

VSI OpenVMS Delta/XDelta Debugger Manual

Document Number: DO-DDXDDM-01A

Publication Date: April 2024

Operating System and Version: VSI OpenVMS IA-64 Version 8.4-1H1 or higher
VSI OpenVMS Alpha Version 8.4-2L1 or higher

VSI OpenVMS Delta/XDelta Debugger Manual



VMS Software

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Preface

This manual describes the OpenVMS DELTA and XDELTA debuggers. OpenVMS DELTA is used to debug programs that run in privileged processor mode at interrupt priority level 0. OpenVMS XDELTA is used to debug system software that runs at an elevated interrupt priority level.

1. About VSI

VMS Software, Inc. (VSI) is an independent software company licensed by Hewlett Packard Enterprise to develop and support the OpenVMS operating system.

2. Intended Audience

This manual is written for programmers who debug system code for device drivers and other images that execute in privileged processor-access modes or at an elevated interrupt priority level (IPL).

3. Document Structure

This manual is organized as follows:

- Chapter 1 provides an overview and descriptions for the DELTA and XDELTA Debuggers and breakpoints.
- Chapter 2 describes the DELTA and XDELTA symbols.
- Chapter 2 describes how to debug programs.
- Chapter 3 describes the DELTA and XDELTA commands.
- Appendix A describes an OpenVMS I64 debugging session using DELTA.
- Appendix B describes an OpenVMS Alpha debugging session using DELTA.
- Appendix C describes an OpenVMS VAX debugging session using DELTA.

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5. OpenVMS Documentation

The full VSI OpenVMS documentation set can be found on the VMS Software Documentation webpage at <https://docs.vmssoftware.com>.

6. Typographical Conventions

The following conventions are used in this manual:

Convention	Meaning
Ctrl/<i>x</i>	A sequence such as Ctrl/<i>x</i> indicates that you must hold down the key labeled Ctrl while you press another key or a pointing device button.
PF1 <i>x</i>	A sequence such as PF1 <i>x</i> indicates that you must first press and release the key labeled PF1 and then press and release another key (<i>x</i>) or a pointing device button.
. . .	A horizontal ellipsis in examples indicates one of the following possibilities: <ul style="list-style-type: none"> • Additional optional arguments in a statement have been omitted. • The preceding item or items can be repeated one or more times. • Additional parameters, values, or other information can be entered.
. . . .	A vertical ellipsis indicates the omission of items from a code example or command format; the items are omitted because they are not important to the topic being discussed.
()	In command format descriptions, parentheses indicate that you must enclose choices in parentheses if you specify more than one.
[]	In command format descriptions, brackets indicate optional choices. You can choose one or more items or no items. Do not type the brackets on the command line. However, you must include the brackets in the syntax for directory specifications and for a substring specification in an assignment statement.
|	In command format descriptions, vertical bars separate choices within brackets or braces. Within brackets, the choices are optional; within braces, at least one choice is required. Do not type the vertical bars on the command line.
{ }	In command format descriptions, braces indicate required choices; you must choose at least one of the items listed. Do not type the braces on the command line.
bold type	Bold type represents the name of an argument, an attribute, or a reason. Bold type also represents the introduction of a new term.
<i>italic type</i>	Italic type indicates important information, complete titles of manuals, or variables. Variables include information that varies in system output (Internal error <i>number</i>), in command lines (/PRODUCER= <i>name</i>), and in command parameters in text (where <i>dd</i> represents the predefined code for the device type).
UPPERCASE TYPE	Uppercase type indicates a command, the name of a routine, the name of a file, or the abbreviation for a system privilege.
Example	This typeface indicates code examples, command examples, and interactive screen displays. In text, this type also identifies website addresses, UNIX commands and pathnames, PC-based commands and folders, and certain elements of the C programming language.
–	A hyphen at the end of a command format description, command line, or code line indicates that the command or statement continues on the following line.
numbers	All numbers in text are assumed to be decimal unless otherwise noted. Nondecimal radices—binary, octal, or hexadecimal—are explicitly indicated.

