IAS ODT Reference Manual

Order Number: AA–M507B–TC

Operating System and Version: IAS Version 3.4

May, 1990

This document was prepared using VAX DOCUMENT, Version 1.2

Contents

Preface

Manual Objectives

This manual describes the On-Line Debugging Tool, ODT-11, used to debug user task images on IAS systems. It provides reference information on all ODT commands, plus information on how to use the commands to debug user task images.

Intended Audience

This manual is intended for all systems and applications programmers who develop task images under IAS. You should be familiar with the contents of the *IAS Guide to Program Development* before you read this manual.

Structure of this Document

This manual is divided into eight chapters and two appendixes, as follows:

Chapter 1 gives an overview of ODT. It then explains how to link the debugger into a user task image and how to begin and end a debugging session.

Chapter 2 explains the special symbols used in ODT and includes a reference table of all ODT commands, in alphabetical order. Readers who are approaching ODT for the first time should read Chapter 3 through Chapter 7 for explanations of the commands before studying the table of commands in detail. Experienced ODT users can use Chapter 2 by itself for quick reference.

Chapter 3 describes the command used to begin program execution, to stop execution at breakpoints and to continue execution after breakpoints. It also explains how to execute a program one or more instructions at a time.

Chapter 4 explains how to open and close task locations, how to change the contents of locations, and how to display the contents of locations in different modes.

Chapter 5 describes all the registers used by ODT. It includes reference tables as well as explanations of how registers are set and cleared. Experienced ODT users might want to consult the tables in this chapter, as well as those in Chapter 2, for quick reference regarding specific registers.

Chapter 6 describes ODT's memory search, fill, and list capabilities.

Chapter 7 describes how to use ODT to perform arithmetic calculations.

Chapter 8 explains how to link debuffers other than ODT into a user task image. It describes the trace program, a debugging aid that can be used in conjunction with ODT.

Appendix A describes how ODT responds to errors in user input or program logic. It lists all ODT error message codes in alphabetical order.

Appendix B shows the format of the PSW and summarizes the functions of its bits.

Associated Documents

The *IAS Documentation Directory and Master Index* describes other manuals of interest to ODT users.

Conventions Used in this Document

Throughout this book, symbols and other notation conventions are used to represent keyboard characters and to convey textual information. Conventions are explained below.

Convention	Meaning
$\boxed{\text{XXX}}$	A symbol with a 1- to 3-character abbreviation, such as $\boxed{\text{LF}}$ or $\boxed{\text{RETURN}}$, indicates that you press a key on the terminal.
$\boxed{\text{Ctrl/X}}$	This phrase indicates that you press the key labeled Ctrl while simultaneously pressing another key, such as C or Y. In examples, this control key sequence can be shown as ^X (for example, ^C or ^Y), because that is how the system displays it on your terminal.

Summary of Technical Changes

This manual describes four new ODT commands for use on IAS systems:

D	Accesses data space
I	Accesses instruction space
U	Sets the current mode of ODT to user mode
Z	Sets the current mode of ODT to supervisor mode

This manual also corrects small technical errors in the text and examples of the previous version. It represents a significant reorganization of material, intended to make information more available to readers.

1 Introduction to ODT

ODT, or Online Debugging Tool, is a utility for debugging task images. You can use ODT to perform the following operations:

- Control program execution
- Display the contents of locations or registers
- Alter the contents of locations or registers
- Search and fill memory
- Perform calculations

ODT commands consist of one character; some commands take a numeric or alphabetic argument. All ODT commands and the symbols that are used in them are listed in Table 2–3. Chapter 3 through Chapter 7 describe how you use the commands.

This chapter introduces ODT and describes how the debugger is initiated.

1.1 Overview of ODT

ODT is special code that you link into your task image to help you debug your program. When you run a task into which ODT has been linked, the debugger receives control automatically upon task initiation. Then, through ODT, you can execute your task gradually, setting breakpoints at selected locations or stepping through the program one instruction at a time. Chapter 3 describes ODT commands for controlling program execution.

You can examine any location in your program—instruction or data, word or byte—by "opening" the location with ODT. While the location is open, you can immediately change the contents. You can proceed forward or backwards to examine and modify other locations. Thus, you can test any number of modifications without rebuilding you task. Chapter 4 describes ODT commands for examining and altering locations and for moving from one location to another.

ODT operates through the use of a number of registers all of which you can set and reset. Some of these registers are used to store information about your program while ODT has control. Eight registers can be set to the locations of breakpoints. Eight can be set to relocation biases—the absolute base addresses of relocated object modules. You can use other registers to store values that you may want to use repeatedly during your debugging session. Chapter 5 describes the ODT registers.

You can use ODT to search for bit patterns in memory, to fill blocks of memory with a value, or to list blocks of memory on an output device. Chapter 6 describes these operations.

During a debugging session, you can perform a variety of calculations: determining offsets, evaluating arithmetic expressions, and constructing Radix-50 words. These calculations are described in Chapter 7.

1.2 Linking ODT With a User Program

ODT is provided on your system as an object module, LB[1,1]ODT.OBJ. LB:[1,1]ODT.OBJ. To use ODT, you must link the appropriate object module with the object module(s) of your program. When the resulting task image is run, ODT is invoked and initiated automatically.

If the task image is overlaid, ODT is linked into the root segment so that the debugger will always be available.

The following sections describe how to link ODT into a task image in different environments. Section 1.2.1 describes how to link ODT if your command line interpreter is MCR. Section 1.2.2 describes how to link ODT using the DCL command line interpreter. Section 1.2.3 describes how to use the IAS Program Development System (PDS) to link ODT into your task image.

The information in subsequent sections on initiating and using ODT applies to all environments, except as noted.

1.2.1 Linking ODT from MCR

To link ODT with your program when your command line interpreter is the Monitor Console Routine (MCR), you first invoke the Task Builder by typing TKB in response to the MCR prompt. The Task Builder replies with its own prompt, TKB>. In response to this prompt, enter a Task Builder command specifying the name of the file(s) to be linked. Include the /DA switch, which indicates that a debugger (in this case ODT, the default) should be linked into the image. The following example shows the resulting command line:

```
TKB>MYTASK/DA=MYFILE1,MYFILE2
```

The Task Builder accesses the file ODT.OBJ in UFD [1,1] on the library device and links it with the files MYFILE1.OBJ and MYFILE2.OBJ into the task MYTASK.

Using ODT requires that you consult an up-to-date map of your task. Therefore, you should in most cases request a new map when you build the task, as in the following command line:

```
TKB>MYTASK/DA,MYTASK/CR/-SP=MYFILE1,MYFILE2
```

For more information on using the Task Builder, consult the *IAS Task Builder Reference Manual*.

1.2.2 Linking ODT from MCR

To link ODT with your program(s) when your command line interpreter is the Monitor Console Routine (MCR), use the /DEBUG qualifier with the LINK command. To obtain a current map of the image file produced, you should also include the /MAP qualifier. The following example shows the resulting command line:

```
>LINK/MAP/DEBUG/TASK:MYTASK MYFILE1,MYFILE2
```

Object modules MYFILE1.OBJ and MYFILE2.OBJ are linked with object module ODT.OBJ in UFD [1,1] on the library device. The resulting task image is named MYTASK.TSK.

For further information on using MCR, consult the *IAS MCR User's Guide*.

1.2.3 Linking ODT Using IAS PDS

To link your program(s) with the IAS Program Development System (PDS), enter the LINK command with the /DEBUG switch in response to the PDS prompt. To obtain a map of the image file produced, include the /MAP switch as well. The following example shows the resulting command line:

```
PDS>LINK/MAP/DEBUG MYFILE
```

This command links the object module MYFILE.OBJ with the object module ODT.OBJ from LB:[1,] to produce the task image MYFILE.TSK.

For more information on linking under IAS, consult the *IAS Task Builder Reference Manual.*

IF your CLI is MCR, you enable instruction and data space commands by using the qualifier /CODE:DATA_SPACE, as well as the /DEBUG qualifier, with the LINK command. The following example shows the resulting command line:

```
>LINK/DEBUG/CODE:DATA_SPACE MYTASK
```

1.3 Invoking ODT

ODT is invoked automatically when you run a task image into which ODT has been linked, as described in the previous sections. Regardless of what operating system or CLI you use, enter the RUN command, specifying the name of the task image file.

ODT responds with a message indicating that it has been invoked and identifying the task image that it controls. On the next line, ODT displays its prompt, and underscore (_), indicating that it is ready to accept commands.

The following example (using MCR) shows how ODT is invoked when HIYA.TSK is run:

```
>RUN HIYA
ODT:TT15

_
```

In response to the ODT prompt, you can enter any ODT command. ODT commands are immediate-action commands; that is, ODT responds to the commands as soon as they are typed, without waiting for a line terminator. Therefore, commands cannot be corrected once they have been typed. You can, however, erase an incorrectly typed command argument by typing an illegal character or command (such as 8 or 9), or by typing CTRL/U or DEL. In response, ODT discards your input line, displays a question mark (?), and prompts for another command.

Error detection is described in greater detail in Appendix A.

1.4 Returning Control to the Host System

To return control from ODT to the host operating system, type X in response to the ODT prompt. This command causes execution of the system Task Exit directive, which terminates task execution.

1.5 Interrupting a Debugging Session

When you run a task linked with ODT, you can return to the command line interpreter prompt at any time by typing CTRL/C. Your task is still active. To stop execution of the task, enter the ABORT command in response to the MCR or DCL prompt. You cannot resume the aborted debugging session; you can only run your program again.

You can interrupt task execution without aborting your task and then continue debugging. After typing CTRL/C, use the commands described in the following sections, as appropriate for your system.

1.5.1 Resuming a Debugging Session

On an IAS timesharing system using the PDS command line interpreter, you can use the CONTINUE/DEBUG command to interrupt task execution and return to the ODT prompt. ODT responds with a TE error message, showing the current value of the program counter as the location where the error occurred.

