are identified: global and program specific. The latter are produced for each source program. The number of records in each file is also
identified. These files need not concern the general user since they are used at run time by the RTMPOS operating system (see the section Data-Base Files).

The global data segment listing is shown on listing pages 10 to 12. The operational messages are identified and listed. The global constants are identified as well as their data type and precision, values, scale factors, if any, and whether or not the constant is parametric. If a constant is multivalued, the values are tabulated below the main identification table. The first value in the multivalue table for PRXVALS is read as "one value at zero."

The last table in the global data segment listing identifies the transfer maps for data transmission in the simulation. The table specifies the source channel and processor and the variable name and destination channel. If a variable is only transferred to the other processor in its channel, that is designated "local." The table further specifies the transfer address in the destination channel's external memory and the address where the transfer map is stored. Finally it specifies the data path to be used to implement the transfer.

The local data segment for the COMP in the DATAPROC channel is given on listing pages 13 to 14. Other local data segments are given on subsequent listing pages to illustrate this listing phase. During this phase the characteristics of local variables, external variables, local constants, arguments, executives, and tasks are tabulated.

Local variables are listed in terms of name, data type and precision, values, and scale factor, if any (e.g., listing page 16). Additionally the entry under the XREF header will indicate "YES" if the variable is referenced in another program. The entries under the PVAL header indicate the number of past values associated with the variable. Finally the absolute location of the variable is given. Note that in the DATAPROC (COMP) listing no user-defined variables are listed (listing page 13). Four target state variables are listed. All target state variables defined in the target definition files will always appear in this table. As is true with all variables and constants, an asterisk preceding the name indicates that the item is not used in the execution segment of the simulation.

Variables external to the local program are identified in terms of name and assigned location. The "$0$" appendage to the name indicates that the current value is used.

Local constants (listing page 16) are tabulated in a format similar to that for global constants. In addition, the size (arrayness) and assigned location of the constant are provided. If a local constant is defined globally, it will be so indicated in the value entry. If the value of a constant is used as an immediate data operand only, it will have no location assigned. In this case "$0$-DATA" will appear as its location entry.

Argument groups (listing page 16) are tabulated in terms of name, data type and precision, location, maximum size, number of programmed entries, and an item list. The item list shows each entry to be initially contained in the group. The list may of course be changed at run time. For each entry the type and name are given. The types XV, LV, and CN indicate external variable, local variable, and constant, respectively.

Tasks (listing page 17) are tabulated in terms of name, initial enable latch setting, reenterability, amount of scratch pad memory required, and the locations of the external variables required if the task is referenced in the DISPATCH command.

Executives (listing page 17) are tabulated in terms of name, priority level, service tasks, and scratch pad memory requirements. Three types of scratch pad memory (exec, task, macro) are defined. These need not concern the user: they indicate the amount of temporary memory required to compute the executive proper and its service tasks and macros.

An execution segment listing is illustrated on listing pages 18 and 19. It is the listing for the DATAPROC PREP. The executable statements of each task and executive in the program are interpretively listed to help ensure that the utilities interpretation of the program corresponds to the user's intention. The general listing format is

(STATEMENT NUMBER) (OBJECT LABEL) (STATEMENT) (CALCULATION TIME)

The statement number is relative to its location in the task or executive. The object label is either the statement label assigned in the source or a sequential utility assignment. Utility label assignment is sequential within a program (as opposed to statement numbers, which are sequential within a record). The utility label, SSN, would be assigned to the n-th statement in a program if it was not labeled by the user. The statement, as listed, is an edited version of the corresponding source file statement. Unnecessary constant delimiters (semicolon, underscore, exclamation point) are removed to enhance readability. Furthermore statements within conditionals are indented proportionally to the conditional level to aid in identifying the structure of the program. Heavily nested conditionals can be easily identified.

The calculation time listed to the right of the statement is an estimate (in machine cycles) of how long it will take to compute the statement on the target processor. This number is obtained by adding the calculation time (from target definition files) of each macro used in generating the assembly source for the statement. To convert this number to seconds, the user should multiply it by the cycle time of the target processor. The "MAX PATH EXECUTION TIME" appearing after the listing of the
statements is the number of cycles estimated for the calculation executive or task when the maximum time path is taken through the conditional statements. Note that in the case of the GETAN executive the user should add the times for the library subroutine READ and the tasks JOBDONE., WRTACN., and WRTADN to get the total estimated calculation time of GETAN.

Finally the execution segment phase of the listing lists both the variables computed locally and transferred to other programs and those computed externally and referenced as operands in the local program. This listing is handy when accounting for data transfer times in partitioning the simulation.

The RTMPL listing file was designed to aid the user in creating efficient simulation code. An attempt has been made to have the utility generate meaningful messages to facilitate debugging and program optimization. The information in the listing file, coupled with that in the RTMPL object files, provides a comprehensive description of the simulation.
Chapter 9: RTMPL Object Files

If no errors are encountered during translation of the RTMPL source files and the scan option is not selected, the RTMPL utility will generate two sets of object files—data-base files and assembler source files. The data-base files describe all elements in the simulation. These files are compatible with the RTMPOS operating system and furnish it with the information necessary to allow the user to interactively execute the simulation on the target simulator. The assembler source files provide a fully coded assembly language source program for each processor in the simulation. These files must be assembled on the target macro assembler and linked to form load modules. The load modules are then available for loading through RTMPOS at run time. This section describes these files from a user’s standpoint. For illustration the assembler source files for the DATAPROC channel of the dual-nozzle simulation are listed in appendix C. No illustrations of the data-base files are provided since these are not text files. Note that the format of the assembler source files depends on the requirements of the target processor assembler as specified in the target definition files. The files in appendix C were generated for the MC68000 assembler.

Assembler Source Files

The assembler source files are text files and may be listed by using the DOS. The resource name string used to identify an assembler source file contains the following components:

- LOCATION
- OPERATION
- OPERAND
- COMMENT

Each field is separated by one or more space characters. The location field contains mnemonic descriptors of the statement that are used for memory referencing. If referencing is not required, this field is filled with spaces. The operation field contains a macro name. The target code defined for that name will be substituted by the assembler on the target processor as specified in the target definition files. The files in appendix C were generated for the MC68000 assembler.

FILE NAME logical name assigned to source program channel
EXTENSION “SA,” indicating a text file

The assembler source file names for the dual-nozzle simulation are

DEV1:0.OBJPREP.DATAPROC
DEV1:0.OBJCOMP.DATAPROC
DEV1:0.OBJPREP.CORESIM
DEV1:0.OBJCOMP.CORESIM
DEV1:0.OBJPREP.DUCTSIM
DEV1:0.OBJCOMP.DUCTSIM

The OBJCOMP.DATAPROC and OBJPREP.DATAPROC files are listed in appendix C. The line numbers given are for listing purposes only and they are referenced in the following discussion of the example.

The assembler source files consist of statements and comments. Comments are denoted by an asterisk in the first character location in the line. The comments are ignored by the assembler. Each statement is broken down into the following fields:

LOCATION OPERATION OPERAND COMMENT
(8 characters) (8 characters) (variable) (remainder)

Each field is separated by one or more space characters. The location field contains mnemonic descriptors of the statement that are used for memory referencing. If referencing is not required, this field is filled with spaces. The operation field contains a macro name. The target code defined for that name will be substituted by the assembler for that name in the target macro file. The macro names used in the dual-nozzle simulation are defined in table VI. The available macros would be defined in the systems manual generated for the target simulator during RTMPL installation. The operand field contains the operands to be used by the macro. Multiple
TABLE VI.—DESCRIPTION OF Macros USED IN DUAL-NOZZLE SIMULATION

<table>
<thead>
<tr>
<th>Macro</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVATES</td>
<td>Implement ACTIVATE</td>
</tr>
<tr>
<td>ADDSSIR1</td>
<td>Add immediate data to register (DTP = S1)</td>
</tr>
<tr>
<td>ADVISEHS</td>
<td>Implement ADVISE.H</td>
</tr>
<tr>
<td>ADVISEM</td>
<td>Implement ADVISE.M</td>
</tr>
<tr>
<td>ADVISERS</td>
<td>Implement ADVISE.R</td>
</tr>
<tr>
<td>BACKEXEC</td>
<td>Executive initialization</td>
</tr>
<tr>
<td>CALLS</td>
<td>Implement CALL</td>
</tr>
<tr>
<td>CVPSSI2</td>
<td>Convert precision (1 − 2)</td>
</tr>
<tr>
<td>CVPSSI1</td>
<td>Convert precision (2 − 1)</td>
</tr>
<tr>
<td>DC$</td>
<td>Define constant</td>
</tr>
<tr>
<td>DIVPC</td>
<td>Implement DISPATCH</td>
</tr>
<tr>
<td>DIVSSI1RM</td>
<td>Divide register by memory (DTF = S1)</td>
</tr>
<tr>
<td>DIVSSI2RM</td>
<td>Divide register by memory (DTP = S2)</td>
</tr>
<tr>
<td>DL$</td>
<td>Define 32-bit word</td>
</tr>
<tr>
<td>DNS</td>
<td>Define name</td>
</tr>
<tr>
<td>DSS</td>
<td>Reserve storage</td>
</tr>
<tr>
<td>EQU$</td>
<td>Define address relationships to firmware</td>
</tr>
<tr>
<td>ENTER$</td>
<td>Implement ENTER</td>
</tr>
<tr>
<td>EXITS</td>
<td>Jump to specified argument</td>
</tr>
<tr>
<td>FUN1</td>
<td>Multivariable function</td>
</tr>
<tr>
<td>FOREEXEC</td>
<td>Executive initialization</td>
</tr>
<tr>
<td>HLDSSI1</td>
<td>Store value for comparison</td>
</tr>
<tr>
<td>INCLUDES</td>
<td>Specify macro file</td>
</tr>
<tr>
<td>JFSOVERT</td>
<td>Jump if no overflow</td>
</tr>
<tr>
<td>JGTHSS1</td>
<td>Compare and jump if greater than</td>
</tr>
<tr>
<td>JNEQSS1</td>
<td>Compare and jump if not equal</td>
</tr>
<tr>
<td>JNGTSS1</td>
<td>Compare and jump if not greater than</td>
</tr>
<tr>
<td>JNLTSS1</td>
<td>Compare and jump if not less than</td>
</tr>
<tr>
<td>JTR$</td>
<td>Jump if expression true</td>
</tr>
<tr>
<td>LDISS1</td>
<td>Load register with immediate data</td>
</tr>
<tr>
<td>LDMSBV</td>
<td>Load register from memory (DTP = B)</td>
</tr>
<tr>
<td>LDMSI</td>
<td>Load register from memory (DTP = S1)</td>
</tr>
<tr>
<td>MULSSI2R1</td>
<td>Multiply register by immediate data (DTP = S2)</td>
</tr>
<tr>
<td>MULSSI2RM</td>
<td>Multiply register by memory (DTP = S2)</td>
</tr>
<tr>
<td>MULSSI2RR</td>
<td>Multiply register by register (DTP = S2)</td>
</tr>
<tr>
<td>NOTSVBR</td>
<td>Logical NOT</td>
</tr>
<tr>
<td>ORGS</td>
<td>Define load start address</td>
</tr>
<tr>
<td>REDO$</td>
<td>Implement REDO</td>
</tr>
<tr>
<td>RETURNSE</td>
<td>Return from background executive</td>
</tr>
<tr>
<td>RETURNSI</td>
<td>Return from foreground executive</td>
</tr>
<tr>
<td>RETURNST</td>
<td>Return from task</td>
</tr>
<tr>
<td>SCLISS1L</td>
<td>Scale register left (DTP = S1)</td>
</tr>
<tr>
<td>SCLISS1R</td>
<td>Scale register right (DTP = S1)</td>
</tr>
<tr>
<td>SCLISS2L</td>
<td>Scale register left (DTP = S2)</td>
</tr>
<tr>
<td>SCLISS2R</td>
<td>Scale register right (DTP = S2)</td>
</tr>
<tr>
<td>SLVSS1</td>
<td>Store register in local memory</td>
</tr>
<tr>
<td>SSSPSI1</td>
<td>Store register in scratch pad memory</td>
</tr>
<tr>
<td>STVB$</td>
<td>Send value via local bus (DTP = BV)</td>
</tr>
<tr>
<td>STVSS1</td>
<td>Send value via local bus (DTP = S1)</td>
</tr>
<tr>
<td>STXSBV</td>
<td>Send value via external bus (DTP = BV)</td>
</tr>
<tr>
<td>STXSSI1</td>
<td>Send value via external bus (DTP = S1)</td>
</tr>
<tr>
<td>SUBBSSI1R</td>
<td>Subtract immediate data from register (DTP = S1)</td>
</tr>
<tr>
<td>SUBBSSI1RM</td>
<td>Subtract memory from register (DTP = S1)</td>
</tr>
<tr>
<td>SUBBSSI1RR</td>
<td>Subtract memory from register (DTP = S2)</td>
</tr>
<tr>
<td>SUBBSSI2RR</td>
<td>Subtract memory from register (DTP = S2)</td>
</tr>
<tr>
<td>SQT$</td>
<td>Unary function</td>
</tr>
<tr>
<td>TSTXVAS</td>
<td>Test currency from alternate processor</td>
</tr>
<tr>
<td>TSTXVLS</td>
<td>Test currency from local bus</td>
</tr>
<tr>
<td>XREF</td>
<td>External reference</td>
</tr>
</tbody>
</table>

Operands are separated by commas. In the example listings, “Dn” denotes the nth data register and “An” denotes the nth address register. Register mnemonics are target dependent. The comment field is not processed by the assembler and should be self-explanatory.