Chapter 1. Invoking, Exiting, and Setting Breakpoints

This chapter presents an overview of the DELTA and XDELTA debuggers, and provides the following information:

- Privileges required for running DELTA
- Guidelines for using XDELTA
- Invoking and terminating DELTA and XDELTA debugging sessions on OpenVMS systems
- Booting XDELTA, requesting interrupts, and accessing initial breakpoints on OpenVMS systems

1.1. Overview of the DELTA and XDELTA Debuggers

The DELTA and XDELTA debuggers are used to monitor the execution of user programs and the OpenVMS operating system. They use the same commands and the same expressions, but they differ in how they operate. DELTA operates as an exception handler in a process context. XDELTA is invoked directly from the hardware SCB vector in a system context.

Use DELTA to debug process-context programs that execute at interrupt priority level (IPL) 0 in any processor mode. You cannot use DELTA to debug code that executes at an elevated IPL. To debug with DELTA, invoke it from within your process by specifying it as the debugger (as opposed to the symbolic debugger).

Use XDELTA to debug system software executing in any processor mode or at any IPL level. Because XDELTA is not process specific, it is not invoked from a process. To debug with XDELTA, you must boot the processor with commands to include XDELTA in memory. XDELTA's existence terminates when you reboot the processor without XDELTA.

1.2. Privileges Required for Running DELTA

No privileges are required to run DELTA to debug a program that runs in user mode. To debug a program that runs in other processor-access modes, the process in which you run the program must have the necessary privileges.

To use the **;M** command, your process must have change-mode-to-kernel (CMKRNL) privilege. The **;M** command sets all processes writable.

To use the **;L** command (List All Loaded Executive Modules), you must have change-mode-to-executive (CMEXEC) privilege.

1.3. Guidelines for Using XDELTA

Because XDELTA is not process specific, privileges are not required.

When using XDELTA, you must use the console terminal. You should run XDELTA only on a standalone system because all breakpoints are handled at IPL 31.

You cannot redirect output from XDELTA. To determine if your system maintains a log file, check your hardware manual. You can produce a log of console sessions by connecting the console serial port of the system that will boot with XDELTA to the serial port of a LAT server. Then, from another system, use the command SET HOST/LAT/LOG to that LAT port.

1.4. Restrictions for XDELTA on OpenVMS I64 Systems

The following Intel® Itanium® hardware registers are not supported by XDELTA on OpenVMS I64 systems:

- CPUID
- Debug Data Break Registers
- Debug Instruction Break Registers
- Region Registers
- Protection Key Registers
- Instruction Translation Registers
- Data Translation Registers
- Device Interrupt Control Register

1.5. Invoking DELTA

To invoke DELTA, perform the following steps after assembling (or compiling) and linking your program:

1. Define DELTA as the default debugger instead of the symbolic debugger with the following command:

```
$ DEFINE LIB$DEBUG SYS$LIBRARY:DELTA
```

2. Use the following RUN command to execute your program:

```
$ RUN/DEBUG MYPROG
```

When DELTA begins execution, it displays its name and the first executable instruction in the program with which it is linked. It displays the address of that instruction, a separator—an exclamation point (!) on I64 and Alpha, and a slash (/) on VAX—and the instruction and its operands.

On I64, the name and starting address are displayed as follows:

```
hp OpenVMS Industry Standard 64 DELTA Debugger
Brk 0 at address
address!      instruction      operands
```

On Alpha, the name and starting address are displayed as follows:

```
OpenVMS Alpha DELTA Debugger
Brk 0 at address
```


address! instruction operands

On VAX, the name, current version number, and address are displayed as follows:

```
DELTA Version 5.5
address/instruction operands
```

DELTA is then ready for your commands.

You can redirect output from a DELTA debugging session by assigning DBG\$DELTA to the I/O device.