The following example shows how the CONTINUE/DEBUG command is used:

```
PDS> RUN MYFILE
ODT:TT%
_G
^C
PDS> CONTINUE/DEBUG
TE:004020

_
```

Note that this command can be used only on a timesharing system. For further information, consult the *IAS PDS User's Guide*.

2 ODT Characters and Symbols

This chapter presents all of the ODT operators and commands and explains the meanings of ODT-specific symbols used in this book. (Symbols common to the document set are presented in the Preface.)

2.1 Variables Used in Command Descriptions

Table 2–3 and the command descriptions in Chapter 3 through 7 use lowercase alphabetic variables to represent numeric and alphabetic arguments specified in commands. These symbols are explained in Table 2–1.

Table 2–1 Variables Used in ODT Command Descriptions

Variable	Meaning
a	An address expression representing the address of a task image location. The various forms in which an address expression can be specified are explained in Section 2.2.
k	An octal value up to 6 digits long with a maximum value of 177777 (octal), or an expression representing such a value. An expression can include arithmetic operators or indicators, as described in Section 2.2.2. If more than 6 digits are specified, PDT truncates to the low-order 16 bits. If the octal value is preceded by a minus sign, ODT takes the two's complement of the value.
m	An octal value six digits long, used to represent a search mask .
n	An octal integer in the range 0 through 7.
x	An alphabetic character. A list of permitted alphabetic characters is given in the tables where the variable x is used.

2.2 Address Expression Formats

An address expression, represented throughout this manual by the lowercase letter a, is an expression interpreted by ODT as a 16-bit (6-digit octal) value. You use a address expression to refer to a location in your task.

You can specify an address expression in either absolute or relative (relocatable) form, as described in Section 2.2.1. You can include in the address expression various operators and symbols, as described in Section 2.2.2.

2.2.1 Absolute and Relative Addressing

Each location has an absolute address assigned to it when the task is built. You can refer to the location using this 6-digit octal value. However, when the task is built again, with modules added or changed, this value cannot refer to the same location. Therefore, it is often more convenient to refer to locations using relative (relocatable) addressing, which is less likely to be affected by subsequent task builds.

When you use relative addressing, you refer to a location not by its absolute value but by its position relative to a movable point. Usually, this movable point is the base (starting) address of the module to which the location belongs, because the distance between the base address and the addresses of locations within the module is easily determined from a task map or listing and is not likely to change without your knowledge. The movable point can, however, be any point that is convenient for debugging.

To use this form of addressing, you must first establish a simple means of referring to movable points through the use of ODT's relocation registers $R0 through $R7. Each time you run a task built with ODT, consult a task map to determine the absolute addresses of convenient movable points. The map's memory allocation synopsis contains the base addresses of all the modules in the task. Follow the procedure described in Section 5.2.1.1 to set ODT's eight relocation registers to absolute addresses.

Once a relocation register is set, you can use the number of that register, 0 through 7, in forming relative addresses.

A relative address has the following form:

```
n,k
```

where:

- n = The number of a relocation register, 0 through 7, representing $R0 through $R7.
- , = A required separator between the two parts of the relative address.
- k = The relative location, the distance of the desired location from the value contained in register $Rn. Usually, this is the location's position within the module whose base address is the value of the register.

Thus, relative address 0,100 refers to location 100 within the module whose base address is stored in ODT's relocation register $R0. Relative address 5,300 refers to location 300 within the module whose base address is stored in relocation register $R5.

A general term for the value stored in a relocation register is "bias value": a quantity equal to the distance (bias) between a relative location and its absolute address. A general term for the second part of a relative address is "offset": the distance of a relative location from the closest value (less than that location) stored in a relocation register. These terms are used throughout this manual.

2.2.2 Forming Expressions

An expression is a string of numbers, symbols, and operators that is interpreted as a number. For example, 3+6 is an expression; ODT would interpret it as the octal value 11.

You can use an expression to represent an absolute address, a register containing a bias value, or an offset, as described in Section 2.2.1.

An expression used in an ODT session can contain any of the following elements:

- Octal numbers. ODT will not accept input containing an 8 or 9; instead, it displays a question mark and a new prompt.
- The arithmetic operators plus sign (+) or space, indicating that values should be added, or minus sign (-), indicating that the value that follows it should be subtracted from the value that precedes it.
- The unary operator minus sign (-), indicating that the value that follows it is negative and should be interpreted in two's complement form.

- ODT register indicators Q or C , representing $Q and $C registers, as described in 7.3.4 and 7.3.3 respectively. When Q or C is used to represent a register containing a bias value, it must have a value in the range 0 through 7. When Q or C is used to represent an offset, it can contain any 16-bit value.
- The name of one of ODT's registers, used in the operations described in Chapter 5 and 6.
- The current location indicator (.), described in Section 7.3.2.

In evaluating expressions, ODT proceeds from left to right. It does not assign precedence to any operator, or recognize parentheses to establish precedence. Therefore, you must be careful to form expressions so that they will be interpreted correctly. You can use the equal sign operator (=), described in Section 7.3.1, to determine the value of expressions before using them in ODT operations.

Table 2–2 shows how ODT interprets the various forms of address expressions. This table assumes a value of 003400 for relocation register 3 ($R3) and a value of 3 for the constant register ($C).

Table 2–2 Forms of Address Expressions

Address Expression Input	ODT Octal Interpretation
5	000005
-17	177761
3,150	003550
C	000003
c,10	003410
c,C+C	003406
3,C	003403
$3	Task general register 3

2.3 Operator and Command Summary

ODT commands are made up of a combination of symbols and uppercase letters. Some commands have multiple forms.

Table 2–3 summarizes the ODT commands and operators, which are explained in detail in Chapter 3 through Chapter 7. The lowercase letters used in the command descriptions are explained in Section 2.1.

Table 2–3 ODT Operators and Commands

Format	Meaning
+ or space	Arithmetic operator used in expressions. Add the preceding argument to the following argument to form the current argument.
-	Arithmetic operator used in expressions. Subtract the following argument from the preceding argument to form the current argument. Also used as a unary operator to indicate a negative value.
, (comma)	Argument separator. Separates the number of a relocation register from a relative location to specify a relocatable address.
*	Radix-50 separator used in constructing Radix-50 words (see Section 7.3.5).
.	Current location indicator. Causes the address of the last explicitly opened location to be used as the current address for ODT operations.
;	Argument separator. Separates multiple arguments, allowing an address expression or ODT register value to be identified.
RETURN or kRETURN	Closes the currently open location and prompts for the next command. If RETURN is preceded by k, the value k replaces the contents of the currently open location before it is closed.
LF or kLF	Closes the currently open location, opens the next sequential location (a word or a byte, depending on the mode in effect) and displays its contents. If LF is preceded by k, the value k replaces the contents of the currently open location before it is closed.
^ or k^	Closed the currently open location, opens the immediately preceding location and displays its contents. If ^ is preceded by k, the value k replaces the contents of the currently open location before it is closed.
_ or k_	Interprets the contents of the currently open location as a PC-relative offset and calculates the address of the next location to be opened; closes the currently open location, and opens and displays the contents of the new location thus evaluated. If _ is preceded by k, the value k replaces the contents of the currently open location before it is closed.
@ or k@	Interprets the contents of the currently open word location as an absolute address, closes the currently open location, and opens and displays the contents of the absolute location thus evaluated. If @ is preceded by k, the value k replaces the contents of the currently open location before it is closed.
> or k>	Interprets the low-order byte of the currently open word location as a relative branch offset, and calculates the address of the next location to be opened; closes the currently open location, and opens and displays the contents of the relative branch location thus evaluated. IF > is preceded by k, the value k replaces the contents of the currently open location before it is closed.
< or k<	Closes the currently open location (opened by a _, @ or > command), and reopens the word location most recently opened by /, LF, or ^. If the currently open location was not opened by a , @, or >, then < simply closes and reopens the current location. If < is preceded by k, the value k replaces the contents of the currently open location before it is closed.
$n	Represents the address of one of eight general registers, where n is an octal digit identifying R0 through R7.

$x or $nx	Represents the address of one of ODT's internal registers, where x is one of the following alphabetic characters, and n is one octal digit. Registers exist within ODT in the following order:
	S = Processor Status register (hardware PS)
	W = Directive Status Word register for the user's task
	A = Search argument register
	M = Search mask register
	L = Low memory limit register

Table 2–3 (Cont.) ODT Operators and Commands

Format	Meaning
	H = High memory limit register
	C = Constant register
	Q = Quantity register
	F = Format register
	X = Reentry vector register
	nB = Breakpoint address registers
	ng = Breakpoint proceed count registers
	nI = Breakpoint instruction registers
	nR = Relocation registers
	nV = SST vector registers
	nE = SST (synchronous system trap) stack contents registers
	nD = Device control LUN (logical unit number) registers
" or a"	Word mode ASCII operator. Interprets and displays the contents of the currently open (or the last previously opened) location as two ASCII characters, and stores this word in the quantity register ($Q). If " is preceded by a, the value a is taken as the address of the location to be interpreted and displayed.
' or a'	Byte mode ASCII operator. Interprets and displays the contents of the currently open (or the last previously open) location as one ASCII character, and stores this byte preceded by a, the value a is taken as the address of the location to be interpreted and displayed.
% or a%	Word mode Radix-50 operator. Interprets and displays the contents of the currently open (or the last previously opened) location as three Radix-50 characters, and location as three Radix-50 characters, and stores this word in the quantity register ($Q). If % is preceded by a, the value a is taken as the address of the location to be interpreted and displayed.
/ or a/	Word mode octal operator. Displays the contents of the last word location opened, and stores this octal word in the quantity register ($Q). If / is preceded by a, the value is taken as the address of a word location to be opened and displayed.
\ or a\	Byte mode octal operator. Displays the contents of the last byte location opened, and stores this octal byte in the quantity register ($Q). If \ is preceded by a, ODT takes the value a as the address of a byte location to be opened and displayed.
k=	Interprets and displays expression value k as six octal digits and stores this word in the quantity register ($Q).
8 or 9, RUBOUT, or CTRL/U	Cancels the current command and awaits a new command. The decimal value 8 or 9 is not a legal character and thus, when entered, causes ODT to ignore the current command.
B	Removes all breakpoints from the user task.
nB	Removes the nth breakpoint from the user task.
a;nB	Sets breakpoint n in the user task at address a. If n is omitted, ODT assumes the lowest-numbered available sequential breakpoint.
C	Constant register indicator. Represents the contents of register $C (constant register).
D	Accesses data space. After this command is issued, ODT interprets all references to locations as referring to the D-space of the task.