Each assembler source file is arranged as follows:

- Required target macros (e.g., lines 9 to 176, OBJCOMP.DATAPROC)
- Control and initialization (e.g., lines 177 to 181, OBJCOMP.DATAPROC)
- Foreground executive maps (e.g., lines 182 to 203, OBJCOMP.DATAPROC)
- Entry addresses (e.g., lines 204 to 210, OBJCOMP.DATAPROC)
- Simulation transfer maps (e.g., lines 211 to 273, OBJCOMP.DATAPROC)
- Transfer memory (e.g., lines 274 to 362, OBJCOMP.DATAPROC)
- Local variables (e.g., lines 502 to 509, OBJPREP.DATAPROC)
- Program constants (e.g., lines 510 to 513, OBJPREP.DATAPROC)
- Dispatch task list (e.g., lines 514 to 518, OBJPREP.DATAPROC)
- Argument groups (e.g., lines 519 to 572, OBJPREP.DATAPROC)
- Executable segment (e.g., lines 573 to 641, OBJPREP.DATAPROC)
- Target procedures (e.g., lines 642 to 647, OBJPREP.DATAPROC)

The following paragraphs describe these components of the assembler source file.

The target macros define the assembly language equivalents for all RTML-generated macros in the program. These include assembly instruction macros such as INITIAL, DATASEG, and DATAEND (lines 9 to 52, OBJCOMP.DATAPROC), RTMPL data transfer operation and command macros (lines 53 to 151, OBJCOMP.DATAPROC), and target library procedures referenced through the use of the CALL command or internally by other macros (lines 152 to 175, OBJCOMP.DATAPROC). The structure and content of these macros are arbitrarily set up by systems programmers to meet specific target simulator requirements.

The first statements to be assembled in every RTMPL-generated program are the control and initialization statements (INITIAL$ and DATASEGS). These statements set up the program for assembly by defining absolute interfaces with the simulator hardware and resident software and by furnishing any other initialization required by the target assembler.

The foreground executive maps are used by the processor’s firmware to service the ACTIVATE
command that appears in the program for the alternate processor in the channel. The first location is reserved to hold the entry address of the active executive. All foreground executives are then listed in decreasing order of priority. For each, the entry address is followed by a busy flag and a pending flag. The busy flag is set by the firmware if that executive is being executed. The pending flag is set if the execution of that executive is being delayed due to the execution of a higher priority foreground executive.

The entry address part of the program contains the entry addresses of all executives and tasks in the program. They are used for various operating system functions at run time.

The simulation transfer maps are used for interprocessor data transmission by the STVS/STXS macros. They list the destination channels for each transfer variable in the simulation. The format is:

Destination channel codes (none, 0, 4, 8, ...)
Expansion (-2)
End of map (-1)

A destination channel code is included for every channel requiring reception of the variable ("0" representing the first channel in the simulation,"4" representing the second, etc.). Since the value of a transfer variable is always stored in the transfer and external memory of the local channel, no destination code is required for the local channel. Expansion (-2) is included to allow the addition of another destination channel to the map at run time. The feature supports the run-time manipulation of argument group entries. The end of the map is signified by −1.

The transfer memory allocation details the variables assigned to transfer and external memory. This allocation as well as the transfer maps is global. Therefore the allocations are identical in all assembler source files in the simulation. Each transfer memory allocation consists of a "CALC FLAG" (set appropriately by the firmware to indicate value currency), an initial-value assignment, and the variable’s transfer map address. These allocations are used by the TSTXVSS/TSTXVLS/TSTXVAS macros to test the currency of data transfer.

Local variable assignment details the memory assignments of all program variables not assigned to either transfer memory or external memory. Program constant assignment details the memory assignments of all program constants. The dispatch task list provides the argument for the DISPATCH command and lists the tasks to be dispatched.

The argument group is represented in the assembler source file by a translation of the ARGGROUP construct. It contains the information supplied by the user in the RTMPL source program formatted into a data record compatible with both the argument requirements of target library procedures and the data-handling requirements of the RTMPOS operating system. In the OBJPREP.DATAPROC listing, lines 523 to 526 reserve memory for record identification information supplied by RTMPOS. This information identifies the record when it is downloaded into a run-time-generated disk file. It contains, among other things, the name of the argument group and the channel. Line 527 specifies the maximum number of items that can be contained in the group. Lines 528 and 529 are for RTMPOS record-keeping. Line 530 specifies the current number of items contained in the group. Line 531 specifies the number of words needed for a value of a group item. Following this are the addresses of all items presently contained in the group and memory reservation for the addresses of items that may be added at run time. Finally memory is reserved for values of each item in the group (line 533). These values are determined by the calling procedure using the group as an argument.

Each target library procedure, invoked by the CALL command, that uses the group as an argument may handle the information described differently. For example, the read procedure invoked in line 579 uses the item addresses in ADCCHN to obtain ADC channel numbers and the addresses in ADCVAR to determine where the data are stored. This procedure does not use the memory reserved for values at all. The sample procedure invoked in OBJCOMP.DATAPROC obtains values from the specified items’ addresses and stores them in the value locations reserved within the data argument group. It is therefore necessary that the user understand the action of all target library procedures invoked.

The executable code segment contains the sequence of assembly language macros corresponding to the executable statements of the source file. This code is separated into executives and tasks as specified in the source file. Each block of code contains overhead information necessary for execution. Executive overhead is as follows:

1) Macro scratch pad allocation—memory reserved for scratch pad required internally by macros resident in either the executive or its service tasks
2) Task scratch pad allocation—memory reserved for scratch pad required for translation of service tasks (reserving task scratch pad here allows tasks to be reenterable)
3) Executive scratch pad allocation—memory reserved for scratch pad required for translation of the executive
4) Entry overhead—memory reserved for register and miscellaneous storage necessary to enter and return from the executive

Memory is allocated by using one of the housekeeping macros BACKEXEC or FOREEXEC.
An example of task overhead is given in lines 415 to 425 of OBJCOMP.DATAPROC. First, the addresses of all external variables referenced in the task are listed, followed by the number of these variables. These overhead items are used in executing task DISPATCH command. The task overhead continues with the location of the task enable and complete latches (see ENABLE and DISABLE commands). Finally, a task entry overhead of two memory words is reserved and assigned the task name. Task execution begins at line 412.

Finally, as shown in lines 645 to 647 of OBJPREP.DATAPROC, all referenced library procedures are invoked by RTMPL. This causes the procedures to be attached to the end of the program and simplifies the program linking process.

Note that the example programs shown in appendix C were targeted to the MC68000 macro assembler. For other processors the basic program structure would be the same, but the macro content could be significantly different.

**Data-Base Files**

Data-base files are not text files and therefore may not be listed by using a standard DOS list command. They are files of Pascal records. Their format should be of no concern to the user (for more information, see ref. 3). Both RTMPL and RTMPOS contain facilities for listing the information contained in the data-base files in a usable form. All pertinent data-base information is given in the RTMPL listing.

The data-base files generated for the dual-nozzle simulation are identified on listing pages 7 to 9 in appendix A. The catalog name (e.g., SIMDEF) indicates the type of information contained in the file. Global data-base files contain information pertaining to the simulation as a whole. Program-specific data-base files contain information pertaining to a particular program.

Six global data-base files may be generated for a simulation. The SIMDEF file always contains one record and roughly corresponds to the simulation control segment. The MESSDEF file contains the global messages. The VALUEDEF file contains all values referenced in the simulation. The GLCDEF file contains the global constants. The OSTSKDEF file is not currently used but is reserved for RTMPL expansion. The PRGDEF file defines each program in the simulation in general terms. Note that, in the listing, if the number of records in a file is 0, the file was not generated for the simulation.

Up to eight program-specific data-base files may be generated for each program in a simulation. LVAR, XVAR, CNST, and AGRP files define the program's local variables, external variables, constants, and argument groups, respectively. The ALST file contains the items assigned to each argument group. The EXEC and TASK files provide pertinent information about the program's execution segment. The TKLB file is used to support the DISPATCH command.

The contents of these files may be modified to some extent by the user, through RTMPOS, to form a run-time data base. Copies of the run-time data base may be saved and used for different simulation starting conditions and to support simulation documentation (ref. 3).
Chapter 10: Concluding Remarks

The real-time multiprocessor programming language (RTMPL) combines the efficiency and versatility of assembly language programming with the advantages of having an easily understood, engineering-oriented, high-level programming language. RTMPL is intended for time-critical applications (e.g., real-time simulation) and is suitable for programming the following simulator configurations:

1. Multiprocessors with dual-bus communication
2. Multiprocessors with single-bus communication
3. Multiprocessors with shared-memory communication
4. Single processor

RTMPL is a structured language that provides many program-development aids to help in producing time-efficient code.

The language is targetable, not only to various simulator configurations, but also to various processors and macroassemblers. A targeting utility is available to automate the targeting procedures. The power of a macro-based language is determined by the assembly language macros written to support it. Multivariable and unary functions, firmware interfacing commands, and target library procedures have been incorporated in RTMPL. Other macros may be incorporated within the language structure to meet specific installation requirements. Since RTMPL supports both fixed-point (scaled fraction) and floating-point data types, operations on these data types can be incorporated (or not) to meet installation needs. For example, if a simulator includes an efficient floating-point processor, macros to support fixed-point operations might not be needed at all.

The versatile targeting capability of RTMPL eliminates the need for designing special compilers or translators. If a new processor and its companion macroassembler fall within the targeting restrictions of the language, RTMPL can easily be targeted to this processor, thereby saving many hours of software development.

RTMPL, coupled with its companion operating system, RTMPOS, provides for interactive execution of multiprocessor simulators at a level comparable to analog computers. Data-base files are generated by the RTMPL utility for use by RTMPOS. This provides an extensive engineering-level interface between the users and the simulation at run time. Listings are provided to establish the dialog and to summarize and document the characteristics of the simulation.

As is the case with initial versions of any language, there is room for improvement in RTMPL. At this time the following enhancements are contemplated:

1. Reducing and streamlining the specifications of data type and precision and scale factor required for defining variables and constants
2. Allowing the use of direct-value specification within expressions
3. Extending the EXECUTE command to accept target-specified arguments
4. Reducing RTMPL processing time by reducing the number of target definition file reads

Since RTMPL is a research language, the implementation of these improvements will depend on user acceptance and response.

The author and other members of the staff at the Lewis Research Center have a continuing interest in improving the cost effectiveness and utilization of real-time simulation. We hope that RTMPL and other RTMPS developments will provide a vehicle for constructive discussion and development of simulation techniques and standardizations to meet these goals.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, January 14, 1985
Appendix A—Listing for Dual-Nozzle Simulation

RTNLPL LISTING : DUALNOZZ 11/27/84 10:28:52 PAGE 1

GLOBAL OPERATIONAL MESSAGES: DEV1:0000.GLOBAL.DUALNOZZ.SA

...8 MESSAGE(S)
...0 ERROR(S)

GLOBAL OPERATIONAL TASKS: DEV1:0000.GLOBAL.DUALNOZZ.SA

...0 TASK(S)
...0 ERROR(S)

GLOBAL CONSTANTS: DEV1:0000.GLOBAL.DUALNOZZ.SA

...20 CONSTANT(S)
...0 ERROR(S)

PROGRAM CONSTANTS: DEV1:0000.RTX.DATAPROC.SA

...0 TASK(S)
...0 ERROR(S)

PROGRAM TASKS: DEV1:0000.RTX.DATAPROC.SA

...0 TASK(S)
...0 ERROR(S)

PROGRAM CONSTANTS: DEV1:0000.RTXPREP.DATAPROC.SA

...6 CONSTANT(S)
...0 ERROR(S)

PROGRAM VARIABLES: DEV1:0000.RTXPREP.DATAPROC.SA

...2 VARIABLE(S)
...0 ERROR(S)

PROGRAM EXECUTIVES: DEV1:0000.RTXPREP.DATAPROC.SA

...0 EXECUTIVE(S)
...0 ERROR(S)

PROGRAM TASKS: DEV1:0000.RTXPREP.DATAPROC.SA

...0 TASK(S)
...0 ERROR(S)
RTMPL LISTING : DUALNOZZ  11/27/84  10:28:52  PAGE 2

...3 TASK(S)
...0 ERROR(S)

PROGRAM CONSTANTS: DEV1:0000.DSC.CORESIM.SA

...5 CONSTANT(S)
...0 ERROR(S)

PROGRAM VARIABLES: DEV1:0000.DSC.CORESIM.SA

...8 VARIABLE(S)
...0 ERROR(S)

PROGRAM EXECUTIVES: DEV1:0000.DSC.CORESIM.SA

...1 EXECUTIVE(S)
...0 ERROR(S)

PROGRAM TASKS: DEV1:0000.DSC.CORESIM.SA

... NONE ENCOUNTERED

PROGRAM CONSTANTS: DEV1:0000.DSCPREP.CORESIM.SA

...4 CONSTANT(S)
...0 ERROR(S)