Note

The image activator on OpenVMS Alpha systems automatically activates SYS\$SHARE:SYS\$SSISHR.EXE when an image is debugged using the RUN/DEBUG command or is linked using the /DEBUG qualifier. The presence of this image should not alter your program's correctness, but if your program is sensitive to virtual address layout or if for some reason SYS\$SHARE:SYS\$SSISHR.EXE is not installed properly on your system, you may want to bypass its automatic activation.

To keep the image activator from activating SYS\$SHARE:SYS\$SSISHR.EXE for you, define the logical name SSI\$AUTO_ACTIVATE to be OFF before running the program to be debugged with DELTA.

1.6. Exiting from DELTA

To exit from DELTA, type EXIT and press the **Return** key. When you are in user mode, you exit DELTA and your process remains. When you are in a privileged access mode, your process can be deleted.

1.7. Invoking XDELTA

To invoke XDELTA, perform the following steps:

1. Boot the system using a console command or a command procedure that includes XDELTA.
2. On VAX, an initial XDELTA breakpoint is taken so that you can set additional breakpoints or examine and change locations in memory. XDELTA displays the following breakpoint message:

```
1 BRK at address
address/instruction
```

Note

Never clear breakpoint 1 from any code being debugged in XDELTA. If you accidentally clear breakpoint 1 and no other breakpoints are set, you cannot use XDELTA until you reboot again with XDELTA.

On I64 and Alpha, two initial XDELTA breakpoints are taken so that you can set additional breakpoints or examine and change locations in memory. XDELTA displays the following message for the first breakpoint:

```
BRK 0 at address
address!instruction
```

3. On all processors, proceed from the initial breakpoint, using the following command:

```
;P Return
```

On VAX, the procedure for booting the system with XDELTA differs, depending on the model of your system. Each procedure uses commands that include XDELTA in memory and cause the execution of a breakpoint in OpenVMS initialization routines. Execution of the breakpoint instruction transfers program control to a fault handler located in XDELTA.

Some boot procedures require the use of the /R5 qualifier with the boot command. The /R5 qualifier enters a value for a flag that controls the way XDELTA is loaded. The flag is a 32-bit hexadecimal integer loaded into R5 as input to VMB.EXE, the primary boot program. For a description of the valid values for this flag, see Table 1.1.

Note

When you deposit a boot command qualifier value in R5, make sure that any other values you would normally deposit are included. For example, if you were depositing the number of the system root directory from which you were booting and an XDELTA value, R5 would contain both values.

For directions for booting XDELTA on VAX, see the OpenVMS VAX supplement specific to your computer.

On Alpha, the procedure for booting all Alpha systems with XDELTA is the same. For one example of how to boot XDELTA, use the boot command as follows:

```
>>> BOOT -FLAG 0,6
```

On I64, the procedure for booting with XDELTA is the same. For an example of how to boot XDELTA, use the boot command as follows:

```
fs0:\efi\vms\> vms_loader -fl 0,6
```

On I64 and Alpha, the flag for specifying boot qualifiers is a 64-bit integer that is passed directly as input to the primary boot program; IPB.EXE on I64 and APB.EXE on Alpha. For a description of the valid values for this flag, see Table 1.1.

Table 1.1. Boot Command Qualifier Values

Value	Description
0	Normal, nonstop boot (default)
1	Stop in SYSBOOT
2	Include XDELTA, but do not take the initial breakpoint
3	Stop in SYSBOOT, include XDELTA, but do not take the initial breakpoint
6	Include XDELTA, and take the initial breakpoint
7	Include XDELTA, stop in SYSBOOT, and take the initial breakpoint at system initialization

1.8. Requesting an Interrupt

If you set the boot control flag to 6, XDELTA will stop at an initial breakpoint during the system boot process. You can then set other breakpoints or examine locations in memory.

Your program can also call the routine `INI$BRK`, which in turn executes the first XDELTA breakpoint. For the breakpoint procedure, see Section 1.9.