Table 2–3 (Cont.) ODT Operators and Commands

Format	Meaning
E or kE or m;E or m;kE	Searches memory between the address limits specified by the low memory limit register ($L) and the high memory limit register ($H). ODT examines these locations for references to the effective address specified in the search argument register ($A), as masked by the value specified in the search mask register ($M). (The mask should normally be set to 177777 for the E command.) Such references might be equal to, PC-relative to, or a branch displacement to the location specified in $A. If E is preceded by k, the value k replaces the current contents of $A before ODT initiates the search. If E is preceded by m, the current contents of $M are replaced with the value m before ODT initiates the search.
F or kF	Fills memory locations within the address limits specified by the low memory limit register ($L) and the high memory limit register ($H) with the contents of the search argument register ($A). If F is preceded by k, the value k replaces the current contents of $A before ODT initiates the fill operation.
G or aG	Begins task execution, following these steps: sets BPT instructions in or restores BPT instructions to all breakpoint locations in the task image; restores the Processor Status Word and user program registers; and starts execution at the address specified by the program counter (user register $7). If G is preceded by a, the value a replaces the current contents of $7 before proceeding as described above.
I	Accesses instruction space. After this command is issued, ODT interprets all references to locations as referring to the I-space of the task.
K	Using the relocation register whose contents are equal to or closest to (but less than) the address of the currently open location, ODT computes the physical distance (in bytes) between the address of the currently open location and the value contained in that relocation register. ODT displays this offset and stores the value in the quantity register ($Q).
nK	Computes the physical distance (in bytes) between the address of the currently open or the last-opened location and the value contained in relocation register n. ODT displays this offset and stores the value in the quantity register ($Q).
a;nK	Computes the physical distance (in bytes) between address a and the value contained in relocation register n. ODT displays this offset and stores the value in the quantity register ($Q).
L or kL or a;L or a;kL	Lists all word or byte locations in the task between the address limits specified by the low memory limit register ($L) and the high memory limit register. If L is preceded by k, the value k replaces the current contents of $H before initiating the list operation. If L is preceded by a, the value a replaces the current contents of $L before initiating the list operation.
N or kN or m;N or m;kN	Searches memory between the address limits specified by the low memory limit register ($L) and the high memory limit register ($H) for words with bit patterns that do not match those of the search argument specified in the search argument specified in the search argument register ($A). Only bit positions set to 1 in the mask are compared. This search is identical in form and function to the word (W) search described below, except the ODT performs a test for inequality.
aO or a;kO	Calculates and displays the PC-relative offset and the 8-bit branch displacement from the currently open location to address a; or calculates and displays the PC-relative offset and the 8-bit branch displacement from the specified address a to the specified address k.
P or kP	Proceeds with user program execution from the current breakpoint location and stops when the next breakpoint location is encountered or the end of the program is reached. If k is specified, ODT proceeds with program execution from the current location and stops at the breakpoint only after encountering it the number of times specified by integer k.
Q	Quantity register indicator. Represents the contents of register $Q (quantity register).
R	Sets all relocation registers to the highest address value, 177777 (octal), so that they cannot be used in forming addresses.

Table 2–3 (Cont.) ODT Operators and Commands

Format	Meaning
nR	Sets relocation register n to the highest address value, 177777 (octal), so that it cannot be used in forming addresses.
a;nR	Sets relocation register n to address value a. If n is omitted, ODT assumes relocation register 0.
S or nS	Executes one instruction and displays the address of the next instruction to be executed. If n is specified, ODT executes n instructions and displays the address of the next instruction to be executed.
U	Sets the current mode of ODT to user mode.
V	Enables ODT's handling of all SST vectors, and writes the addresses of ODT's trap entry points into the table used by the SVDB$ Executive directive. (See Table 5–2) for a discussion of the SST vector registers and the $nV/ command.
W or kW or m;W or m;kW	Searches memory between the address limits specified by the low memory limit register ($L) and the high memory limit register ($H) for words with bit patterns that match those of the search argument specified in the search argument register ($A). ODT compares each memory word and the search argument for equality under the mask specified in the search mask register ($M). Only bit positions set to 1 are compared. When a match occurs, ODT displays the address of the matching location and its contents. If W is preceded by k, the value k replaces the current contents of $A before initiating the search. If W is preceded by m (identified by the semicolon that follows it), the value m replaces the current contents of $M before ODT initiates the search.
X	Exits from ODT and returns control to the Executive of the host operating system.
Z	Sets the current mode of ODT to supervisor mode.

3 Controlling Program Execution

When you run a task image into which ODT has been linked, ODT takes control before the first instruction of the task is executed. Information about the task is stored in ODT's internal registers, as described in Section 5.1.2.

At this point, you can execute your task immediately or issue ODT commands to affect locations or registers.

3.1 Setting and Removing Breakpoints

A common method of using ODT is to set breakpoints at important points in the task and then to execute the task. When a breakpoint is reached, execution is suspended. You can examine locations or registers to see how your task is executing. You can then change elements of your task and see how the changes affect execution.

3.1.1 Setting Breakpoints

To set a breakpoint at a location, issue a B (for "breakpoint" command in the following format:

```
a;nB
```

where:

- a = An address expression (in any of the forms described in Section 2.2) representing the location at which the breakpoint is to be set. This location must always be the first word of an instruction.
- n = The number of the breakpoint address register (from 0 to 7) to be used to store the address of the specified location. If you omit n, breakpoint address registers are assigned sequentially, beginning with register 0.

You can also set a breakpoint by opening a breakpoint address register as a word location and changing its contents. The address of a breakpoint address register is its register name, $nB. Opening and changing the contents of word locations is described in Chapter 4. Registers are described in Chapter 5.

3.1.2 Removing Breakpoints

You can clear breakpoint address registers (and thus remove breakpoints) using the nB command, where n represents the number of the register. If you omit n, all breakpoint address registers are cleared. You can also clear a breakpoint and reset it by specifying a new address expression for a breakpoint address register, using the a;nB command.

The following example shows how breakpoints are set, cleared, and reset:

```
_B
_1020;B
_2030;B
_3040;B
_4050;B
_2032;1B
_3B
_
```

At this point, breakpoint address register 0 is set to location 1020, breakpoint address register 1 is set to 2032, and breakpoint address register 2 is set to 3040. Breakpoint address register 3 is clear.

Note that ODT generates a carriage return, a line feed, and a new prompt immediately when you type the letter B.

You can also clear a breakpoint register by opening it as a word location whose address is $nB and changing its contents, as described in Chapter 4.

3.2 Beginning Program Execution

To begin execution of your task, type the G (for 'go') command. This command has the following effects:

- The task's starting address is returned to the program counter from the ODT general register in which it was stored.
- The task's stack and other general registers are restored.
- The contents of each location at which a breakpoint was set are swapped with the contents of the corresponding breakpoint instruction register. (These registers, described in Section 5.2, are initialized by ODT to BPT instructions.)
- Execution of the task begins.

Execution continues until it reaches one of the following:

- A breakpoint
- An error of type BE, EM, FP, IO, or TR (described in Appendix A)
- The end of the program

Once the program is executing, you cannot stop it except by aborting the program and restarting it. For commands to reenter an interrupted program, see Section 1.5.1.

When the task reaches a breakpoint, ODT executes the BPT instruction that was swapped into the breakpoint location. This instruction has the following effects:

- Task execution is suspended.
- The contents of the user task general registers are stored in ODT internal registers.
- The original contents are restored to all breakpoint locations from the breakpoint instruction registers where they have been stored.
- ODT issues a message indicating that a breakpoint has been reached. This message has the format nB:a, where n is the breakpoint address register number and a is the location of the breakpoint that was stored in that register.
- ODT issues its prompt.

While task execution is suspended, you may issue any ODT command.

3.3 Continuing Program Execution

You can continue program execution using either the P (for "proceed") command, the G command, or the aG command. Execution continues until a breakpoint, the end of the program, or an error of the types specified above is reached.

Use the P command to continue execution after a breakpoint. When you type P, the contents of the user general registers are restored, the BPT instructions are swapped into all breakpoint locations, and task execution resumes at the instruction following the last logical instruction executed. If execution stopped because of a breakpoint, it will resume at the breakpoint location. If execution stopped because of an error, it will resume at the location following the error location, not at the error location itself.

You can resume execution using the G command; however, because the G command does not transparently restore the breakpoint instruction, you should not use it to resume execution after a breakpoint.

To resume execution at a specific location, use the aG command. The argument a is an address expression regpresenting the task location. The address specified must correspond to a word location boundary, that is, an even location. Registers are affected as described in Section 3.2, and execution begins at the specified location.

Note that you can use only G or aG to begin execution of a task. If you type P when no G command has been executed, ODT responds with a question mark and a new prompt.

3.4 Using the Breakpoint Proceed Count

If you set a breakpoint inside an execution loop, you may want to suspend execution only when the loop has been executed a certain number of times. You can specify how many times a loop should be executed by including a breakpoint proceed count with the P command, in the form kP. The loop is executed k-1 times; execution is suspended when the breakpoint is reached for the kth time.