PROGRAM VARIABLES: DEV1:0000.DSCPREP.CORESIM.SA

...6 VARIABLE(S)
...0 ERROR(S)

PROGRAM EXECUTIVES: DEV1:0000.DSCPREP.CORESIM.SA

...1 EXECUTIVE(S)
...0 ERROR(S)

PROGRAM TASKS: DEV1:0000.DSCPREP.CORESIM.SA

... NONE ENCOUNTERED

PROGRAM CONSTANTS: DEV1:0000.DSC.DUCTSIM.SA

...4 CONSTANT(S)
...0 ERROR(S)

PROGRAM VARIABLES: DEV1:0000.DSC.DUCTSIM.SA

...5 VARIABLE(S)
...0 ERROR(S)

PROGRAM EXECUTIVES: DEV1:0000.DSC.DUCTSIM.SA

...1 EXECUTIVE(S)
...0 ERROR(S)
PROGRAM TASKS: DEUI:0000.DSC.DUCTSIM.SA
..........................................................................
... NONE ENCOUNTERED

PROGRAM CONSTANTS: DEUI:0000.DSCPREP.DUCTSIM.SA
..........................................................................
... 3 CONSTANT(S)
... 0 ERROR(S)

PROGRAM VARIABLES: DEUI:0000.DSCPREP.DUCTSIM.SA
..........................................................................
... 9 VARIABLE(S)
... 0 ERROR(S)

PROGRAM EXECUTIVES: DEUI:0000.DSCPREP.DUCTSIM.SA
..........................................................................
... 1 EXECUTIVE(S)
... 0 ERROR(S)

PROGRAM TASKS: DEUI:0000.DSCPREP.DUCTSIM.SA
..........................................................................
... NONE ENCOUNTERED

PROGRAM ARGUMENT GROUPS: DEUI:0000.RTX.DATAPROC.SA
..........................................................................
... 1 ARGUMENT GROUP(S)
... 0 ERROR(S)

PROGRAM ARGUMENT GROUPS: DEUI:0000.RTXPREP.DATAPROC.SA
..........................................................................
... 4 ARGUMENT GROUP(S)
... 0 ERROR(S)

PROGRAM ARGUMENT GROUPS: DEUI:0000.DSC.CORESIM.SA
..........................................................................
... NONE ENCOUNTERED

PROGRAM ARGUMENT GROUPS: DEUI:0000.DSCPREP.CORESIM.SA
..........................................................................
... NONE ENCOUNTERED

PROGRAM ARGUMENT GROUPS: DEUI:0000.DSC.DUCTSIM.SA
..........................................................................
... NONE ENCOUNTERED

PROGRAM ARGUMENT GROUPS: DEUI:0000.DSCPREP.DUCTSIM.SA
..........................................................................
... NONE ENCOUNTERED
RTMPL LISTING: DUALNOZZ 11/27/84 10:28:52

* * * * * * * * * * * * * * * * *

SCAN - EXECUTABLE SEGMENTS

**DUALNOZZ**

* * * * * * * * * * * * * * * * *

MAIN. EXECUTIVE: DEV1:0000.RTX.DATAPROC.SA

...2 STATEMENT(S)
...0 ERROR(S)

BADADC. EXECUTIVE: DEV1:0000.RTX.DATAPROC.SA

...4 STATEMENT(S)
...0 ERROR(S)

GETDATA. TASK: DEV1:0000.RTX.DATAPROC.SA

...3 STATEMENT(S)
...0 ERROR(S)

GETAN. EXECUTIVE: DEV1:0000.RTXPREP.DATAPROC.SA

2 AN=AN+K2;

WARNING! AN MAY NOT BE COMPUTED YET (PAST VALUE USED)

9 !!ANF=K1P049-K1P622M9*AN;

WARNING! CONSTANT RESCALING ENCOUNTERED:K1P049 RSF=11 NSF=1

*** CREATED SC$1 FOR RESCALING OF K1P049

...12 STATEMENT(S)
...0 ERROR(S)

WRTECN. TASK: DEV1:0000.RTXPREP.DATAPROC.SA

...2 STATEMENT(S)
...0 ERROR(S)

WRTECN. TASK: DEV1:0000.RTXPREP.DATAPROC.SA

...2 STATEMENT(S)
...0 ERROR(S)

JOBDONE. TASK: DEV1:0000.RTXPREP.DATAPROC.SA

...4 STATEMENT(S)
...0 ERROR(S)

MAINSIM. EXECUTIVE: DEV1:0000.DSC.CORESIM.SA

PAGE 4
WARNING! CONSTANT PRECISION ADJUSTMENT :P0  RPRC=2 NPRC=1
WARNING! CONSTANT RESCALING ENCOUNTERED:PO  RPRC=2 NPRC=1

RSF=8 NSF=6

WARNING! CONSTANT RESCALING ENCOUNTERED:K1P  RSF=2 NSF=1

*** CREATED SC#1 FOR RESCALING OF K1P

WARNING! CONSTANT RESCALING ENCOUNTERED:TCN  RSF=12 NSF=13

WARNING! CONSTANT RESCALING ENCOUNTERED:KP2588  RSF=2 NSF=-1

WARNING! VARIABLE RESCALING ENCOUNTERED:ACNA  RSF=20 NSF=11

WARNING! CONSTANT RESCALING ENCOUNTERED:ZERO  RSF=10 NSF=0

WARNING! CONSTANT RESCALING ENCOUNTERED:ZERO  RSF=10 NSF=0

WARNING! MULTIPLE ASSIGNMENTS OF JOBDONE

WARNING! MULTIPLE ASSIGNMENTS OF JOBDONE

WARNING! MULTIPLE ASSIGNMENTS OF PREPDONE

WARNING! MULTIPLE ASSIGNMENTS OF DUCTDONE

WARNING! CONSTANT RESCALING ENCOUNTERED:TDN  RSF=12 NSF=13
WARNING! CONSTANT RESCALING ENCOUNTERED: KP2588  RSF=2 NSF=0
*** CREATED SC*2 FOR RESCALING OF KP2588

...12 STATEMENT(S)
...0 ERROR(S)

PRFCTNS. EXECUTIVE: DEV1:0000.DSCPREP.DUCTSIM.SA

2        PRD=P0/PRD;   RPRC=2 NPRC=1
          WARNING! CONSTANT PRECISION ADJUSTMENT :P0
7        THEN=FLC=KP825; RSF=8 NSF=6
          WARNING! CONSTANT RESCALING ENCOUNTERED: KP825
*** CREATED SC*1 FOR RESCALING OF KP825
9        PREPDONE=TRUE;
          WARNING! MULTIPLE ASSIGNMENTS OF PREPDONE

...10 STATEMENT(S)
...0 ERROR(S)
RTMP LISTING : DUALNOZZ 11/27/84 10:28:52

**GENERAL SIMULATION INFORMATION**

**DESCRIPTION** : RTMP TEST CASE

**ORIGINATORS NAME** : DALE J. ARPASI

**USER NUMBER** : 0000

**SIMULATOR CONFIGURATION** : DUAL

**NUMBER OF CHANNELS IN SIMULATION** : 3

**RTMP SOURCE FILES**

```
DEVI:0000.RTX,DATAPROC,SA
DEVI:0000.RTXPREP,DATAPROC,SA
DEVI:0000.DSC,CORESIM,SA
DEVI:0000.DSCPREP,CORESIM,SA
DEVI:0000.DSC,DUCTSIM,SA
DEVI:0000.DSCPREP,DUCTSIM,SA
```

**GLOBAL SOURCE FILE**

```
DEVI:0000.GLOBAL,DUALNOZZ,SA
```

**TARGET FILES**

```
DEVI:0000,M68000,MACHCHAR,TD
DEVI:0000,M68000,TGTCPCM,TD
DEVI:0000,M68000,TGTPRCDR,TD
DEVI:0000,M68000,TGTODEF,TD
DEVI:0000,M68000,TGTHKDEF,TD
DEVI:0000,M68000,TGUSTDEF,TD
```

**ASSEMBLER SOURCE FILES**

```
DEVI:0000,OBJCOMP,DATAPROC,SA
DEVI:0000,OBJJPREP,DATAPROC,SA
DEVI:0000,OBJCOMP,CORESIM,SA
DEVI:0000,OBJJPREP,CORESIM,SA
DEVI:0000,OBJCOMP,DUCTSIM,SA
DEVI:0000,OBJJPREP,DUCTSIM,SA
```

**GLOBAL DATA BASE FILES**

```
RESOURCE NAME STRING      # OF RECORDS
-------------------------  --------
DEVI:0000.SIMDEF,DUALNOZZ,DB  1
DEVI:0000.MESSDEF,DUALNOZZ,DB  8
DEVI:0000.VALUEDEF,DUALNOZZ,DB 144
DEVI:0000.CLICDEF,DUALNOZZ,DB  12
DEVI:0000.DSTSKDEF,DUALNOZZ,DB  0
DEVI:0000.PRGDEF,DUALNOZZ,DB  6
```
### PROGRAM SPECIFIC DATA-BASE FILES: DATAPROC (COMP)

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<tr>
<th>RESOURCE NAME STRING</th>
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<td>1</td>
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<tr>
<td>DEV1:0000.AGRP.DATAPROC.DB</td>
<td>1</td>
</tr>
<tr>
<td>DEV1:0000.ALST.DATAPROC.DB</td>
<td>16</td>
</tr>
<tr>
<td>DEV1:0000.EXEC.DATAPROC.DB</td>
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</tr>
<tr>
<td>DEV1:0000.TKLB.DATAPROC.DB</td>
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### PROGRAM SPECIFIC DATA-BASE FILES: DATAPROC (PREP)

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<td>7</td>
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<tr>
<td>DEV1:0000.AGRPREPREP.DATAPROC.DB</td>
<td>4</td>
</tr>
<tr>
<td>DEV1:0000.ALSTPREP.DATAPROC.DB</td>
<td>66</td>
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<tr>
<td>DEV1:0000.EXECPREP.DATAPROC.DB</td>
<td>1</td>
</tr>
<tr>
<td>DEV1:0000.TASKPREP.DATAPROC.DB</td>
<td>3</td>
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<td>DEV1:0000.TKLBPREP.DATAPROC.DB</td>
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### PROGRAM SPECIFIC DATA-BASE FILES: CORESIM (COMP)

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<td>DEV1:0000.CNST.CORESIM.DB</td>
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<tr>
<td>DEV1:0000.ALST.CORESIM.DB</td>
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**PROGRAM SPECIFIC DATA-BASE FILES: CORESIM (PREP)**

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<td>DEV1:0000.AGRPPREP.CORESIM.DB</td>
<td>0</td>
</tr>
<tr>
<td>DEV1:0000.ALSTPREP.CORESIM.DB</td>
<td>1</td>
</tr>
<tr>
<td>DEV1:0000.EXECPREP.CORESIM.DB</td>
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<td>DEV1:0000.TKLBPREP.CORESIM.DB</td>
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**PROGRAM SPECIFIC DATA-BASE FILES: DUCTSIM (COMP)**

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<tr>
<td>DEV1:0000.AGRP.DUCTSIM.DB</td>
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<tr>
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<td>DEV1:0000.TASK.DUCTSIM.DB</td>
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<tr>
<td>DEV1:0000.TKLB.DUCTSIM.DB</td>
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**PROGRAM SPECIFIC DATA-BASE FILES: DUCTSIM (PREP)**

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<tr>
<td>DEV1:0000.XVARPREP.DUCTSIM.DB</td>
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</tr>
<tr>
<td>DEV1:0000.CNSTPREP.DUCTSIM.DB</td>
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</tr>
<tr>
<td>DEV1:0000.TASKPREP.DUCTSIM.DB</td>
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<td>DEV1:0000.TKLBPREP.DUCTSIM.DB</td>
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DUALNOZZ OPERATIONAL MESSAGES

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<td>SIMULATION HALT! ADC VALUE OF AN &lt; MINAREA</td>
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<td>SIMULATION HALT! PRO OVERFLOW</td>
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DUALNOZZ GLOBAL CONSTANTS

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DUALNOZZ MULTIVALUED GLOBAL CONSTANTS

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DUALNOZZ MULTIVALUED GLOBAL CONSTANTS (CONTINUED)

**PRXVALS (CONT.)**

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<td>JOBDONE</td>
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**RTML LISTING : DUALNOZZ  11/27/84  10:28:52**

**LOCAL DATA SEGMENT**

**DAFPROC (COMP)**

**DATA**

---

### DATAPROC COMPUTATIONAL PROCESSOR LOCAL VARIABLES

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<th>XREF</th>
<th>PVAL</th>
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### DATAPROC COMPUTATIONAL PROCESSOR EXTERNAL VARIABLES

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### DATAPROC COMPUTATIONAL PROCESSOR ARGUMENT GROUP VARIABLES

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| DATA | S1  | 10000    | 16   | 7    | 1) XV: DATAPROC.P.AN$0  
2) XV: DATAPROC.P.ANF$0  
3) XV: CORESIM.C.ACN$0  
4) XV: CORESIM.C.ADN$0  
5) XV: CORESIM.C.PRC$0  
6) XV: DUCTSIM.C.PRD$0  
7) XV: CORESIM.C.WDN$0 |
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## DATAPROC COMPUTATIONAL PROCESSOR EXECUTIVES

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<th>SCRATCH-PAD-MEMORY</th>
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RTMPI LISTING : DUALNOZZ 11/27/84 10:28:52

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* EXECUTABLE STATEMENT SEGMENT *
* ...DATAPROC (COMP) *
* *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

MAIN, EXECUTIVE: DEV1:0000,RTX,DATAPROC,SA

1 S$1 ENTER GETDATA
2 S$2 RETURN

MAX PATH EXECUTION TIME: 56 CYCLES (WITHOUT COMPUTE DELAYS) +GETDATA.