Once loaded into memory, XDELTA can also be invoked at any time from the console by requesting a software interrupt. For example, you might need to use a software interrupt to enter XDELTA if your program is in an infinite loop or no `INI$BRK` call had been made.

On VAX, `INI$BRK` is defined as XDELTA's breakpoint 1.

Note

On VAX, never clear breakpoint 1 from any code being debugged in XDELTA. If you accidentally clear breakpoint 1 and no other breakpoints are set, you cannot use XDELTA again until you reboot with XDELTA.

On I64 and Alpha, `INI$BRK` is defined as XDELTA's breakpoint 0. It is not possible to clear breakpoint 0 from any code being debugged in XDELTA.

1.8.1. Requesting Interrupts on VAX

On VAX 8530, 8550, 8600, 8650, 8810 (8700), 8820, 8820-N (8800), 8830, 8840, VAX-11/780, or VAX-11/785 computers, enter the following commands at the console terminal to request the interrupt:

```
$ Ctrl/P
>>> HALT
>>> D/I 14 E
>>> C
```

For a VAX 9000 computer, enter the following commands at the console terminal to request the interrupt:

```
$ Ctrl/P
>>> HALT/CPU=ALL
>>> D/I 14 E
>>> C/CPU=ALL
```

For a VAX 6000 series, 8200, 8250, 8300, 8350, VAX-11/730, or a VAX-11/750 computer, enter the following commands:

```
$ BOX
>>> D/I 14 E
>>> C
```

For a VAX station 3520 or 3540 computer, perform the following steps:

1. Press and release the **Halt** button on the CPU control panel. When you release the **Halt** button, make sure it is popped out or the system will remain halted. You can also press the **Break** key (if enabled) on the console terminal.
2. Enter the following commands:

```
>>>
D/I 14 E
>>>
C/ALL
```

For a VAXft-3000, VAXft-410, VAXft-610, or VAXft-612 computer, enter the following commands at the console terminal to request the interrupt:

```
$ Break or F5
>>> HALT
>>> D/I 14 E
>>> CONT
>>> PIO
```

For a VAX 7000 or VAX 10000 series computer, enter the following commands at the console terminal to request the interrupt. If you are operating in secure mode, first set the key switch to `ENABLE` before entering these commands.

```
$ Ctrl/P
>>> D IPR:14 E
>>> CONT
```

For a VAXstation 2000, MicroVAX 2000, MicroVAX 3300/3400 series, MicroVAX or VAXstation 3500/3600 series, MicroVAX 3800/3900 series, VAX 4000 series, or MicroVAX II computer, perform the following steps:

1. Press and release the **Halt** button on the CPU control panel. When you release the **Halt** button, make sure it is popped out or the system will remain halted. You can also press the **Break** key (if enabled) on the console terminal.
2. Enter the following commands:

```
>>> D/I 14 E
>>> C
```

For an alternative method of accessing OpenVMS through a lower priority interrupt, see the *VSI OpenVMS System Manager's Manual, Volume 1: Essentials*.

1.8.2. Requesting Interrupts on Alpha

On Alpha systems, perform the following steps to request an interrupt:

1. Halt the processor with the following command:

```
^P
```

2. Request an IPL 14 software interrupt with the following command:

```
>>> DEP SIRR E
```

This command deposits a 14₁₀ into the software interrupt request register.

3. Reactivate the processor by issuing the `CONTINUE` command as follows:

```
>>> CONT
```

The process should enter `XDELTA` as soon as IPL drops to 14.

The following message is displayed:

```
Brk 0 at address
address!instruction
```

At this point, the exception frame is on the stack. The saved PC/PS in the exception frame tells you where you were in the program when you requested the interrupt.

1.8.3. Requesting Interrupts on I64

To request an interrupt on I64, type **Ctrl/P** on the console terminal. Note that XDELTA must have been loaded previously.