The kP command is associated only with the breakpoint that has most recently occurred. The count k is stored as an octal value in a breakpoint proceed count register ($nG), where n is a number corresponding to the number of the appropriate breakpoint address register.

You can examine the breakpoint proceed count registers, or set them directly, at any time following the procedures for examing and setting word locations described in Chapter 4.

3.5 Stepping Through the Program

Another methond of executing a task in stages is to use the S (for "step") command. With this command, you can execute user task instructions one at a time or several at a time.

The command has the format nS, where n is the number of instructions that ODT should execute before suspending execution. The default value of n is 1.

When n instructions have been executed ODT suspends task execution and prints a message of the form 8B:a, where a is the loction of the next instruction to be executed. (The format of a is relative by default, as explained in Chapter 4.) ODT then prompts for another command.

The S command is implemented through the T-bit in the Processor Status Word (described in Appendix B). The T-bit is set when you issue the command; when the nth instruction is executed, control is returned to the user.

The following example shows ODT's response to the program execution commands described in this chapter:

```
_1,1052;B
_1,2052;1B
_G
0B:1,001052
_P
1B:1,002052
_S
8B:1,002056
_S
8B:1,002062

_
```

4 Displaying and Altering the Contents of Locations

During an ODT session, you can alter the contents (either instructions or data) of locations in your task. To alter the contents of a location, you must first *open* the location.

You open a location by displaying its contents, using any of the commands described in Section 4.3 through 4.9. The contents displayed are automatically placed into the quantity ($Q) register.

ODT displays a location by showing the address followed by a mode operator (either word mode or byte mode, depending on the size of the location opened) and the contents of the location. The format in which the location is displayed is controlled by the contents of the format register ($F), as described in Table 5–1. By default, ODT displays addresses in relative form whenever it has the information necessary to construct such an address: the number of the relocation register containing the bias value closest to (but less than) the address, and the relative location of the address from that value. When this information is not available, ODT prints the address in absolute form. (Relative and absolute forms are described in Section 2.1.)

ODT does not generate a carriage return or line feed after displaying the contents of a location. Until the location is closed the cursor remains on the same line, wrapping around as necessary.

4.1 Altering the Contents of a Location

You alter the contents of a location by typing the new contents immediately after the displayed contents. The new contents can be an absolute octal value (of up to six digits) or an expression equivalent to a 6-digit octal value, as described in Section 2.2.2.

If you enter an octal value, you may omit leading zeros.

In the following examples, the value 1234 is substituted for the value 123456 in the location represented by the address expression 2,0. The value 177426 (the two's complement result of the expression 16-370) replaces the value 000000 in the location represented by the address expression 4,10.

```
_2,0/123456 1234
_4,10/000000 16-370
```

After you have altered the contents of a location, you can verify the new contents by displaying them in a variety of modes, using the commands described in Section 4.10. These commands do not close the location. You can also verify the contents by closing the location and then reopening it, so that the new contents are displayed.

Before you can alter the contents of a new location, you must close the currently open location.

4.2 Closing a Location

To close a location without automatically opening another location, enter the RETURN command. This command has no effect on ODT when no location is open.

The RETURN command generates a carriage return and a line feed. ODT then prompts for another command, as follows:

```
_1,200/450123 RETURN
_
```

To close a location and automatically open another location, you can use any of the following commands described in Section 4.4 through 4.9:

```
LF    ^    _    @    <    >
```

4.3 Opening Word and Byte Locations

ODT interprets the slash character (/) as a word mode octal operator and the backslash character (\ ) as a byte mode octal operator. Using these operators in ODT commands is the most direct way to open word and byte locations. These commands are described in the following sections.

You can also open word and byte locations and display their contents in ASCII, or open and display words in Radix-50. Using these modes is described in Section 4.10.

4.3.1 The a/ and a \ Commands

To open a word location beginning at an address, type an address expression corresponding to that address, followed by a slash, in response to the ODT prompt. The address must be even numbered. ODT opens the word location beginning at the specified address and displays the contents of that location as a 6-digit octal number.

To open a byte location, type an address expression corresponding to an odd- or even-numbered address, followed by a backslash. ODT opens the byte location beginning at the specified address and displays the contents of that location as a 3-digit octal number.

The following examples show the effects of the a/ and a\ commands:

```
_1000/012675 RETURN
_1001\025 RETURN
_
```

4.3.2 The / and \ Commands

You can use the word mode and byte mode octal operators without address arguments to reopen the location last opened. The / command opens the word location last opened and displays the word at that location. The \ command opens the byte last opened and displays the contents of that byte. (If the last location opened was a word, the byte opened and displayed is the low-ordered byte of that word.)

When no location is open, you can also use the ^ command to open the last-opened location, as described in Section 4.5.

4.3.3 Moving Between Word and Byte Modes

The word mode and byte mode octal operators establish word mode and byte mode, respectively.

Once you have opened a location using the word mode octal operator (/), all locations subsequently opened will be octal words until the mode is changed. Once you have opened a byte location using the byte mode octal operator (\ ), all locations subsequently opened will be octal bytes until the mode is changed.

You can change from word to byte mode by opening a location with the a\ command or by specifying an odd-numbered address as the value a in the a/ command. Subsequent locations will be displayed as bytes until a word location is explicitly opened using an even-numbered address as the value a in the a/ command (or the a" or a% commands, described in Section 4.10.

The following example shows a change from word mode to byte mode and back again using an odd-numbered address in the a/ command. (The LF command, which opens the next sequential location in whatever mode is currently in use, is described in Section 4.4.)

```
_1001/123 321 RETURN
_/321 LF

001002 \021 LF

001003 \010 LF

001004 \201 RETURN
_1006/102054
```

If a word location is open, you can examine its low-order byte by typing the byte mode octal operator (\ ) immediately after the displayed contents of the location. The location is not closed and you do not leave word mode. The following example shows this use of the byte mode octal operator:

```
_1006/102054 \054 LF

1010/012345
```

You can also examine words or bytes of an open location in ASCII or Radix-50 modes, as described in Section 4.10.

4.4 Opening the Next Sequential Location

To open and examine successive locations, use the LF command. The LF command closes the currently open location and opens the next sequential location. If the currently open location is a word, the next sequential location will be opened as a word. If the currently open location is a byte, the next sequential location will be opened as a byte.

If you specify a value before entering the LF command, that value replaces the contents of the open location, as described Section 4.1.

4.5 Opening the Preceding Location

To back up in your task and open the location preceding the location that is currently open, use the ^ command. This command closes the currently open location. If the currently opened location is a word location, the command opens the word location immediately preceding it. If the currently open location is a byte, the ^ command opens the preceding byte.

If no location is currently open, the ^ command opens and displays the contents of the last-opened location, a word or a byte, depending on the mode currently in effect.

If you specify a value before entering the ^ command, that value replaces the contents of the open location, as described in Section 4.1.

The following example shows the use of the LF and ^ commands. Location 232, relative to the bias contained in relocation register 0, is opened as a word and its contents are altered. In response to the LF and ^ commands, ODT proceeds to the next word location and then backs up to 232 to display the new contents.

```
_0,232/005036 005046 LF

0,000234 /012746 ^
0,000232 /005046
```

4.6 Opening Absolute Locations

To proceed from an open location to the location whose address is contained in that location, use the @ command. This command closes the currently open location and uses the contents of that location as the absolute address of the next location to be opened. You can specify new contents for the original location by entering a value before the @ command, as described in Section 4.1.

You can only use the @ command if the currently open location is a word.

Opening an absolute location does not necessarily mean that the location is displayed as an absolute address. As shown in the following example, where relocation register 2 is set to contain the bias value 370 (as described in Section 5.2.1, ODT still by default displays the location as a relative address.

```
_370;2R
_2,600/012345 12746@
2,012356 /027117
```

Location 12356 relative to bias value 370 is equivalent to the absolute address specified, 12746.

4.7 Opening PC-Relative Locations

To open a location relative to the program counter, use the _ command. This command adds the contents of the currently open location to the value of the program counter, which is the address of the currently opened location plus 2. ODT closes the currently open location and opens the location whose address is the result of its calculation. If you enter a value before the _ command, this value replaces the contents of the open location and is used in the calculation.

You can only use the _ command if the currently open location is a word.

If the currently open location contains an odd number (or if it contains an even number but is already a byte location), so that the calculated address does not fall on a word boundary, the _ command opens a byte at the location calculated.

The following examples show how the _ command is used:

```
_1000/000040_
001042 /052407

_0,232/012345_
0,012601 /041

_0,232/123456_
0,123712 /020301
```

4.8 Opening Relative Branch Offset Locations

Use the > command to open a location at a branch offset relative to the currently open location. The offset is calculated as follows:

1 The low-ordered byte of the contents of the currently open location is interpreted as a signed value. A negative value results in a negative branch offset.

2 This value is multiplied by 2.

3 The resulting offset is added to the PC value, which is the address of the currently open location plus 2.

The > command closes the currently open location and opens the location whose address is the value calculated. Its effects are shown in the following examples:

```
_1,66/05046>
1,000204 /000601

_1032/000407 301>
000636 /000010
```

If you specify a value before entering the > command, the low-order byte of that word is used in the offset calculation. The value replaces the contents of the open location, as described in Section 4.1.

4.9 Returning From a Calculated Location

If you have used any of the three address calculation commands described in the last three sections (@, _, or >) and wish to return to the location from which you began to calculate addresses, use the < command. This command closes the currently open location and reopens the word most recently opened by a /, LF, or ^ command.

The following example shows the use of the < command:

```
_1036/021346 ^
1034/101025 101036_
102074 /000000 @
000000 /000000 >
000002 /000102 <
001034 /101036
```

If the currently open location was not opened by < @, _, or > command, the < command simply closes and reopens the current location.