BADADC, EXECUTIVE: DEV1:0000,RTX,DATAPROC,SA

1 S$3 IF *P:AN=*P:MINAREA
   THEN
2 S$4 ADVISE H:ADCMESS1
   ELSE
3 S$5 ADVISE H:ADCMESS2
4 S$6 RETURN

MAX PATH EXECUTION TIME: 346 CYCLES (WITHOUT COMPUTE DELAYS)

GETDATA, TASK: DEV1:0000,RTX,DATAPROC,SA

1 S$7 CALL SAMPLE[DATA]
2 S$8 ADVISE R:DATA
3 S$9 RETURN

MAX PATH EXECUTION TIME: 272 CYCLES (WITHOUT COMPUTE DELAYS) +SAMPLE

TRANSFERRED VARIABLES

...NONE

OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

DATAPROC:*P:AN
DATAPROC:*P:ANF
CORESIM:C:ACN
CORESIM:C:ADN
CORESIM:C:PRC
DUCTSIM:C:PRD
CORESIM:C:WON

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DATAPROC PRE-PROCESSOR LOCAL VARIABLES

<table>
<thead>
<tr>
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<th>HOLD VALUE</th>
<th>SCAL FAC</th>
<th>XREF</th>
<th>PVAL</th>
<th>LOCATION</th>
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DATAPROC PRE-PROCESSOR EXTERNAL VARIABLES

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<tr>
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<tr>
<td>CORESIM.C.ADN$0</td>
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DATAPROC PRE-PROCESSOR LOCAL CONSTANTS

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<tr>
<th>NAME</th>
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<th>PRMTR</th>
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DATAPROC PRE-PROCESSOR ARGUMENT GROUP VARIABLES

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### DATAPROC PRE-PROCESSOR TASKS

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### DATAPROC PRE-PROCESSOR EXECUTIVES

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GETAN, EXECUTIVE: DEV1:0000,RTXPREP,DATAPROC.SA

1  S$1  CALL READ(ADCVAR,ADCCBNJ)
2  S$2  AN=AN+K2
3  S$3  IF AN<MINAREA
4      THEN
5  S$4  AN=MINAREA
6  S$5  ACTIVATE BADADC
7      ELSE
8  S$6  IF AN>MAXAREA
9      THEN
10 S$7  AN=MAXAREA
11 S$8  ACTIVATE BADADC
12 S$9  ANF=K1P049-K1P622M*AN
13 S$10 ENTER JOEDONE
14 S$11 DISPATCH WRTACN,WRTADN
15 S$12 RETURN

MAX PATH EXECUTION TIME: 1991 CYCLES (WITHOUT COMPUTE DELAYS)
+READ
+JOEDONE.
+WRTACN.
+WRTADN.

WRTACN, TASK: DEV1:0000,RTXPREP,DATAPROC.SA

1  S$13  CALL DAC1[ACNGJ]
2  S$14  RETURN

MAX PATH EXECUTION TIME: 48 CYCLES (WITHOUT COMPUTE DELAYS)
+DAC1

WRTADN, TASK: DEV1:0000,RTXPREP,DATAPROC.SA

1  S$15  CALL DAC2[ACNGJ]
2  S$16  RETURN

MAX PATH EXECUTION TIME: 48 CYCLES (WITHOUT COMPUTE DELAYS)
+DAC2

JOEDONE, TASK: DEV1:0000,RTXPREP,DATAPROC.SA

1  TEST  IF #Coresim.C.JOEDONE
      THEN
2  S$18  REDO TEST
      ELSE
3  S$19  ADVISE H.DPMESS

122  18  178

72
AN

73

RETURN

MAX PATH EXECUTION TIME: 316 CYCLES (WITHOUT COMPUTE DELAYS)

TRANSFERRED VARIABLES

AN

ANF

OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

CORESIM.C.ACN
CORESIM.C.ADN
CORESIM.C.JOBDONE
**CORESIM COMPUTATIONAL PROCESSOR LOCAL VARIABLES**

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**CORESIM COMPUTATIONAL PROCESSOR EXTERNAL VARIABLES**

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**CORESIM COMPUTATIONAL PROCESSOR LOCAL CONSTANTS**

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CORESIM COMPUTATIONAL PROCESSOR EXECUTIVES

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RTMPL LISTING: DUALNOZZ 11/27/84 10:28:52

* * * * * * * * * * * * * * * * * * * * * *
* EXECUTABLE STATEMENT SEGMENT *
* ...CORESIM (COMP) *
* * * * * * * * * * * * * * * * * * * * * *

MAINSIM. EXECUTIVE: DEV1:0000, DSC, CORESIM, SA

1  S$1  JOBDONE=FALSE  270
2  S$2  PRC=P0/PCN  374
3  S$3  IF OVERFLOW  10
4  S$4  ADVISE H.COREMES1  180
5  S$5  FFBN=SQRT(K1P-FUN1[PRXVALS, PRNVALS, XT02857, PRC])  1156
6  S$6  ACNA=KCN*WC*N*SQRT(TCN)  780
7  S$7  IF *.P.PREPDONE  122
     THEN  180
8  S$8  ADVISE M.COREMES3  38
9  S$9  IF PRC>*KP53  44
     THEN  222
10 S$10 FFN=KP2583  10
     ELSE  10
11 S$11 FFN=FFBN*.P.FFNA  38
12 S$12 IF OVERFLOW  736
     THEN  258
13 S$13 ADVISE H.COREMES2  122
14 S$14 IF FFN>ZERO  180
     THEN  38
15 S$15 ACN=ACNA/PCN*FFN*.P.FLC  268
     ELSE  410
16 S$16 ACN=ZERO  458
17 S$17 IF *.P.DUCTDONE  38
     THEN  270
18 S$18 ADVISE M.COREMES4  16
19 S$19 IF ACN=ZERO  4
     THEN  76
20 S$20 ADN=ZERO  258
     ELSE  122
21 S$21 ADN=DATAPROC.P.ANF-ACN
22 S$22 WDN=ADN*.P.WDN
23 S$23 JOBDONE=TRUE
24 S$24 RETURN

MAX PATH EXECUTION TIME: 5792 CYCLES (WITHOUT COMPUTE DELAYS)

TRANSFERRED VARIABLES

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OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

CORESIM.P, PREPDONE

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RTMPL LISTING : DUALNOZZ  11/27/84  10:28:52  PAGE 23

CORESIM.P.FFNA
CORESIM.P.FLC
CORESIM.P.DUCTDONE
DATAPROC.P.ANF
CORESIM.P.WDNC
**CORESIM PRE-PROCESSOR LOCAL VARIABLES**

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**CORESIM PRE-PROCESSOR EXTERNAL VARIABLES**

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**CORESIM PRE-PROCESSOR LOCAL CONSTANTS**

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<td>EXEC / TASK / MACRO</td>
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<tr>
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<td>NONE</td>
<td>0</td>
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PRFCTNS, EXECUTIVE: DEV1:0000, DSCPREP, CORESIM, SA

1  S$1  PREPDONE=FALSE
2  S$2  DUCTDONE=FALSE
3  S$3  PRC=P0/PCN
4  S$4  FLC=K1P3625-KP7158*PRC
5  S$5  IF FLC<K1P
   THEN
6  S$6  FLC=K1P
   ELSE
7  S$7  IF FLC<KP825
   THEN
8  S$8  FLC=KP825
9  S$9  FFNA=FUN1(PRNXVALS, PRNVALS, XT07143, PRC)
10 S$10 PREPDONE=TRUE
11 S$11 WDNS=PDN*DUCTSIM.C, WDNS
12 S$12 DUCTDONE=TRUE
13 S$13 RETURN

MAX PATH EXECUTION TIME: 2622 CYCLES (WITHOUT COMPUTE DELAYS)

TRANSFERRED VARIABLES

<table>
<thead>
<tr>
<th>FFNA</th>
<th>FLC</th>
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<th>PREPDONE</th>
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<tr>
<td>DUCTDONE</td>
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OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

| DUCTSIM.C, WDNS |
DUCTSIM COMPUTATIONAL PROCESSOR LOCAL VARIABLES

<table>
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<tr>
<th>NAME</th>
<th>DTP</th>
<th>IC VALUE</th>
<th>HOLD VALUE</th>
<th>SCAL FAC</th>
<th>XREF</th>
<th>PVAL</th>
<th>LOCATION</th>
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<tr>
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<td>PRD</td>
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</table>
* NEGATIVE | BT  |                |            |          |      |      |          |
* OVERFLOW | BT  |                |            |          |      |      |          |
* POSITIVE | BT  |                |            |          |      |      |          |
* ZERO   | BT  |                |            |          |      |      |          |

DUCTSIM COMPUTATIONAL PROCESSOR EXTERNAL VARIABLES

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<td>DUCTSIM.P.FLC$0</td>
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DUCTSIM COMPUTATIONAL PROCESSOR LOCAL CONSTANTS

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<tr>
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</table>
RTMPL LISTING : DUALNOZZ 11/27/84 10:28:52

EXECUTABLE STATEMENT SEGMENT

...DUCTSIM (COMP)

CPROCE, EXECUTIVE: DEVI:0000,DSC,DUCTSIM.SA

1 S$1  PROD=P0/PDN
2 S$2  IF OVERFLOW
       THEN
3 S$3  ADVISE H.COREMES2
4 S$4  FFNB=SQRT(K1P-FUNI,PRXVALS,PRNVALS,XT02857,PRD)
5 S$5  WDNB=KDN*SQRT(TDN)
6 S$6  IF P,P,PREPDONE
       THEN
7 S$7  ADVISE M.DUCTMESS
8 S$8  IF PRD<>KP53
       THEN
9 S$9  FFN=KP2588
       ELSE
10 S$10 FFN=FFNB*,P,FFNA
11 S$11 WDNB=FFN,P,FFNA
12 S$12 RETURN

MAX PATH EXECUTION TIME: 3618 CYCLES (WITHOUT COMPUTE DELAYS)

TRANSFERRED VARIABLES

WNB            PRD

OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

DUCTSIM*,P,PREPDONE
DUCTSIM*,P,FFNA
DUCTSIM*,P,FLC
DUCTSIM PRE-PROCESSOR LOCAL VARIABLES

<table>
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<tr>
<th>NAME</th>
<th>DTP</th>
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<th>SCAL FAC</th>
<th>XREF</th>
<th>PVAL</th>
<th>LOCATION</th>
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DUCTSIM PRE-PROCESSOR LOCAL CONSTANTS

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DUCTSIM PRE-PROCESSOR EXECUTIVES

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<th>SCRATCH-PAD-MEMORY</th>
<th>NAME</th>
<th>LEVEL</th>
<th>TASK(S)</th>
<th>EXEC / TASK / MACRO</th>
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</tbody>
</table>
RTMPL LISTING: DUALNOZZ 11/27/84 10:28:52

EXECUTABLE STATEMENT SEGMENT

DUCTSIM (PREP)

PRFCTNS. EXECUTIVE: DEVI:0000,DSCPREP,DUCTSIM,SA

1. $\text{PREPDONE}=\text{FALSE}$
2. $\text{PRD}=\text{P0/PDN}$
3. $\text{FLC}=\text{K1F575-PRD}$
4. $\text{IF FLC}>\text{K1P}$
   $\text{THEN}$
5. $\text{FLC}=\text{K1P}$
   $\text{ELSE}$
6. $\text{IF FLC}<\text{KP825}$
   $\text{THEN}$
7. $\text{FLC}=\text{KP825}$
8. $\text{FFNA}=\text{FUN1[PRXVALS,PRNVALS,XT07143,PRD]}$
9. $\text{PREPDONE}=\text{TRUE}$
10. $\text{RETURN}$

MAX PATH EXECUTION TIME: 1776 CYCLES (WITHOUT COMPUTE DELAYS)

TRANSFERRED VARIABLES

FFNA FLC PREPDONE

OPERANDS SUBJECT TO COMPUTATIONAL DELAY (EXT MEM)

...NONE
Appendix B—Error and Warning Messages

SPECIFIC INFORMATION PERTAINING TO THE PROGRAM IS ENCLOSED WITHIN ANGLE BRACKETS (<...>) IN THE MESSAGES.

RIMPL ERROR MESSAGES

1. STATEMENT SIZE (3200):<NUMBER OF CHARACTERS ENTERED>
2. EXCESS STATEMENT DELIMITERS (120):<NUMBER OF DELIMITERS ENTERED>
3. SIMULATION DESCRIPTION SIZE (64):<ENTRY>
4. ORIGINATOR ID SIZE (32):<ENTRY>
5. NUMBER OF SIMULATOR CHANNELS (1..<MAX NUMBER>):<ENTRY>
6. CONFIGURATION ENTRY (SINGLE OR DUAL):<ENTRY>
7. PROGRAM CATALOG ID (RTX, IOP, DSC):<ENTRY>
8. GLOBAL CATALOG ID (GLOBAL):<ENTRY>
9. TARGET CATALOG ID (M68000):<ENTRY>
10. VOLUME SPECIFICATION:<ENTRY>
11. RESOURCE NAME STRING:<ENTRY>
12. USER NUMBER (0..9999):<ENTRY>
13. INCOMPLETE FILE
14. OPTION SPECIFICATION:<ENTRY>
15. ONLY 1 RTX PROCESSOR ALLOWED:<NUMBER SPECIFIED>
16. ONLY 1 IOP PROCESSOR ALLOWED:<NUMBER SPECIFIED>
17. MULT-DEFINED CHANNEL ID:<CHANNEL ID>
18. ILLEGAL CHAR IN INTEGER:<INTEGER AS SPECIFIED>
19. NON-ALPHABETIC NAME:<NAME AS SPECIFIED>
20. NAME EXCEEDS 8 CHARACTERS:<NAME AS SPECIFIED>
21. INTEGER ENTRY EXPECTED BETWEEN <CHARACTER> AND <CHARACTER>
22. NON-ALPHANUMERIC CHAR(S) IN NAME:<NAME AS SPECIFIED>
23. NAME ENTRY EXPECTED BETWEEN <CHARACTER> AND <CHARACTER>
24. NULL GLOBAL DEFINITION:??
25. MULT-DEFINED OP-SYS TASK::<TASK ID>
26. TOO MANY DELIMITERS:<ENTRY>
27. UNDEFINED SYSTEM TASK::<TASK ID>
28. NAME=MESSAGE FORMAT REQUIRED:<ENTRY>
29. MULT-DEFINED MESSAGE ID:<MESSAGE ID>
30. MESSAGE EXCEEDS 64 CHARACTERS:<ENTRY>
31. NAME=SYS-TASK ID REQUIRED:<ENTRY>
32. EXTRANEOUS END:<ENTRY>
33. TOO MANY COLONS:<ENTRY>
34. UNDEFINED RECORD NAME:<ENTRY>
35. END MISSING:<ENTRY>
36. MULT-DEFINED CONSTANT ID:<CONSTANT ID>
37. = EXPECTED:<ENTRY>
38. CONSTANT DEFINITION FORMAT:<ENTRY>
39. SCALE FACTOR REQUIRED!
40. ILLEGAL VALUE DEFAULT!
41. ILLEGAL DTP DEFAULT!
42. TOO MANY VALUES ENTERED: SIZE =<NUMBER OF VALUES ENTERED>
43. VALUE EXPECTED FOR ITEM NUMBER <ITEM NUMBER>
44. CONSTANT CANNOT BE BOOLEAN!''
45. <COUNT> @S IN VALUE SPECIFICATION!''
46. MISMATCH OF CONSTANT SIZE/VALUES:<SIZE SPECIFIED>/<NUMBER OF VALUES>
47. <COUNT> ILLEGAL CHAR(S) IN REAL NUM: REAL NUMBER AS SPECIFIED>
48. TOO MANY DECIMAL PTS (<COUNT>):<ENTRY>
49. TOO MANY EXPONENTS (<COUNT>):<ENTRY>
50. REAL NUMBER FORMAT:<REAL NUMBER AS SPECIFIED>
51. NO DTP ENTERED:<ENTRY>
52. ILLEGAL DTP:<DTP AS SPECIFIED>
53. ILLEGAL DATA TYPE(I,S,F,B):<DATA TYPE AS SPECIFIED>
54. ILLEGAL PRECISION:<PRECISION SPECIFIED>
55. ARG GROUP FORMAT:<ARGGROUP AS SPECIFIED>
56. MULTI-DEFINED ARG GROUP:<ARGGROUP ID>
57. ARG GROUP DEFINITION EXPECTED!
58. ARG GROUP SIZE EXCEEDED: SIZE=<SIZE>: <CNT>=<NUMBER OF ITEMS SPECIFIED>
59. EXTERNAL ARG GROUP REFERENCE:<CHANNEL ID>,<ARGGROUP ID>
60. ARG GROUP ITEM IN ARG GROUP:<ITEM ID>
61. EXTERNAL PREP VRBL REFERENCE:<VARIABLE ID>
62. ARGGROUP/ARGUMENT DTP CONFLICT:<VARIABLE ID>
63. EXTERNAL TARGET STATE REFERENCE:<TARGET STATE ID>
64. NON-PARAMETRIC CONSTANT REFERENCE:<CONSTANT ID>
65. TOO MANY PERIODS:<ARGUMENT AS SPECIFIED>
66. TOO MANY DOLLARS:<ARGUMENT AS SPECIFIED>
67. UNDEFINED ARGUMENT SOURCE:<ARGUMENT AS SPECIFIED>
68. ILLEGAL PROCESSOR TYPE:<ARGUMENT AS SPECIFIED>
69. UNDEFINED ARGUMENT:<CHANNEL ID>,<PROCESSOR TYPE>,<NAME>
70. ARG GROUP ITEM SPECIFICATION:<ARGGROUP ID>
71. ITEM NUMBER > SPECIFIED SIZE:<CONSTANT OR VARIABLE ID>
72. CONFIGURATION CONFLICT (SINGLE CHANNEL)
73. UNDEFINED DEFAULT SOURCE PROGRAM
74. GLOBAL CNST SOURCE SPECIFIED:<ENTRY>
75. CONSTANT FORMATION ID CONFLICT WITH <CONSTANT ID>
76. ID CONFLICT WITH GLOBAL CONSTANT:<CONSTANT ID>
77. NULL RECORD IN PROGRAM
78. FOREGROUND EXEC PRIORITY DURATION WITH <EXEC ID>
79. MULTI-DEFINED TASK:<TASK ID>
80. NAME[PRIORITY] FORMAT REQUIRED:<ENTRY>
81. MULTI-DEFINED EXECUTIVE:<EXEC ID>
82. / EXPECTED:<ENTRY>
83. NO EXECUTIVES IN <CHANNEL ID>,<PROCESSOR TYPE>
84. [ EXPECTED:<ENTRY>
85. ] EXPECTED:<ENTRY>
86. VARIABLE DEFINITION FORMAT:<ENTRY>
87. VARIABLE ID REQUIRED:<ENTRY>
88. MULTI-DEFINED VARIABLE:<VARIABLE ID>
89. BOOLEAN VALUE REQUIRED:<ENTRY>
90. VRBL DEFINED IN COMP PROCESSOR:<CHANNEL ID>
91. VARIABLE/CONSTANT ID CONFLICT:<CONSTANT ID>
92. VARIABLE/GLBCNST ID CONFLICT:<CONSTANT ID>
93. TASK STATEMENTS REQUIRED:<TASK ID>
94. EXEC STATEMENTS REQUIRED:<EXEC ID>
95. UNRECONCILED IF STATEMENT(S):<LIST OF IF-STATEMENT LABELS>
96. UNDEFINED STATEMENT LABEL(S):<LIST OF STATEMENT LABELS>
97. RETURN EXPECTED AT END OF EXEC/TASK!
98. NO IF STATEMENT TO END (! ILLEGAL)
99. STATEMENT FORMAT! ONLY <COUNT> DELIMITERS FOUND
100. UNDEFINED RESULT VARIABLE:<VARIABLE ID>
101. OMITTED LABEL END DELIMITER:<LABEL AS SPECIFIED>
102. UNDEFINED COMMAND/CONDITIONAL:<COMMAND AS SPECIFIED>
114. DUPLICATE LABEL (TASK/EXEC):<LABEL>
115. COMMAND DISALLOWED IN TASK:<COMMAND>
116. UNDEFINED ARGUMENT TASK:<TASK ID>
117. THEN OR ELSE CLAUSE EXPECTED!
118. EXTRANEOUS INFO IN STATEMENT:<EXTRANEOUS INFORMATION>
119. THEN NOT EXPECTED HERE:<ENTRY>
120. ELSE NOT EXPECTED HERE:<ENTRY>
121. UNDEFINED DESTINATION (REDO/EXIT)
122. COMMAND ILLEGAL UNLESS IN IF STATEMENT:<COMMAND ID>
123. RESULT IS TARGET STATE VARIABLE:<VARIABLE ID>
124. FORMAT OF CALL COMMAND:<ENTRY>
125. UNDEFINED TARGET PROCEDURE:<NAME>
126. UNDEFINED ADVISORY TYPE (USE .M,.H,.R,.W,.E)
127. NUMBER OF TASKS EXCEEDS 999999
128. UNDEFINED ARGUMENT GROUP:<NAME>
129. PROCEDURE/ARG GROUP DTP CONFLICT:<ARGGROUP ID>
130. UNDEFINED ADVISORY ARGUMENT:<ENTRY>
131. BE MORE ORIGINAL WITH ERRORS!
132. DISPATCH COMMAND ILLEGAL ON COMPUTATIONAL PROCESSOR!
133. YOU ARE GENERATING AN INFINITE LOOP!
134. UNDEFINED COMMAND:<COMMAND ID>
135. MVF ARGUMENT COUNT MISMATCH (REQ=<COUNT>) <> (<NUMBER OF ARGUMENTS>)
136. ARG-SUPPLIED<>ARG-REQUIRED! (<COUNT>) <> (<COUNT>)
137. NULL EXPRESSION ENCOUNTERED
138. ILLEGAL RESCALING OF CONSTANT REQUIRED:<SCALING INFORMATION>
139. REQUIRED MACRO NOT TARGET SUPPORTED:<MACRO ID>
140. MULTIPLE ] ENCLOSED IN MVF
'41. [ MISSING IN MVF
142. MVF NAME MISSING
143. EXPRESSION PROCESSING ABORTED
144. ( NOT EXPECTED )LOCATION:STATEMENT CHARACTER INDEX
145. OPERATOR MISSING )LOCATION:STATEMENT CHARACTER INDEX
146. [ NOT EXPECTED )LOCATION:STATEMENT CHARACTER INDEX
147. MISSING OPERAND AFTER )LOCATION:STATEMENT CHARACTER INDEX LOCATION <INDEX>
148. UNDEFINED MVF NAME:<NAME>
149. MVF/RESULT DATA TYPE CONFLICT:<FUNCTION ID> #<DTP>
150. UNDEFINED UF NAME:<NAME>
151. UF/RESULT DATA TYPE CONFLICT:<FUNCTION ID> #<DTP>
152. OPERAND MISSING )LOCATION:STATEMENT CHARACTER INDEX
153. EXTRANEOUS ] ENCOUNTERED!
154. OPERAND/RESULT DATA CONFLICT:<OPERAND ID>
155. OPERAND NOT TARGET SUPPORTED:<OPERATION ID>
156. OPERATION/OPERAND DATA TYPE CONFLICT:<OPERATION ID> #<DTP>
157. RTMPL SCRATCH PAD MEMORY OVERFLOW
158. RTMPL SCALE FACTOR SHIFT OVERFLOW
159. RTMPL EXTERNAL VARIABLE MEMORY OVERFLOW
160. NUMBER TOO LARGE FOR SCALE FACTOR:<NUMBER SPECIFIED>
161. INTEGER TYPE HAS FRACTIONAL VALUE:<INTEGER SPECIFIED>
162. INTEGER TOO LARGE FOR PRECISION:<INTEGER SPECIFIED>
163. DECODED INTEGER EXCEEDS 9999999999:<INTEGER SPECIFIED>
164. LOCAL VARIABLE SPECIFICATION REQUIRED INSTEAD OF <NAME>
165. PAST VALUE CANNOT BE SENT:<ENTRY>
166. EXTERNAL VARIABLE SPECIFICATION REQUIRED INSTEAD OF <NAME>
167. SOURCE/DESTINATION DTP CONFLICT:<NAME>/</NAME>
168. PROCESSOR TYPE CONFLICT:<CHANNEL ID>,<PROC TYPE> /<CHANNEL ID>,<PROC TYPE>
169. UNDEFINED LOCAL VARIABLE:<NAME>
170. CONFIGURATION (SINGLE) DOES NOT SUPPORT INTRA-PROCESSOR INTERRUPTS!
171. UNDEFINED FOREGROUND EXECUTIVE (<NAME>) IN <CHANNEL ID>
172. BACKGROUND EXECUTIVE CANNOT BE ACTIVATED: <EXEC ID>