4.10 Using Different Output Modes

The examples in the previous sections have shown ODT output in word mode octal and byte mode octal. However, you can also use ODT to display the contents of locations in word or byte mode ASCII and word mode Radix-50.

These modes follow the same rules as word mode octal and byte mode octal:

- You can use the LF command to open succeeding locations in the same mode in which the currently open location was opened.
- You can enter any mode operator to display the contents of the currently open location in another mode without changing the mode in effect or closing the location.

The interaction of mode operators was shown in Section 4.3.3, where a location opened in word mode octal was examined in byte mode. The LF command that followed opened the next sequential location in word mode octal.

4.10.1 ASCII mode

ODT interprets the double-quote character (") as a word mode ASCII operator and the apostrophe (') as a byte mode ASCII operator. You open a location in word mode ASCII with the a" command and in byte mode ASCII with the a' command.

IF you open a location in any mode and then type a word mode ASCII operator, the contents of the open location will be displayed as two ASCII characters but the location will not be closed.

If you open a location in any mode and then type a byte mode ASCII operator, the contents of the low-order byte of the open location will be displayed as one ASCII character. The location will not be closed.

The following examples show these uses of the ASCII operators:

```
_0,440"AB

_2,100'H

_0,232/034567 'w "w9 LF

0,000234/000123 RETURN
_ S
```

If you enter the word mode ASCII operator to examine the contents of a location and the location is aligned on a byte boundary (an odd-numbered address), ODT will not return as ASCII character Instead, it will display the contents of the location in the mode currently in effect, as follows:

```
0,000235\025 "025
```

4.11 Radix-50 Mode

ODT interprets the percent sign (%) as a word mode Radix-50 operator. (There is no byte mode Radix-50 operator, since Radix-50 is a method of fitting three characters into a word and cannot be used in smaller units.)

You can use the Radix-50 operator to open locations. The a% command opens the location specified in the address expression a and displays its contents as three Radix-50 characters. The % command reopens the last-opened word and displays its contents as three Radix-50 operator:

```
_4,232%IG1

_4,232/034567 RETURN
_%IG1

_4,000232/034567 %IG1
```

Like the word mode ASCII operator, the Radix-50 operator cannot be used to interpret values beginning on byte boundaries. If you enter the Radix-50 operator when the currently open location has an odd address, ODT simply displays the byte value in the current mode.

Remember that you must enter new contents for a location as an octal value or an expression, not as Radix-50 characters. To determine the octal equivalent of Radix-50 characters, use the Radix-50 evaluator (*), as described in Section 7.3.5.

5 Using Registers

ODT has a number of 16-bit registers. Some of these registers are used for temporary storage of values; some contain values used repeatedly throughout the execution of your task under ODT. All of the registers are word locations that you can examine and alter.

Each ODT register has a unique name beginning with a dollar sign ($). The $ and the character or characters that follow it make up an address expression that identifies the register.

This chapter explains how ODT uses its registers. Table 5–1 and 5–2 summarize the registers and are useful for quick reference.

5.1 General Registers

ODT has eight general registers, numbered $0 through $7, which store the contents of the user program's general registers when ODT has control. These registers are automatically set when ODT first is invoked and when a breakpoint occurs. They can also be set by the user.

5.1.1 Examining and Setting General Registers

To examine a general register, enter the register name as the address expression in the a/, a", or a% command. For example, you can enter any of the following:

```
$7/
$3%
1"
```

ODT opens a register like any other word location. You can then alter the contents of the register or use any of the following commands, as described in Chapter 4:

RETURN   LF   /   ^   _   @   "   %

ODT treats the general registers as sequential word locations.

5.1.2 Contents of General Registers

When you issue the RUN command and ODT initially gains control, information about the user task is stored in the general registers as follows;

Register	Contents
$0	Task's entry-point address
$1	First three characters of task's run-time name (Radix-50)
$2	Last three characters of task's run-time name (Radix-50)
$3-$4	Version number of user task if the program included the .IDENT directive; otherwise, the version number of ODT

When a breakpoint occurs, ODT's general registers store the contents of the task's general registers.

5.2 ODT Internal Registers

The ODT internal registers store values for use during a debugging session. For example, they store the locations of breakpoints and the memory limits to be used in search operations. Each register is a 16-bit location that you can open by specifying the register name as the address expression with any ODT command that opens a word location. You can enter any of the following:

```
$3R/
$A"
$C%
```

It is rarely useful to examine an internal register in ASCII or Radix-50 mode.

You can alter the contents of these registers as you would the contents of any word; however, this is not recommended in some cases, as described in Table 5–1 and 5–2.

Ten of the ODT internal registers are single registers; that is, there is only one register for each function. You refer to one of these registers as $x, where x is an alphabetic character. Table 5–1 lists these registers in alphabetical order. In the task, they appear in the order listed in Table 2–3, that is:

$S $W $A $M $L $H $C $Q $F $X

You can access these registers as sequential word locations in this order, as in the following example:

```
_$S/000000 LF
$W /000001 LF
$A /000000 LF
$M /177777
```

Table 5–1 ODT Single Registers

Register	Function
$A	Search argument register. You set this register to a word search argument by opening with the / operator, or to a byte search argument by opening with the \ operator. Can also be set through the memory commands described in Chapter 6.
$C	Constant register. The 16-bit value in this registers can be used as an address expression or a value through the constant register indicator C, described in Section 2.2 and 3.1.
$H	High memory limit register. The location contained in this register is the upper location limit for ODT search, list, and fill memory operations. Initialized to 0.
$L	Low memory limit register. The location contained in this register is the lower location limit for ODT search, list, and fill memory operations. Initialized to 0.
$M	Search mask register. You set this register to a word search mask by opening with the / operator, or to a byte search mask by opening with the \ operator. Can also be set by arguments specified with the memory commands described in Chapter 6. Initialized to minus one, 177777(octal).
$Q	Quantity register. ODT sets this register to the last value displayed, as described in Section 7.3.4. $Q is also used for the results of expression calculations using the = operator.
$S	Processor status register. Stores the Processor Status Word (see Appendix B) resulting form the last instruction executed prior to a breakpoint. Users do not normally change the contents of this register directly.

Table 5–1 (Cont.) ODT Single Registers

Register	Function
$W	Directive Status Word register. Contains the Directive Status Word (DSW) of the task, indicating the success or specific cause of rejection of the most recently executed directive. The contents of this register are maintained across breakpoints. See the Executive Reference Manual of the host system for details on the DSW.
$X	Reentry vector register. A positive value cause's ODT to retain register values for successive entries of ODT, as described in Section 5.2.2.

The other ODT internal registers are grouped into sets of eight or three sequential word locations. The integer n is part of the register name, in the form $nx; you must always include n, even if its value is 0.

Table 5–2 lists the register sets alphabetically. In the task, they appear as sequential word locations in the order listed in Table 2–3, that is:

$nB nG $nI $nR nV $nE $nD

Table 5–2 ODT Register Sets

Register	Range of n	Function
$nB	0 - 7	Breakpoint address register n. Contains user-specified address of location (breakpoint) in the user task whose contents are to be swapped with the contents of $nI when a G or P command is executed. A ninth register, $8B, is used by ODT for single-step execution.
$nD	0 - 2	Device control LUN (logical unit number) register n. As described in Section 6.1.4, register $0D contains the LUN of the user terminal and register $1D contains the LUN of the console device. Register $2D contains the QIO event flag number, normally a default value of 000034 (octal).
$nE	0 - 2	SST stack contents register n. The top three items on the user program stack are placed into these registers when a synchronous system trap occurs. Stack contents depend on the type of trap taken, as explained in the Executive reference manual of the host operating system.
$nG	0 - 7	Breakpoint proceed count register n, where a corresponds to breakpoint address register n. Contains number of times the breakpoint location should be encountered before the breakpoint is recognized. Each register is initially set to 1 and can be set through the kP command (see Section 3.4), or by opening $nG and altering its contents. A ninth register, $8G, is used by ODT for single-step execution.
$nI	0 - 7	Breakpoint instruction register n. Initialized to contain a BPT instruction, op code 000003, which is swapped with the contents of register $nB when the G or P command is executed. The functions of the BPT instruction are described in Section 3.2. A ninth register, $8I is used by ODT for single-step execution.
$nr	0 - 7	Relocation register n. Contains the relocation bias of a relocatable object module, enabling ODT to display user task addresses in relative form, if $F is set to 0 (see Table 5–1). ODT initializes each register to 177777 (octal).

Table 5–2 (Cont.) ODT Register Sets

Register	Range of n	Function
$nV	0 - 7	SST vector register n. Contains entry-point address of ODT routine for handling a synchronous system trap. If both ODT and the user program have SST vectors enabled for the trap, ODT automatically receives the trap, except for vector 6 ($6V), which must be explicitly enabled through the V command (see Table 2–3). ODT handling of a trap can be disabled by clearing the register; the user program vector then receives the trap. Registers correspond to traps as follows:

Register	SST Vector
$0V	Odd address reference in word instruction (also, on some processors, illegal instruction executed)
$1V	Memory protection violation
$2V	T-bit trap or BPT instruction executed
$3V	IOT instruction executed
$4V	Reserved or illegal instruction executed
$5V	Non-IAS EMT instruction executed
$6V	TRAP instruction executed
$7V	PDP-11/40 floating-point exception error

The following sections describe the functions of ODT internal registers $nR, $X, $C, and $Q in greater detail. Registers used in memory operations ($L, $H, $M, $A, and $nd) are described in Chapter 6.

5.2.1 Relocation Registers

ODT's eight relocation registers allow you to refer to locations by relative addresses instead of absolute addresses. Since relative addresses are easy to determine from source file listings, using them makes debugging faster and simpler.