RTMP: WARNING MESSAGES

1. END OF IF-STATEMENT EXPECTED
2. UNNECESSARY COMA ENCOUNTERED
3. MULTIPLE ASSIGNMENTS OF <VARIABLE ID>
4. STRUCTURE VIOLATION! REDO BEING USED AS GOTO
5. VARIABLE RE-SCALING ENCOUNTERED: <VARIABLE ID> RSF=<N> NSF=<N>
6. CONSTANT RE-SCALING ENCOUNTERED: <CONSTANT ID> RSF=<N> NSF=<N>
7. VARIABLE PRECISION ADJUSTMENT: <VARIABLE ID> RPRC=<N> NPRC=<N>
8. CONSTANT PRECISION ADJUSTMENT: <CONSTANT ID> RPRC=<N> NPRC=<N>
9. DECIMAL POINT ENCOUNTERED IN INTEGER: <ENTRY>
10. DECIMAL POINT EXPECTED IN SCALED-FRACTION: <ENTRY>
11. DECIMAL POINT EXPECTED IN FLOATING POINT NUMBER: <ENTRY>
Appendix C—Assembler Source Files for Dual-Nozzle Simulation

```assembly
1  * RTMPL: DUALNOZZ
2  * DALE J. ARPASI
3  * PROGRAM: DATPROC - COMP
4  * FUNCTION: RTX
5  * GENERATED: 11/27/84 10:28:52
6  *
7  *
8  * REQUIRED TARGET MACRO FILE
9  INITIAL$ MACRO
10  .CHE  EQU  $B1C
11  .AVT  EQU  $B44
12  .AVX  EQU  $B45
13  .AVS  EQU  $B46
14  .AVB  EQU  $B47
15  .AWC  EQU  $B4C
16  .NOFE  EQU  ($918)*2
17  .XA1$P  EQU  ($982)*2
18  .XA2$C  EQU  ($9B6)*2
19  .XA2$P  EQU  ($9B8)*2
20  .XV2$P  EQU  ($9BC)*2
21  .XV2$C  EQU  ($9C2)*2
22  .FE$P  EQU  ($9C8)*2
23  .FE$C  EQU  ($9CC)*2
24  .AK$P  EQU  ($9D4)*2
25  .AK$C  EQU  ($9D6)*2
26  .PB$P  EQU  ($9D8)*2
27  .PB$C  EQU  ($9DA)*2
28  .PI$E  EQU  ($9DA)*2
29  .EAD  EQU  $1400
30  .XVM  EQU  $1F00
31  .XVC  EQU  $1F01
32  ENDM
33  ORG$ MACRO
34      ORG \1
35  ENDM
36  DC$ MACRO
37      DC \1
38  ENDM
39  DS$ MACRO
40      DS \1
41  ENDM
42  DL$ MACRO
43      DC.L \1
44  ENDM
45  DN$ MACRO
46      DC.L \1
47  ENDM
48  DATASEG$ MACRO
49  ENDM
50  DATAEND$ MACRO
51  ENDM
52  TSTXVA$ MACRO
53      CMP.B \(\1-1),D7
54      BEQ.S TA3\@+4
55      CMP.B \((\1-A),XVC)*2(A4),D7
56      BEQ.S TA2\@  
```

58 CLR D5
59 TA1 @ ADDR $1,D5
60 TRAPV
61 CMPA $0,A4
62 CMP.E ((1-\text{XVC})\times2)(A4),D7
63 NOP
64 BNE.S TA1 @
65 CMP. (1+$10100),D5
66 BLE.S TA2 @
67 MOVE D5,\text{\$1}+$10100
68 TA2 @ MOVEP,L ((1-\text{XVM})\times2)(A4),D5
69 MOVE.L D5,\text{\$1}
70 MOVE.B \$0,((1-\text{XVC})\times2)(A4)
71 TA3 @ MOVE.B D7,((1-\text{1})
72 ENDM
73 ADVISE@H MACRO
74 MOVE.B \$1,D5
75 TRAP \#9
76 ENDM
77 ADVISE@R MACRO
78 MOVE.B \$1,PI4B(A4)
79 CLR.L D5
80 AR1 @ TST.B \#AV8
81 NOP
82 BEQ.S AR2 @
83 ADDQ.L \#1,D5
84 TRAPV
85 CMPA D7,A4
86 BRA.S AR1 @
87 AR2 @ CMP.L \#AWC,D5
88 BLE.S AR3 @
89 MOVE.L D5,\#AWC
90 AR3 @ MOVE.B \#3,AV8
91 MOVE.B \#3,AVT
92 MOVE.B \$1,\#AUX
93 MOVE.B \$1,AVS
94 ORI \$6,\$1FF0
95 ENDM
96 RETURN@I MACRO
97 MOVEA.L \#1-4,A0
98 JMP (A0)
99 ENDM
100 RETURN@E MACRO
101 RTS
102 ENDM
103 RETURN@T MACRO
104 RTS
105 ENDM
106 BACKEXEC MACRO
107 LEA \#1-\text{2},A3
108 ENDM
109 FOREEXEC MACRO
110 LEA \#1-\text{2},A3
111 ENDM
112 ENTER@ MACRO
113 TST \#1-4
114 BEQ.S \#4

115 JSR \1+4
116 ENDM
117 EXIT$ MACRO
118 JMP \1
119 ENDM
120 CALL$ MACRO
121 IFNC '','\2'
122 LEA \2,A0
123 MOVE.L A0,-(A7)
124 ENDC
125 IFNC '','\3'
126 LEA \3,A0
127 MOVE.L A0,-(A7)
128 ENDC
129 IFNC '','\4'
130 LEA \4,A0
131 MOVE.L A0,-(A7)
132 ENDC
133 IFNC '','\5'
134 LEA \5,A0
135 MOVE.L A0,-(A7)
136 ENDC
137 JSR \1
138 ENDM
139 HLD$S1 MACRO
140 MOVE \1,-(A7)
141 ENDM
142 JNEQ$S1 MACRO
143 CMP (A7)+,\2
144 BNE \1
145 ENDM
146 LDI$S1 MACRO
147 MOVE \#2,\1
148 ENDM
149 LDM$S1 MACRO
150 MOVE \2,\1
151 ENDM
152 RCNT$ EQU 898
153 SAMPLE MOVEA,L (A7)+,A0
154 MOVEA,L (A7)+,A1
155 MOVE.L A0,-(A7)
156 ADDA \$28,A1
157 MOVE (A1)+,D0
158 ASL \$2,D0
159 MOVEA D0,A0
160 TST (A1)+
161 BEQ.S SM1@
162 RTS
163 SM1@ MOVE \#1,-(A1)
164 MOVE.L RCNT$(A1)+
165 MOVE (A1)+,D1
166 MOVE (A1)+,D0
167 ADDA A1,A0
168 SM2@ MOVE.L (A1)+,A2
169 SM3@ MOVE D0,D5
170 MOVE (A2)+,(A0)+
171 SUBQ \$1,D5
172        BNE.S     SM3\@
173        SUBQ     \$1,01
174        BNE.S     SM2\@
175        RTS
176
177        *
178        *
179        * CONTROL AND INITIALIZATION
180        INITIAL$  DATASEG$
181
182        *
183        *
184        * FOREGROUND EXECUTIVE MAPS
185        ORG$     5120
186        DL$      0        *ACTIVE EXECUTIVE
187        DL$      BADAC$.  *PRIORITY=1
188        DC$      0        *.BUSY FLAG
189        DC$      0        *.PENDING FLAG
190        DL$      0        *NOT USED
191        DL$      0        *NOT USED
192        DL$      0        *NOT USED
193        DL$      0        *NOT USED
194        DL$      0        *NOT USED
195        DL$      0        *NOT USED
196        DL$      0        *NOT USED
197        DL$      0        *NOT USED
198        DL$      0        *NOT USED
199        DL$      0        *NOT USED
200        DL$      0        *NOT USED
201        DL$      0        *NOT USED
202        DL$      0        *NOT USED
203        DL$      0        *NOT USED
204        *
205        *
206        * EXECUTABLE SEGMENT ENTRY ADDRESSES
207        ORG$     5376
208        DL$      MAIN$.  
209        DL$      BADAD$. 
210        DL$      GETDATA$.  
211        *
212        *
213        * SIMULATION TRANSFER MAPS
214        ORG$     5888
215        5888     FROM DATAPROC.P.AN
216        DC$      -2        *.RESERVED
217        DC$      -1        *.END OF MAP
218        5892     FROM DATAPROC.P.ANF
219        DC$      4         *.TO CORESIM RT-BUS
220        DC$      -2        *.RESERVED
221        DC$      -1        *.END OF MAP
222        5898     FROM CORESIM.C.JOBDONE
223        DC$      0         *.TO DATAPROC RT-BUS
224        DC$      -2        *.RESERVED
225        DC$      -1        *.END OF MAP
226        5904     FROM CORESIM.C.ACN
227        DC$      0         *.TO DATAPROC RT-BUS
228        DC$      -2        *.RESERVED
229   DC$   -1   x...END OF MAP
230   DC$   -1   FROM CORESIM.C.ADN
231   DC$   0   x..TO DATAPROC RT-BUS
232   DC$   -2   x...RESERVED
233   DC$   -1   x...END OF MAP
234   DC$   -1   FROM CORESIM.C.WDN
235   DC$   0   x..TO DATAPROC RT-BUS
236   DC$   -2   x...RESERVED
237   DC$   -1   x...END OF MAP
238   DC$   0   FROM CORESIM.C.PRC
239   DC$   -2   x...RESERVED
240   DC$   -1   x...END OF MAP
241   DC$   -1   FROM CORESIM.P.FFNA
242   DC$   -2   x...RESERVED
243   DC$   -1   x...END OF MAP
244   DC$   -1   FROM CORESIM.P.FLC
245   DC$   -2   x...RESERVED
246   DC$   -1   x...END OF MAP
247   DC$   -1   FROM CORESIM.P.WDNDC
248   DC$   -2   x...RESERVED
249   DC$   -1   x...END OF MAP
250   DC$   -1   FROM CORESIM.P.PREPDONE
251   DC$   -2   x...RESERVED
252   DC$   -1   x...END OF MAP
253   DC$   -1   FROM CORESIM.P.DUCTDONE
254   DC$   -2   x...RESERVED
255   DC$   -1   x...END OF MAP
256   DC$   -1   FROM DUCTSIM.C.WND
257   DC$   -4   x..TO CORESIM RT-BUS
258   DC$   -2   x...RESERVED
259   DC$   -1   x...END OF MAP
260   DC$   0   FROM DUCTSIM.C.PRD
261   DC$   -2   x...RESERVED
262   DC$   -1   x...END OF MAP
263   DC$   -1   FROM DUCTSIM.P.FFNA
264   DC$   -2   x...RESERVED
265   DC$   -1   x...END OF MAP
266   DC$   -1   FROM DUCTSIM.P.FLC
267   DC$   -2   x...RESERVED
268   DC$   -1   x...END OF MAP
269   DC$   -1   FROM DUCTSIM.P.PREPDONE
270   DC$   -2   x...RESERVED
271   DC$   -1   x...END OF MAP
272   DC$   -1   FROM CHANNEL TRANSFER MEMORY ALLOCATION
273   DC$   -1   7936
274   DC$   -1   94
275   DC$   -1   XFER IMAGE OF DATAPROC.P.AN
276   DC$   -1   x..CALC FLAG
277   DC$   25600  x..S1 B+11
278   DC$   0   x..FILLER WORD
279   DC$   5888  x..XFER MAP ADDR
280   DC$   0   XFER IMAGE OF DATAPROC.P.ANF
281   DC$   0   x..CALC FLAG
282   DC$   20210  x..S1 B+11
286 DC$ 0 * ,FILLER WORD
287 DC$ 5892 * ,XFER MAP ADDR
288 X 7952 XFER IMAGE OF CORESIM,C,JOBDONE
289 DC$ 0 * ,CALC FLAG
290 DC$ 0 * ,BOOLEAN
291 DC$ 0 * ,FILLER WORD
292 DC$ 5898 * ,XFER MAP ADDR
293 X 7960 XFER IMAGE OF CORESIM,C,ACN
294 DC$ 0 * ,CALC FLAG
295 DC$ 0 * ,S1 B+10
296 DC$ 0 * ,FILLER WORD
297 DC$ 5904 * ,XFER MAP ADDR
298 X 7968 XFER IMAGE OF CORESIM,C,ADN
299 DC$ 0 * ,CALC FLAG
300 DC$ 0 * ,S1 B+10
301 DC$ 0 * ,FILLER WORD
302 DC$ 5910 * ,XFER MAP ADDR
303 X 7976 XFER IMAGE OF CORESIM,C,WDN
304 DC$ 0 * ,CALC FLAG
305 DC$ 0 * ,S1 B+9
306 DC$ 0 * ,FILLER WORD
307 DC$ 5916 * ,XFER MAP ADDR
308 X 7934 XFER IMAGE OF CORESIM,C,PRC
309 DC$ 0 * ,CALC FLAG
310 DC$ 16384 * ,S1 B+1
311 DC$ 0 * ,FILLER WORD
312 DC$ 5922 * ,XFER MAP ADDR
313 X 7992 XFER IMAGE OF CORESIM,P,FFNA
314 DC$ 0 * ,CALC FLAG
315 DC$ 0 * ,S1 B+1
316 DC$ 0 * ,FILLER WORD
317 DC$ 5928 * ,XFER MAP ADDR
318 X 8000 XFER IMAGE OF CORESIM,P,FLC
319 DC$ 0 * ,CALC FLAG
320 DC$ 13516 * ,S1 B+1
321 DC$ 0 * ,FILLER WORD
322 DC$ 5932 * ,XFER MAP ADDR
323 X 8008 XFER IMAGE OF CORESIM,P,WDNC
324 DC$ 0 * ,CALC FLAG
325 DC$ 0 * ,S1 B+2
326 DC$ 0 * ,FILLER WORD
327 DC$ 5936 * ,XFER MAP ADDR
328 X 8016 XFER IMAGE OF CORESIM,P,PREPDONE
329 DC$ 0 * ,CALC FLAG
330 DC$ 0 * ,BOOLEAN
331 DC$ 0 * ,FILLER WORD
332 DC$ 5940 * ,XFER MAP ADDR
333 X 8024 XFER IMAGE OF CORESIM,P,DUCTDONE
334 DC$ 0 * ,CALC FLAG
335 DC$ 0 * ,BOOLEAN
336 DC$ 0 * ,FILLER WORD
337 DC$ 5944 * ,XFER MAP ADDR
338 X 8032 XFER IMAGE OF DUCTSIM,C,WDNB
339 DC$ 0 * ,CALC FLAG
340 DC$ 0 * ,S1 B+5
341 DC$ 0 * ,FILLER WORD
342 DC$ 5948 * ,XFER MAP ADDR
XFER IMAGE OF DUCTSIM.P,PRD
DC$ 0 "CALC FLAG"
DC$ 16384 "S1 B+1"
DC$ 0 "FILLER WORD"
DC$ 5954 "XFER MAP ADDR"
XFER IMAGE OF DUCTSIM.P,FFNA
DC$ 0 "CALC FLAG"
DC$ 0 "S1 B+1"
DC$ 0 "FILLER WORD"
DC$ 5960 "XFER MAP ADDR"
XFER IMAGE OF DUCTSIM.P,FLC
DC$ 0 "CALC FLAG"
DC$ 13516 "S1 B+1"
DC$ 0 "FILLER WORD"
DC$ 5964 "XFER MAP ADDR"
XFER IMAGE OF DUCTSIM.P,PREPDONE
DC$ 0 "CALC FLAG"
DC$ 0 "BOOLEAN"
DC$ 0 "FILLER WORD"
DC$ 5968 "XFER MAP ADDR"

LOCAL VARIABLE ALLOCATION
ORG$ 10000

PROGRAM CONSTANT ALLOCATION

ARGUMENT GROUP ALLOCATION

DATA DS$ 5 "FOR OP-SYS USE"
DN$ DATA*
DN$ DAPROC
DC$ 1 "ARGGROUP SIZE"
DC$ 0 "BUSY FLAG"
DC$ 0 "EXECUTION COUNT"
DC$ 7 "NUMBER OF ITEMS"
DC$ 1 "WORDS PER ITEM"
DL$ 7938 "AN"
DL$ 7946 "ANF"
DL$ 7962 "ACN"
DL$ 7970 "ADN"
DL$ 7986 "PRC"
DL$ 8042 "PRD"
DL$ 7978 "WDN"
DS$ 18 "RESERVED"
DS$ 16 "RESERVED"
DATAEND$

DATAPROC EXECUTABLE SEGMENT

EXECUTIVE: MAIN, PRIORITY=0
MAIN, BACKEXEC MAIN,02
S+1 ENTER$ GETDATA.
400  S$2   RETURN$E MAIN.
401   *
402   * EXECUTIVE: BADADC, PRIORITY=1
403 BADADC, FOREEXEC BADADC.,82
404 S$3   TSTXVA$ 7938,C  *AN
405   LDM$S1 D0,7938  *B+11
406   MLD$S1 D0
407   LDI$S1 D1,800  *MINAREA.B+11
408   JNEQ$S1 S$5+D1
409 S$4   ADVISE$H 1,C  *ADCMESS1
410   EXIT$  S$6
411 S$5   ADVISE$H 2,C  *ADCMESS2
412 S$6   RETURN$I BADADC.
413   *
414   * TASK: GETDATA,
415   DC$  7938  **XVAR ADDRESS
416   DC$  7946  **XVAR ADDRESS
417   DC$  7962  **XVAR ADDRESS
418   DC$  7970  **XVAR ADDRESS
419   DC$  7986  **XVAR ADDRESS
420   DC$  8042  **XVAR ADDRESS
421   DC$  7970  **XVAR ADDRESS
422   DC$  7  **NUMBER OF XVARS
423   DC$  1  **TASK ENABLE
424   DC$  0  **TASK COMPLETE
425   GETDATA.  DS$  2  **ENTRY OVERHEAD
426 S$7   CALL$ SAMPLE$DATA
427 S$8   ADVISE#R 1,C  **DATA
428 S$9   RETURN$T GETDATA.
429   *
430   *
431   * TARGET LIBRARY PROCEDURES
432 SAMPLE
433   END
434 435 436 437 438 439 440
441  ****RTMPL ERRORS: 0
442  ****RTMPL WARNINGS: 0
RTML: DUALNOZZ
DALE J. ARPASI
PROGRAM: DATAPROC - PREP
FUNCTION: RTX
GENERATED: 11/27/84 10:28:52

REQUIRED TARGET MACRO FILE

CHB EQU $B1C
AVT EQU $B44
AVX EQU $B45
AVS EQU $B46
AVB EQU $B47
AWC EQU $B4C
NOFE EQU ($918)*2
XA1$P EQU ($982)*2
XA1$C EQU ($986)*2
XA2$P EQU ($98A)*2
XV2$P EQU ($98C)*2
XV2$C EQU ($9C2)*2
XV2$C EQU ($9C4)*2
FE$P EQU ($9C8)*2
FE$C EQU ($9CC)*2
AK$P EQU ($9D4)*2
AK$C EQU ($9D6)*2
PB$P EQU ($9D8)*2
PB$C EQU ($9DA)*2
EAD EQU $1400
XVM EQU $1F00
XVC EQU $1F01

ENDM

ORG$ MACRO
ORG \1
ENDM
DC$ MACRO
DC \1
ENDM
DS$ MACRO
DS \1
ENDM
DL$ MACRO
DC.L \1
ENDM
DN$ MACRO
DC.L '\1'
ENDM
DATASEC$ MACRO
ENDM
DATAEND$ MACRO
ENDM
STV4$1 MACRO
MOVEQ \2,((\1-XVM)*2)(A4)
MOVEQ.B D7,((\1-XVC)*2)(A4)
MOVA EA \14, A0
TST (A0)
58  SV1\@  BMI.S  SV2\@+2
59  SV1\@  MOVEA  (A0)+,A1
60  ADDA  #,CHE\@+A1
61   TRAPV
62   MOVEA.L  (A1),A1
63   ADDA  #\@,A1
64   TRAPV
65   MOVE  \@,(A1)
66   MOVE  D7,-(A1)
67   TST  (A0)
68  SV2\@  BPL.S  SV1\@+2
69   ENDM
70   TSTXUL$  MACRO
71   CMP.B  ((\@-XVC)*2)(A4),D7
72   BEQ.S  TL3\@,+4
73   TST.B  ((\@-XVC)*2)(A4)
74   BEQ.S  TL3\@,+4
75   MOVEQ  @,D5
76   TL1\@  ADDQ  #1,D5
77   TRAPV
78   CMPA  @,A4
79   CMP.B  (\@-1),D7
80   NOP
81   BNE.S  TL1\@
82   CMP  (\@+10D100),D5
83   BVE.S  TL2\@
84   MOVE  D5,\@+10D100
85   TL2\@  MOVE.L  \@,D5
86   MOVEP.L  D5,(\@-XVC)*2)(A4)
87   TL3\@
88   ENDM
89   ACTIVATE$  MACRO
90   ACT\@  TST.B  ,NOFE(A4)
91   NOP
92   BNE.S  ACT\@
93   MOVE  \@,D0
94   IFC  'Z','P'
95   MOVEP  D0,FE\@+(A4)
96   AC\@  TST.B  ,PB\@+(A4)
97   NOP
98   BNE.S  AC\@
99   MOVE.B  @,PB\@+(A4)
100  OR.B  @,D7
101  MOVE.B  D7,AK\@+(A4)
102  ANDI.B  @,FB\@+D7
103  MOVE.B  D7,1800\@(A4)
104  ORI.B  @,D7
105  ACA\@  TST.B  ,AK\@+(A4)
106   NOP
107   BNE.S  ACA\@
108   MOVE.B  D7,1800\@(A4)
109   ENDC
110   IFC  'Z','C'
111   MOVEP  D0,FE\@+(A4)
112   AC\@  TST.B  ,PB\@+(A4)
113   NOP
114   BNE.S  AC\@
115  MOVE.B $1,PB$P(A4)
116  MOVE.B $3,AK$C(A4)
117  AND.B #$FB,D7
118  MOVE.B D7,$1800(A4)
119  ORI.B $4,D7
120  ACN
121  TST.B .AK$C(A4)
122  NOP
123  BNE.S ACN
124  MOV.B  D7,$1800(A4)
125  ENDC
126  ADVISE$H MACRO
127  MOVE.B \1,D5
128  TRAP \9
129  ENDM
130  DISPATCH$ MACRO
131  MOVE \2,NT@0
132  BRA.S DP1@0
133  NT@0 DC 0
134  SA0@0 DC.L 0
135  DP1@0 LEA \1+(4*(\2-1)),A0
136  DP2@0 MOVEA.L (A0),A1
137  TST -(A1)
138  BNE.S DP4@0
139  TST -(A1)
140  BEQ.S DP6@0
141  DP3@0 MOVEA -(A1),A2
142  BEQ.S DP5@0
143  IFC '3','C'
144  BTST.L $31,D7
145  BNE.S DP3@0
146  CMP.B -1(2),D7
147  BEQ.S DP3@0
148  MOVE.L A2,D5
149  SUB \1,XVH,D5
150  TRAPV
151  LSL.L \1,D5
152  TRAPV
153  MOVEA.L D5,A5
154  ADDA.L A4,A5
155  TRAPV
156  CMP.B -2(A5),D7
157  BEQ.S DPY@0
158  MOVE A2,D5
159  MOVEP D5,XA1$F(A4)
160  DP2@0 TST.B .PB$F(A4)
161  NOP
162  BNE.S DP2@0
163  MOVE.B $1,PF$P(A4)
164  MOVE.B $1,AK$C(A4)
165  ANDI.B #$FE,D7
166  MOVE.B D7,$1800(A4)
167  ORI.B $1,D7
168  DPV@0 TST.B .AK$C(A4)
169  NOP
170  BNE.S DPV@0
171  MOVE.B D7,$1800(A4)
172  BRA.S  DP4\@  
173  DPY\@  MOVEF.L  0(A5),D5  
174  MOVE.L  D5,(A2)  
175  MOVE.B  D7,-1(A2)  
176  ENDC  
177  IFC  '\3','p'  
178  BTST.L  #31,D7  
179  BNE.S  DP3\@  
180  CMP.B  -1(A2),D7  
181  BNE.S  DP4\@  
182  MOVE.L  A2,D5  
183  SUB  \#XVM,D5  
184  TRAPV  
185  LSL.L  \#1,D5  
186  TRAPV  
187  MOVEA.L  D5,A5  
188  ADDA.L  A4,A5  
189  TRAPV  
190  MOVEF.L  0(A5),D5  
191  MOVE.L  D5,(A2)  
192  MOVE.B  D7,-1(A2)  
193  ENDC  
194  BRA.S  DP3\@  
195  DP4\@  LEA  \#1,A2  
196  CMPA.L  A2,A0  
197  BEQ.S  DP1\@  
198  SUBA  \#4,A0  
199  TRAPV  
200  BRA.S  DP2\@  
201  DP5\@  MOVE.L  A0,SAN0\@  
202  JSR  4(A0)  
203  MOVEA.L  SA0\@,A0  
204  DP6\@  MOVEA.L  (A0),A1  
205  MOVE  \#1,-2(A1)  
206  SUB  \#1,NT\@  
207  TRAPV  
208  BGT.S  DP4\@  
209  LEA  \#1,A2  
210  LEA  \#1+(4*\(#2-1\)),A0  
211  DP7\@  MOVEA.L  (A0),A1  
212  SUBA  \#4,A0  
213  TRAPV  
214  MOVE  \#0,-2(A1)  
215  CMPA.L  A2,A0  
216  BPL.S  DP7\@  
217  ENDM  
218  RETURN$E  MACRO  
219  RTS  
220  ENDM  
221  RETURN$T  MACRO  
222  RTS  
223  ENDM  
224  BACKEXEC  MACRO  
225  LEA  \#1-\#2,A3  
226  ENDM  
227  ENTER$  MACRO  
228  TST  \#1-4
229     BEO.S  x+4
230     JSR   \1+4
231     ENDM
232     REDO$ MACRO
233     JMP   \1
234     ENDM
235     EXIT$ MACRO
236     JMP   \1
237     ENDM
238     CALL$ MACRO
239     IFNC   '','\2'
240     LEA    \2,A0
241     MOVE.L A0,+(A7)
242     ENDC
243     IFNC   '','\3'
244     LEA    \3,A0
245     MOVE.L A0,+(A7)
246     ENDC
247     IFNC   '','\4'
248     LEA    \4,A0
249     MOVE.L A0,+(A7)
250     ENDC
251     IFNC   '','\5'
252     LEA    \5,A0
253     MOVE.L A0,+(A7)
254     ENDC
255     JSR   \1
256     ENDM
257     JTR$ MACRO
258     TST   \2
259     BNE   \1
260     ENDM
261     HLD$S1 MACRO
262     MOVE   \1,+(A7)
263     ENDM
264     JN GT$S1 MACRO
265     CMP   \A7,+\2
266     BCE   \1
267     ENDM
268     JN LT$S1 MACRO
269     CMP   \A7,+\2
270     BLE   \1
271     ENDM
272     ADD$S1RI MACRO
273     ADDI   \3,\2
274     TRAPV
275     ENDM
276     MUL$S2IR MACRO
277     MULS   \2,\3
278     ASL.L  \1,\3
279     TRAPV
280     ENDM
281     NOT$EVR MACRO
282     NOT   \1
283     ENDM
284     SUB$S1IR MACRO
285     SUBI   \2,\3
TRAPV
NEG \3
TRAPV
ENDM
CVP$S21 MACRO
SHAP \2
ENDM
LDI$S1 MACRO
MOVE \#2,\1
ENDM
LDM$S1 MACRO
MOVE \2,\1
ENDM
LDM$EV MACRO
MOVE \2,\1
ENDM
SCL$S1R MACRO
IFLE \2-8
ASR \#2,\1
ENDC
IFGT \2-8
MOVE \#2,DS
ASR DS,\1
ENDC
ENDM
SLV$S1 MACRO
TST D7
BPL.S SL1\0
TST \1-2
BEQ.S SL1\0
MOVE \1,\2
BRA.S SL1\0+4
SL1\0 MOVE \2,\1
ENDM
READ MOVEA.L (A7)+rA0
MOVEA.L (A7)+rA1
MOVEA.L (A7)+rA1
MOVE.L A0,\-(A7)
RTS
DAC1 MOVEA.L (A7)+rA0
MOVEA.L (A7)+rA1
MOVE.L A0,\-(A7)
RTS
DAC2 MOVEA.L (A7)+rA0
MOVEA.L (A7)+rA1
MOVE.L A0,\-(A7)
RTS
x
CONTROL AND INITIALIZATION
INITIAL$
DATAEG$
x
FOREGROUND EXECUTIVE MAPS
...NONE REQUIRED
x
EXECUTABLE SEGMENT ENTRY ADDRESSES