When ODT is initialized, each relocation register is set to 177777 (octal). This is the highest possible memory address and therefore cannot be used in constructing address expressions. To make a relocation register useful, you place in it the base address of a relocatable module or another convenient point, as explained in Section 2.2.1. This address functions as a relocation bia: that is added to the relative address in an address expression to form the absolute address of a location.

You obtain the base (starting) address of a module by consulting the memory allocation synopsis ir your task map. This part of the map gives the octal starting address of each program section and each module that makes up a program section. It also shows the extent of the module, in octal an(decimal.

The following example shows a memory allocation synopsis for a brief task:

```
SECTION                        TITLE  IDENT  FILE

. BLK.:(RW,I,LCL,REL,CON) 001264 001012 00522.
                          001264 000574 00380. HIYA        HIYA.OBJ;1
$$RESL:(RO,I,LCL,REL,CON) 010152 000112 00074.
$$$ODT:(RW,I,GBL,REL,OVR) 002276 005654 02988.
                          002276 005654 02988. ODTRSX M06  ODT.OBJ;1
```

5.2.1.1 Setting Relocation Registers

You can set relocation registers either by opening them as word locations and altering them, or by using special ODT commands that affect relocation registers.

To open a relocation register as an octal word, use the register name $nR as the address expression a in the a/ command (or any of the other commands described in Chapter 4 that open words). You can enter a new value for the register after examining the existing contents.

The ODT command a;nR sets register $nR to the location specified as address expression a. If you omit n, register $0R is assumed.

5.2.1.2 Clearing Relocation Registers

To remove a relocation register from consideration in calculating addresses, enter the nR command, where n is the number of the relocation register. This command sets the register to 177777 (octal), so that it is no longer useful in constructing address expressions. If you omit n, all relocation registers are set to 177777 (octal).

5.2.2 The Reentry Vector Register

If you have fixed a task in memory (using the FIX command, described in the *IAS MCR User's Guide*, and the *IAS PDS Users Guide*, you can use the reentry vector register, $X, to maintain register values set during your debugging session and to keep track of your access to the task.

The reentry vector register contains the value -1 when your task is built. When you execute the task for the first time, the register value is incremented to 0. The 0 value causes ODT to omit the task name from the invocation message line (described in Section 1.3) the next time you enter the task. This omission indicates that the task is fixed in memory.

If you intend to reenter the task for further debugging, you should set $X to 1 or another positive nonzero value. As long as the value of $X is positive and nonzero, the fixed task is reentered at the value stored in $7 (the program counter), and the values stored in ODT's registers are maintained. You can continue to debug the task using the breakpoints, constants, and other values established in an earlier debuffing session. If $X is not positive, all registers are initialized when you reenter the task.

You can use the reentry vector register as a counter to record how many times you have entered a fixed task. To do this, set the register to 1 the first time you enter your task and increment it each time you access the task again.

6 Memory Operations

ODT allows you to perform three kinds of operations on blocks of memory in your task:

- Search memory for bit patterns or references to locations
- Fill memory with a value
- List blocks of memory on an output device

Section 6.1 describes how you establish the registers used in memory operations. The subsequent sections of this chapter describe how you use ODT commands to perform these operations.

6.1 Registers Used in Memory Operations

ODT memory operation commands function between limits in memory that you must specify. Search and fill commands require an argument to be searched for or deposited. Search operations also require a search mask.

ODT maintains registers to contain all of these values. You can set these registers as word or byte locations (as described in Chapter 4 and Chapter 5 before issuing memory operation commands. You can also specify a search argument and a search mask as the k and m arguments in the commands themselves. If you do not specify an argument in one of these commands, ODT uses the current contents of the appropriate register; if you specify an argument, that argument replaces the contents of the register.

6.1.1 Search Limit Registers

There are two search limit registers: $H, containing the high memory limit for a search, fill, or list operation; and $L, containing the low memory limit. You deposit a memory location in one of these registers by opening it as a word location and changing its value to the address of the location. You can specify the location in either absolute or relative form, as follows:

```
_$L/000000 1000 [RETURN]
_/ 001000 2,4060 [LF]
_$H/000000 3,100 [RETURN]
_
```

If the value in $L is greater than the value in $H, ODT will not perform the memory operation requested using these registers. Instead, ODT displays its prompt.

6.1.2 Search Mask Register

ODT initializes the search mask register $M to 177777 (octal), so that all bits are set to 1. You set the value of the register by opening it as a word location and changing its value. Only bit positions set to 1 in the search mask are compared in the search operation. The value compared is that set for the corresponding bit position in the search argument register $A.

You can also set register $M by specifying a value m, followed by a semicolon in any of the search commands described in Section 6.2.

6.1.3 Search Argument Register

The search argument register $A contains the value searched for in a memory search operation or filled with in a memory fill operation. You can set this value by opening register $A as a word or byte location and changing its contents, or by specifying the argument k in one of the search commands described in Section 6.2 and Section 6.3.

As noted in Section 6.1.2, only bit positions set to 1 in the search mask are compared in any memory search operation.

6.1.4 Device Control LUN Registers

The device control LUN registers $0D and $1D contain the logical unit numbers of (respectively) the user terminal (TI:) and the console device (CL:). You specify one of these registers as the valu n in the n:a;kL command (described in Section 6.4.1) to indicate what device should be used for a listing.

The Task Builder assigns default values for these registers: 000007 (octal) for $0D and 000010 (octal) for $1D. To reset these registers, you can link your task using the TKB option UNITS=keyword as described in the *IAS Task Builder Manual.*

You may find it more convenient simply to assign a new value for CL: before beginning your debugging session. Use the MCR command ASN or the DCL command ASSIGN, in one of the following formats:

```
ASN devicename=CL:              (MCR command)
```

and

```
ASSIGN CL: devicename           (DCL command)
```

For more information on these commands, see the command line interpreter manual for your system.

6.2 Searching Memory

There are three memory search commands: W, N, and E. Each of these commands has several forms, depending on the number of registers that already contain values that you want to use in the search operation. The following sections describe these command forms.

6.2.1 Searching for a Word or Byte

The W command searches for occurrences of the search argument (comparing bit positions specifie in the search mask) within the range set by the contents of the search limit registers.

The full form of the command is m;kW, where m specifies the search mask and k specifies the search argument. However, you can omit either or both of these arguments if the corresponding registers contain the values that you want to use. If you omit m, you should also omit the semicolon argument separator.

ODT performs an exclusive OR(XOR) operation on the contents of each location and the search argument; it then adds the result of this comparison with the search mask. A result of zero indicates a match. When a match occurs, ODT prints the address and contents of the location an repeats the search operation until the high memory limit is reached.

6.2.2 Searching for Inequality of a Word or Byte

The N command is the opposite of the W command: It examines the search range for words or bytes that do not exactly match the search argument in the positions determined by the search mask.

The full form of the command is m;kN, where m specifies a search mask and k specifies a search argument. As with W command, you can omit either argument or both.

The search algorithm proceeds like that for the W command, except that a location's address and contents are only displayed by ODT when the AND operation has resulted in a nonzero value.

6.2.3 Searching for a Reference

The E command searches for memory locations containing instructions whose execution results in a reference to the task address specified as the search argument. Because the search argument represents an address, it can only be a word, not a byte.

The full form of the command is m;kE, where m represents the search mask and k the search argument. You can omit either or both of these arguments if you want to use the values already contained in registers $M and $A. For effective use of the E command, the search mask should be set to 177777 (octal), so that all bit positions are compared.

ODT compares each location within the search limits and displays the address and contents of locations that contain any of the following:

- The search argument as an absolute address
- A relative address offset reference to the absolute address specified as the search argument
- A relative address branch reference to the absolute address specified as the search argument

6.3 Filling Memory

The F command fills the block of memory defined by the high and low memory limit registers with the value in the search argument register. You can set this register using the command $A/ (as described in Section 6.1.3, or specify the argument k with the F command, in the corm kF.

If the last location opened was a word, the memory range is filled with words; if the last location was a byte, the memory range is filled with bytes. The low-order byte in register $A is used.

In the following example, word locations 1000 through 1776 are set to zero and byte locations 2000 through 2777 are filled with ASCII spaces (40 octal):

```
_1000;1R
_2000;2R
_3000;3R
_$L/000000 1,0 [RETURN]
_$H/000000 2,-2 [RETURN]
_0F
_$L/001000 2,0 [RETURN]
_$H/001776 3,-1 [RETURN]
_$A\000 40 [RETURN]
_F
```

6.4 Listing Memory

The L command lists on an output device the block of memory defined by the high and low memory limit registers. The following sections describe how you request a listing and what the listing looks like.

6.4.1 Command Format

The L command has the following format:

```
n;a;kL
```

- n = The device control LUN register number for the listing operation. A value of 0 indicates the user terminal (TI:); and other value is interpreted as 1 and indicates the console listing device (CL:). The default is 1.
- a = The low memory limit for the listing operation. If you omit a, the value of register $L is used. If you specify a, that value is placed in $L.
- k = The high memory limit for the listing operation. If you omit k, the value of register $H is used. If you specify k, that value is placed in $H.

You must include the semicolon argument separator (;) between a and k if you specify the argument a. You must include two semicolons if you specify the argument n.

6.4.2 Listing Format

A memory listing is formatted formatted in groups of eight units. Each line begins with a location, in relative form if possible (see Section 2.2.1, followed by eight words or eight bytes in the current output mode. A memory listing is displayed in whatever mode was used to open the last opened location. Thus you can list blocks of memory in word mode octal, byte mode octal, word mode ASCII, byte mode ASCII, or word mode Radix-50, as described in Section 4.10.

The following example shows the output displayed on the output device in response to various to various listing commands. Note that the question mark displayed in response to the ' command is not in this case ODT's error indicator; it is merely the ASCII character stored in the next byte.

Example 6–1 ODT Listing Format

```
_1344;1400L
001344 /047503 046125 020104 020111 040510 042526 054440 052517
001364 /020122 040516 042515 050040 042514 051501 037505
_1344" CO L
001344 "CO UL D  I  HA VE  Y OU
001364 "R  NA ME  P LE AS E?
_1344\ 103 L
1344 \103 117 125 114 104 040 111 040
1354 \110 101 126 105 040 131 117 125
1364 \122 040 116 101 115 105 040 120
1374 \114 105 101 123 105
_1344' C L
001344 'C O U L D  I
001354 'H A V E  Y O U
001364 'R  N A M E   P
001374 'L E A S E
_' ?
_1300;R
_$H/001400 0.101
_1344' C L
0,000044 'C O U L D  I
0,000054 'H A V E  Y O U
0,000064 'R  N A M E  P
0,000074 'L E A S E ?
```

7 Performing Calculations

ODT performs a variety of arithmetic calculations useful in determining offsets, Radix-50 equivalents and other values. The following sections describe commands that perform calculation. Section 7.1 explains how to calculate relocatable addresses. Section 7.3 describes how to evaluate expressions.

7.1 Calculating Relocatable Addresses

If you know the absolute (relocated) address of a location and want to determine what its relative address is, or what relocation register contains the closest base address use one of the forms of the a;nK command.

If you specify both a, the absolute address, and n, a relocation register, in the a;nK command, ODT will calculate and display the relative address, as follows:

```
_4000;2K =2,001460
```

Note that the equal sign is part of ODT's response, not part of the command that you enter.

If you omit n, ODT uses the relocation register whose contents are closest to (but less than) the absolute address specified.

If you omit a, ODT assumes the address of the last location opened. You should omit the semicolon argument separator if you omit a.

To determine the absolute address of an open location or of the last-opened location, enter a dot (current location indicator) followed by an equal sign (expression evaluation operator), as described in Section 7.3.2.

7.2 Calculating Offsets

The O (for "offset") command calculates and displays the PC-relative offset and the branch displacement from one location to another.

There are two forms of this command. The aO command calculates the offset from the currently open location to the location represented by address expression a. This form of the command can only be used when a location is open; you type it on the same line as the displayed contents of the open location.

The a;kO command calculates the offset from the location represented by address expression a to the location represented by address expression k. (In this case, k can have any of the address expression forms described in Section 2.2.) This command can be entered either on the same line as an open location or on a separate line, in response to the ODT prompt.

The O command (in either form) calculates either positive or negative offsets. Negative offsets are displayed in tow's complement form.

ODT displays the PC-relative offset and the branch displacement as 6-digit octal numbers. The PC-relative offset is preceded by an underscore and followed by a space; the branch displacement is preceded by a right arrow (>), as shown in the following example:

```
1034/103421 10460 _000010 >000004
```

A location that is open when you use the aO or a;kO commands remains open after the offset and branch displacement are displayed. You can perform another calculation, change the contents of the location, or enter any ODT command that affects an open location.

7.3 Evaluating Expressions

You can evaluate expressions during your debugging session using the techniques described in the following sections. To evaluate an expression while a location is open, enter the evaluation command on the same line as the displayed contents of the location. ODT places the results of its evaluation into the $Q register. To replace the contents of the open location, you enter Q or the value of the expression. You can also evaluate expressions when no location is open by typing the evaluation command in response to the ODT prompt.

7.3.1 Equal Sign Operator

To evaluate an expression, enter the expression followed by the equal sign (=). The expression is converted to a 6-digit octal value, placed in the $Q register, and displayed. ODT truncates the octal value of 16 bits when necessary.

Negative values are calculated, stored, and displayed in two's complement form. You can specify a negative value either in two's complement form. You can specify a negative value either in two's complement form or with the minus sign.

You can perform addition and subtraction within an expression to be evaluated. To add values, include a plus sign (+) or a space between the values. To subtract values, include a minus sign (-). ODT does not recognize parentheses or assign precedence to any operator; expressions are evaluated left to right.

An address expression, in relative or absolute form, can be all or part of an expression to be evaluated.

You can include in the expression the constant register indicator, the quantity register indicator, o the current location indicator, as described in the following sections.

If you enter the equal sign without an expression to be evaluated, ODT evaluates the null expression as zero and enters zeros in the $Q register.

The following examples show the evaluation of expressions using the equal sign. Relocation registers $OR contains the value 370. The constant register contains the value 40.

```
_0,0=000370
_0,16=406)
_0,C=000430
_0,16+16+2=0000426
_16-370=177426
_177777+16+16=000033
_C 177777=000037
_232323=032323
```

'.3.2 Current Location Indicator

The dot indicator (.) represents the address of the currently open location. You use this symbol to include the address of the currently open location as part or all of an expression to be evaluated.

The following example shows how the current location indicator is used:

```
_320;1R
_1,10000000 .+10=000340
```

'.3.3 Constant Register Indicator

The C indicator specifies the 16-bit value contained in the constant register, $C. You can set this register to any value and use the indicator in place of any a or k argument in an ODT command (as shown in Section 2.2. You change the value of C by opening the $C register as a word location and changing its contents.

'.3.4 Quantity Register Indicator

ODT stores the last value that is displayed in the quantity register, $Q. When you open a location, ODT stores that location's contents in the $Q register. If the location is a byte, the $Q register contains that byte in its low-order byte and zeros in its high-order byte.

You can refer to this 16-bit value by using the quantity register indicator Q. The quantity register indicator is especially useful for changing the contents of open locations and for setting registers, as shown in the following examples:

```
_1342/173214 Q+10 [RETURN]
_\173224 [RETURN]

_$3/013624 Q;5R [RETURN]
_5,20/013644
```

.3.5 Radix-50 Evaluation

To enter Radix-50 characters, you must know the numeric value of each Radix-50 word. A Radix-50 word, as explained in Section 4.11, contains three Radix-50 characters. To determine the value of the Radix-50 word, you enter the numeric equivalents of the Radix-50 characters in that word, separated by asterisks, as an expression to be evaluated. Follow the expression with an equal sign, as shown in Section 7.3.1. ODT calculates a 6-digit octal value, places that value in the $Q register, and displays it immediately after the equal sign as follows:

```
_33*24*12=125752
```

Note that you cannot evaluate Radix-50 characters in conjunction with any other evaluation operation (addition, subtraction, location calculation). You cannot use any other symbol (C, Q, .) in the expression to evaluated.

If you specify the equivalents of only two Radix-50 characters ODT characters (A-Z, 0-9) plus three special characters: dollar sign ($), dot (.), and space ( ). Table 7–1 contains the numeric equivalents of all Radix-50 characters.

Table 7–1 Numeric Equivalents of Radix-50 Characters

Radix-50 Character	Numeric Equivalent	Radix-50 Character	Numeric Equivalent
Space	0	T	24
A	1	U	25
B	2	V	26
C	3	W	27
D	4	X	30
E	5	Y	31
F	6	Z	32
G	7	$	33
H	10	.	34
I	11	Unused	35
J	12	0	36
K	13	1	37
L	14	2	40
M	15	3	41
N	16	4	42
O	17	5	43
P	20	6	44
Q	21	7	45
R	22	8	46
S	23	9	47

The following example shows how the asterisk is used in conjunction with the Radix-50 operator (described in Section 4.11):

```
_1054/003151 %AAA 1*3*5=003275 3275 [RETURN]
%ACE
```

8 Additional Debugging Aids

The task builder on your system enables you to specify the debugger of your choice to help you in program development. You should build only one debugger into your task at a time; if you want to switch from one debugger to another, you must rebuild your task.

Section 8.1 shows how you specify other debuggers to the task builder for the three environments described in . Section 8.2 describes the Trace program, a debugging aid available on your system.

8.1 Accessing Other Debugging Aids

The following sections show how to specify a debugger other than ODT to be linked with your object module(s). The example in each section shows a command line for linking the Trace debugging aid, described in Section 8.2. You can specify the file name of any debugger in place of [1,]TRACE.OBJ.

8.1.1 MCR Command Line

To link a debugger with your task using MCR, specify the name of the debugger object module as input to the task builder. Follow the debugger object module name with the /DA switch, as in the following example:

```
TKB>MYTASK=MYFILE,[1,1]TRACE/DA
```

The /DA switch identifies the file specified as a debugger. Since the task builder assumes that the file type of input files is OBJ, you need not specify the file type of the debugger object module.

8.1.2 DCL Command Line

To link a debugger into your task using DCL, specify the name of the debugger object module as an argument to the /DEBUG qualifier with the LINK command, as in the following example:

```
>LINK/DEBUG:[1,1]TRACE/TASK:MYTASK MYFILE
```

Since DCL assumes that the file type of input files for the linker is OBJ, you need not specify the file type of the debugger object module.

8.1.3 IAS PDS Command Line

To link a debugger with your task using IAS PDS, specify the name of the debugger object module as an argument to the /DEBUG switch, as in the following example:

```
PDS>LINK/DEBUG:[1,1]TRACE MYFILE
```

8.2 The Trace Debugging Program

The Trace program is a debugging aid that can be used instead of or along with ODT to provide information about the execution of a user task. Trace is most appropriate for use with relatively simple tasks or with sections of tasks.

Trace is an object module that you specify to the task builder when you build your task, as described in Section 8.1. It is located in UFD [1,1] on the system disk, with the name TRACE.OBJ

Trace is not an interactive program like ODT. When you run your task, Trace is executed once and prints its listing on pseudo-device CL. To run Trace again, you must run your task again.

8.2.1 The Trace Listing

A Trace listing contains two lines of information for each instruction executed in the user's task. The first line is made up of five octal words, representing the contents of the following registers:

1 Current relative program counter (PC)
2 Current PC
3 Next PC
4 Processor Status Word
5 Directive Status Word

The relative PC is determined by subtracting a user-specified bias value from the actual PC. Section 8.2.2 describes how you specify this bias value.