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SIMULATION TRANSFER MAPS

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<td>5648</td>
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 pressing with the keys `XFER IMAGE OF DATAPROC.P.AN`.

```
400 X 5954 FROM DUCTSIM.C.PRD
401 DC$ 0 *TO DATAPROC I-BUS
402 DC$ -2 *RESERVED
403 DC$ -1 *END OF MAP
404 X 5960 FROM DUCTSIM.P.PFNA
405 DC$ -2 *RESERVED
406 DC$ -1 *END OF MAP
407 X 5964 FROM DUCTSIM.P.FLC
408 DC$ -2 *RESERVED
409 DC$ -1 *END OF MAP
410 X 5968 FROM DUCTSIM.P.PREPDONE
411 DC$ -2 *RESERVED
412 DC$ -1 *END OF MAP
413 X
414 X
415 X CHANNEL TRANSFER MEMORY ALLOCATION
416 ORG$ 7936 XFER IMAGE OF DATAPROC.P.AN
417 X 7936
418 DC$ 0 *CALC FLAG
419 DC$ 25600 *S1 B+11
420 DC$ 0 *FILLER WORD
421 DC$ 5888 *XFER MAP ADDR
422 X 7944 XFER IMAGE OF DATAPROC.P.ANF
423 DC$ 0 *CALC FLAG
424 DC$ 20210 *S1 B+11
425 DC$ 0 *FILLER WORD
426 DC$ 5892 *XFER MAP ADDR
427 X 7952 XFER IMAGE OF CORESIM.C.JOBDONE
428 DC$ 0 *CALC FLAG
429 DC$ 0 *BOOLEAN
430 DC$ 0 *FILLER WORD
431 DC$ 5898 *XFER MAP ADDR
432 X 7960 XFER IMAGE OF CORESIM.C.ACN
433 DC$ 0 *CALC FLAG
434 DC$ 0 *S1 B+10
435 DC$ 0 *FILLER WORD
436 DC$ 5904 *XFER MAP ADDR
437 X 7968 XFER IMAGE OF CORESIM.C.ADN
438 DC$ 0 *CALC FLAG
439 DC$ 0 *S1 B+10
440 DC$ 0 *FILLER WORD
441 DC$ 5910 *XFER MAP ADDR
442 X 7976 XFER IMAGE OF CORESIM.C.WDN
443 DC$ 0 *CALC FLAG
444 DC$ 0 *S1 B+9
445 DC$ 0 *FILLER WORD
446 DC$ 5916 *XFER MAP ADDR
447 X 7984 XFER IMAGE OF CORESIM.C.PRC
448 DC$ 0 *CALC FLAG
449 DC$ 16389 *S1 B+1
450 DC$ 0 *FILLER WORD
451 DC$ 5922 *XFER MAP ADDR
452 X 7992 XFER IMAGE OF CORESIM.P.PFNA
453 DC$ 0 *CALC FLAG
454 DC$ 0 *S1 B+1
455 DC$ 0 *FILLER WORD
456 DC$ 5928 *XFER MAP ADDR
```
457  *  B000  XFER IMAGE OF CORESIM.P.FLC
458     DC$  0  **.CALC FLAG
459     DC$  13516  **.S1 B+1
460     DC$  0  **.FILLER WORD
461     DC$  5932  **.XFER MAP ADDR
462  *  B008  XFER IMAGE OF CORESIM.P.WDNC
463     DC$  0  **.CALC FLAG
464     DC$  0  **.S1 B+2
465     DC$  0  **.FILLER WORD
466     DC$  5936  **.XFER MAP ADDR
467  *  B016  XFER IMAGE OF CORESIM.P.PREPDONE
468     DC$  0  **.CALC FLAG
469     DC$  0  **.BOOLEAN
470     DC$  0  **.FILLER WORD
471     DC$  5940  **.XFER MAP ADDR
472  *  B024  XFER IMAGE OF CORESIM.P.DUCTDONE
473     DC$  0  **.CALC FLAG
474     DC$  0  **.BOOLEAN
475     DC$  0  **.FILLER WORD
476     DC$  5944  **.XFER MAP ADDR
477  *  B032  XFER IMAGE OF DUCTSIM.C.WDNC
478     DC$  0  **.CALC FLAG
479     DC$  0  **.S1 B+5
480     DC$  0  **.FILLER WORD
481     DC$  5948  **.XFER MAP ADDR
482  *  B040  XFER IMAGE OF DUCTSIM.C.FRD
483     DC$  0  **.CALC FLAG
484     DC$  16384  **.S1 B+1
485     DC$  0  **.FILLER WORD
486     DC$  5954  **.XFER MAP ADDR
487  *  B048  XFER IMAGE OF DUCTSIM.P.FFNA
488     DC$  0  **.CALC FLAG
489     DC$  0  **.S1 B+1
490     DC$  0  **.FILLER WORD
491     DC$  5960  **.XFER MAP ADDR
492  *  B056  XFER IMAGE OF DUCTSIM.P.FLC
493     DC$  0  **.CALC FLAG
494     DC$  13516  **.S1 B+1
495     DC$  0  **.FILLER WORD
496     DC$  5964  **.XFER MAP ADDR
497  *  B064  XFER IMAGE OF DUCTSIM.P.PREPDONE
498     DC$  0  **.CALC FLAG
499     DC$  0  **.BOOLEAN
500     DC$  0  **.FILLER WORD
501     DC$  5968  **.XFER MAP ADDR
502  *
503  *
504  *  LOCAL VARIABLE ALLOCATION
505     ORC$  10000
506     DC$  0  **AN H-LTCH
507     AN  DC$  25600  **.S1 B+11
508     DC$  0  **ANF H-LTCH
509     ANF  DC$  20210  **.S1 B+11
510  *
511  *
512  *  PROGRAM CONSTANT ALLOCATION
513    K1  DC$  1  * I1
514 *
515 *
516 * DISPATCH TASKLIST ALLOCATION
517 TL$1  DL$   WRTACN.
518 DL$   WRTADN.
519 *
520 *
521 * ARGUMENT GROUP ALLOCATION
522 *
523 ACNG  DS$   5   FOR OP-SYS USE
524 DN$   ACNG***
525 DN$   DATAPROC
526 DC$   2
527 DC$   1   ARGGROUP SIZE
528 DC$   0   BUSY FLAG
529 DC$   0   EXECUTION COUNT
530 DC$   1   NUMBER OF ITEMS
531 DC$   1   WORDS PER ITEM
532 DL$   7962   .ACN
533 DS$   1   RESERVED
534 *
535 ADNC  DS$   5   FOR OP-SYS USE
536 DN$   ADNC***
537 DN$   DATAPROC
538 DC$   2
539 DC$   1   ARGGROUP SIZE
540 DC$   0   BUSY FLAG
541 DC$   0   EXECUTION COUNT
542 DC$   1   NUMBER OF ITEMS
543 DC$   1   WORDS PER ITEM
544 DL$   7970   .ADN
545 DS$   1   RESERVED
546 *
547 ADCVAR DS$   5   FOR OP-SYS USE
548 DN$   ADCVAR***
549 DN$   DATAPROC
550 DC$   2
551 DC$   32   ARGGROUP SIZE
552 DC$   0   BUSY FLAG
553 DC$   0   EXECUTION COUNT
554 DC$   1   NUMBER OF ITEMS
555 DC$   1   WORDS PER ITEM
556 DL$   10022   .AN
557 DS$   62   RESERVED
558 DS$   32   RESERVED
559 *
560 ADCCHN DS$   5   FOR OP-SYS USE
561 DN$   ADCCHN***
562 DN$   DATAPROC
563 DC$   2
564 DC$   32   ARGGROUP SIZE
565 DC$   0   BUSY FLAG
566 DC$   0   EXECUTION COUNT
567 DC$   1   NUMBER OF ITEMS
568 DC$   1   WORDS PER ITEM
569 DL$   10008   .KI
570 DS$   62   RESERVED
* RESERVED

DATAEND

* DATAPROC EXECUTABLE SEGMENT

* EXECUTIVE: GETAN.  PRIORITY=0

GETAN.  BACKEXEC GETAN.,74

CALL$  READ,ADCVAR,ADCCNH

LDMS1  D0,AN  *B+11

ADD$S1RI  D0,D0,12800  *K2,B+11

SLUS1  AN,D0  *B+11

STUS1  793B,D0  *LBUSXFER

HLD$1  D0

LDI$1  D1,800  *MINAREA,B+11

JNT$1  S6,D1

LDI$1  D2,800  *MINAREA,B+11

SLUS1  AN,D2  *B+11

STUS1  793B,D2  *LBUSXFER

ACTIVAT$  5124,P  *BADADC.

EXIT$  S9

HLD$1  D0

LDI$1  D3,25600  *MAXAREA,B+11

JNT$1  S9,D3

LDI$1  D4,25600  *MAXAREA,B+11

SLUS1  AN,D4  *B+11

STUS1  793B,D4  *LBUSXFER

ACTIVAT$  5124,P  *BADADC.

LDM$1  D0,AN  *B+11

MUL$S1IR  D0,21770,D0  *K1P622M4,B-1

CVP$21  D0,D0  *B-1

SCL$S1R  D0,12  *B+11

SUB$S1IR  D0,16,D0  *SC$1,B+11

SLVS1  ANF,D0  *B+11

STVS1  7946,D0  *LBUSXFER

ENTER$  JOBDONE.

DISPATC$  TL$1,2,P

RETURN$E GETAN.

* TASK: WRTACN.

DC$  7962  *XVAR ADDRESS

DC$  1  *NUMBER OF XVARS

DC$  1  *TASK ENABLE

DC$  0  *TASK COMPLETE

WRTACN.  DS$  2  *ENTRY OVERHEAD

CALL$  DAC1,ACNG

RETURN$T WRTACN.

* TASK: WRTADN.

DC$  7970  *XVAR ADDRESS

DC$  1  *NUMBER OF XVARS

DC$  1  *TASK ENABLE

DC$  0  *TASK COMPLETE

WRTADN.  DS$  2  *ENTRY OVERHEAD

CALL$  DAC2,ADNG

RETURN$T WRTADN.
628  * TASK: JOBDONE.
629  DC$  7954  *XVAR ADDRESS
630  DC$  1   *NUMBER OF XVARS
631  DC$  1   *TASK ENABLE
632  DC$  0   *TASK COMPLETE
633  JOBDONE, DS$  2   *ENTRY OVERHEAD
634  TEST  TSTXVL$  7954,P  *JOBDONE
635  LDM$BV  D0,7954
636  NOT$BV  D0,D0
637  JTR$  S$19,D0
638  S$18  REDO$  TEST
639  EXIT$  S$20
640  S$19  ADVISE$H  3,P  *DPMESS
641  S$20  RETURN$T  JOBDONE.
642
643
644  * TARGET LIBRARY PROCEDURES
645  READ
646  DAC1
647  DAC2
648  END
649
650
651
652
653
654
655
656  *****RTMPL ERRORS: 0
657  *****RTMPL WARNINGS: 0
References

A real-time multiprocessor programming language (RTMPL) has been developed to provide for high-order programming of real-time simulations on systems of distributed computers. RTMPL is a structured, engineering-oriented language. The RTMPL utility supports a variety of multiprocessor configurations and types by generating assembly language programs according to user-specified targeting information. Many programming functions are assumed by the utility (e.g., data transfer and scaling) to reduce the programming chore. This manual describes RTMPL from a user's viewpoint. Source generation, applications, utility operation, and utility output are detailed. An example simulation is generated to illustrate many RTMPL features.