The second line of the Trace listing contains eight octal words representing the contents of the following:

1-6	R0 through R5
7	Stack pointer
8	The top word of the stack

Example 8–1 is a sample Trace listing for part of a user task.

Example 8–1 Sample Trace Output

```
001714  003174  003176  170020  000001
    002637  000120  000000  140200  000000  000000  001256  003074

001716  003176  003202  170024  000001
    002637  000120  000000  140200  000000  000000  001256  003074

001722  003202  003074  170024  000001
    002637  000120  000000  140200  000000  000000  001260  001260

001614  003074  003100  170020  000001
    002612  000120  000000  140200  000000  000000  001260  001260
```

8.2.2 Bias Values and Ranges

You can use the GBLPAT task builder option to specify:

- The bias value to be used in determining the relative PC
- The range(s) of task locations to be traced

8.2.2.1 Specifying a Bias Value

To specify a bias value for relative PC calculation, enter an option line in the following format in response to the task builder prompt:

```
GBLPAT=segname:.BIAS:value
```

where:

segname = The name of the task's root segment.

value = The octal value to be subtracted from the actual PC to establish relative PC. (If a value is not specified, the initial stack pointer is used.)

8.2.2.2 Specifying Ranges to be Traced

To specify up to four ranges of locations for which execution should be traced, enter an option line in the following format in response to the task builder prompt:

```
GBLPAT=segname:.RANGE:low1:high1 [...   :lown:highn]
```

where:

- segname = The name of the task's root segment.
- low1...lown = The low addresses, relative to the bias value, of ranges to be traced.
- high1...highn = The high addresses, relative to the bias value, of ranges to be traced.

There can be up to four ranges. You must specify both the low and the high address of each range.

A Error Detection

ODT responds to errors in user input and to certain hardware-detected errors that occur during task execution. This appendix describes these errors, ODT's response to them, and suggested user action.

\.1 Input Errors

ODT uses the question mark (?) as an indicator that it has detected an error in user input. After displaying the question mark, ODT generates a line feed and carriage return and prompts for another command.

ODT responds with the question mark to any of the following input errors:

- Reference to an address without an operator
- Reference to an address outside the task's partition
- Reference to a nonexistent register—for example, $20
- Reference to supervisor space by a nonprivileged user
- Input of an illegal character—for example, 8 or 9

If you have typed an incorrect input string—for example, contradictory arguments for the W command—you might find that the simplest course of action is to cancel the input string by typing an illegal character. You cannot, however, erase a string once you have entered the command (in this case, the letter W).

ODT does not tell you what error has caused it to display the question mark. However, an error sometimes causes ODT to return one of the error codes listed in Section A.2, plus information on the location where the error occurred.

In some cases (for example, if you attempt a memory operation when $L is greater than $H), ODT repeats its prompt but does not display a question mark.

ι.2 Task Image Error Codes

As described in Table 5–2, ODT has eight SST vector registers used to contain pointers to error-handling routines. If ODT detects an error condition, it activates the appropriate routine and displays an error message. This message has the form cc:k, where cc is a 2-character error code and k is the location as a relative address if there is a relocation register containing a base address less than the absolute address of the location.

The following examples are error messages from a debugging session:

```
MP:007414
MP:007414
```

The remainder of this chapter is an alphabetic list of ODT error codes, their meanings, and suggested user action in response to these codes.

BE

Explanation: Breakpoint instruction executed at unexpected location. The address of the breakpoint instruction does not match the contents of any register, $0B through $7B.

User Action: Examine your code to determine why the unexpected breakpoint occurred; then continue with the P command.

EM

Explanation: Invalid EMT instruction executed. Only EMT 377 and EMT 376 (for a privileged task) are allowed by the Executive for execution of Executive Directives. Normally, vector address 30 is used for this trap sequence.

User Action: If you want to use an EMT trap handler that you have written, set SST vector register 5 ($5V) to the appropriate vector address.

FP

Explanation: Floating-point instruction error. One of the following has occurred: division by zero; illegal Floating Op Code; flotation overflow or underflow; conversion failure.

User Action: Check your code for sequences that may have caused one of these conditions.

IL

Explanation: Reserved or illegal instruction executed. The task tried to execute a nonexistent instruction, or an EIS or FPP instruction in a system with no EIS or FPP hardware.

User Action: Check your code for typographical errors or the use of a nonexistent instruction.

IO

Explanation: IOT instruction executed. Normally, vector address 20 is used for this trap sequence.

User Action: To change the handling of I\O traps, set SST vector register 3 ($3V) to the appropriate vector address.

MP

Explanation: Memory protection violation or illegal memory reference. The task tried to access a location outside of the ranges mapped, or a location which it did not have the privilege to access.

User Action: Check your code for typographical or programming errors that could lead to this condition.

OD

Explanation: Odd address reference on word instruction. The PC contained an odd address when trying to access a word in memory. Also, on some processors, execution of an illegal instruction.

User Action: Check your code for the use of a word instruction when a byte instruction was intended (MOV instead of MOVB, for example) or a typographical error in the address specification.

TE

Explanation: T-bit exception. The T-bit was set by some other mechanism than a breakpoint or an S or P command. This can occur if bit 4 is set in a word that is interpreted as the PSW due to its position on the stack.

User Action: Check that the stack contains appropriate values.

TR

Explanation: TRAP instruction executed. Normally, vector address 34 is used for this trap sequence.

User Action: To change the handling of TRAP instructions, set SST vector register 6 ($6V) to the appropriate vector address.

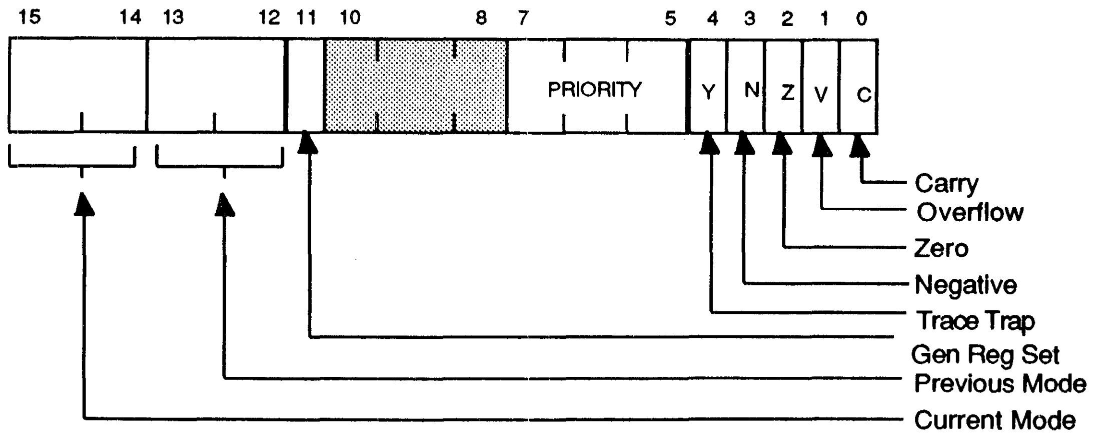
B Processor Status Word

The Processor Status Word (PS), stored at hardware location 777776, contains information on the current status of the processor. The information contained in this location includes:

- The current and previous operational modes of the processor (mapped system only)
- The current processor priority
- An indicator which, when set, causes a trap upon completion of the current instruction
- Condition codes describing the results of the last instruction executed

The format of the Processor Status Word is shown in Figure B–1.

Figure B–1 Format of the Processor Status Word



Bits 15 or 14 indicate the current processor mode: user mode (11), supervisor mode (01), or kernel mode (00). Bits 13 and 12 indicate the previous mode, that is, the mode the machine as in (user, supervisor, or kernel) prior to the last interrupt or trap.

Bits 7 through 5 show the current priority of the central processor. The central processor operates at any one of eight levels of priority (0 through 7). When the central processor is operating at level 7 (the highest priority), an external device cannot interrupt it with a request for service. The central processor must be operating at a lower priority than the external device's request in order for the interrupt to take effect.

The trap bit (bit 4) can be set or cleared under program control. When set, a processor trap occurs through location 14 on completion of the current user instruction, and a new Processor Status Word is loaded. The trap (T) bit is especially useful in debugging programs, since it provides an efficient means for stepping through the task one instruction at a time. ODT uses the T-bit to execute instructions when you are stepping through your program with the S command, described in Section 3.5.

Processor Status Word

The condition codes N, Z, V, and C (bits 3 through 0, respectively) indicate the result of the last central processor operation. These bits are set as follows:

N=1, if the result was negative.
Z=1, if the result was zero.
V=1, if the operation resulted in an arithmetic overflow.
C=1, if the operation resulted in a carry from the most significant bit.

Index

Reader's Comments

This form is for document comments only. Digital will use comments submitted on this form at the company's discretion. If you require a written reply and are eligible to receive one under Software Performance Report (SPR) service, submit your comments on an SPR form.

Did you find this manual understandable, usable, and well organized? Please make suggestions for improvement.

Did you find errors in this manual? If so, specify the error and the page number.

Please indicate the type of user/reader that you most nearly represent:

- ☐ Assembly language programmer
- ☐ Higher-level language programmer
- ☐ Occasional programmer (experienced)
- ☐ User with little programming experience
- ☐ Student programmer
- ☐ Other (please specify)________

Name________ Date________

Organization________

Street________

City________ State________ Zip Code or Country________

Do Not Tear - Fold Here and Tape

digital™

No Postage
Necessary
if Mailed in the
United States

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO 33 MAYNARD MASS

POSTAGE WILL BE PAID BY ADDRESSEE

IAS Engineering/Documentation
Digital Equipment Corporation
5 Wentworth Drive GSF/L20
Hudson, NH 03051-4929

Do Not Tear - Fold Here