When you press **Ctrl/P**, the system is halted at the current PC and at the current IPL. The system must be executing below IPL 8. When the system reaches this state, execution is suspended at the PC that was executing at the time of the interrupt.

1.9. Accessing the Initial Breakpoint

When debugging a program, you can set a breakpoint in the code so that XDELTA gains control of program execution.

To set a breakpoint, place a call to the system routine `INI$BRK` in the source code.

On systems that are booted with XDELTA, the `INI$BRK` routine executes a breakpoint instruction. On systems that are not booted with XDELTA, `INI$BRK` is effectively a NOP instruction.

You can use the `INI$BRK` routine as a debugging tool, placing calls to this routine in any part of the source code you want to debug.

On VAX, the instruction following the breakpoint is `RSB`. After the break is taken, the return address (the address in the program to which control returns when you proceed from the breakpoint) is on the top of the stack.

The following command calls the `INI$BRK` system routine to reach the breakpoint:

```
JSB G^INI$BRK
```

On Alpha, the instruction following the breakpoint is `JSR R31,(R26)`. After the break is taken, the return address (the address in the program to which control returns when you proceed from the breakpoint) is in `R26`.

On I64, simply step until you reach a `br.ret` instruction.

The following C routine calls the `INI$BRK` system routine to reach the breakpoint:

```
extern void ini$brk(void);
main()
{
    ini$brk();
}
```

1.10. Proceeding from Initial XDELTA Breakpoints

On VAX, when XDELTA reaches one of its breakpoints, it displays the following message:

```
1 BRK AT nnnnnnnn
address/instruction operands
```

On I64 and Alpha, when XDELTA reaches one of its breakpoints, it displays the following message:

```
BRK 1 AT nnnnnnnn  
address!instruction operands
```

On multiprocessor computers, the XDELTA breakpoint is taken on the processor upon which the XDELTA software interrupt was requested, which is generally the primary processor.

At this point, XDELTA is waiting for input. If you want to proceed with program execution, enter the **;P** command. If you want to do step-by-step program execution, enter the **S** command. If you know where you have set breakpoints, examine them using the **;B** command. You can also set additional breakpoints or modify existing ones.

If you entered the **;P** command to proceed with program execution and the system halts with a fatal bugcheck, the system prints the bugcheck information on the console terminal. Bugcheck information consists of the following:

- Type of bugcheck
- Contents of the registers
- A dump of one or more stacks
- A list of loaded executive images

The contents of the program counter (PC) and the stack indicate where the failure was detected. Then, if the system parameter BUGREBOOT was set to 0, XDELTA issues a prompt. You can examine the system's state further by entering XDELTA commands.

1.11. Exiting from XDELTA

XDELTA remains in memory with the operating system until you reboot without it.

Chapter 2. DELTA and XDELTA Symbols and Expressions

This chapter describes how to form the symbolic expressions used as arguments to many DELTA and XDELTA commands.

2.1. Symbols Supplied by DELTA and XDELTA

DELTA and XDELTA define symbols that are useful in forming expressions and referring to registers.

- Table 2.1 shows the symbols that pertain to OpenVMS I64 systems.
- Table 2.2 shows symbols that pertain to OpenVMS Alpha systems.
- Table 2.3 shows symbols that pertain to OpenVMS VAX systems.

Table 2.1. DELTA/XDELTA Symbols for OpenVMS I64 systems

Symbol	Description
.	The address of the current location. The value of this symbol is set by the Open Location and Display Contents (/), Open Location and Display Instruction (!), and the Open Location and Display Indirect (TAB) commands.
ARn	Application register n where n can range from 0 to 127 (decimal). Also see the P(ipr) symbol description.
BRn	Branch register n where n can range from 0 to 7.
CRn	Control register n where n can range from 0 to 127 (decimal). See also the P(ipr) symbol description.
FPn	Floating point register n, where n can range from 0 to 127 (decimal).
FPSR	The floating point status register.
G	^XFFFFFFFF80000000, the prefix for system space addresses.
H	^X7FFE0000, the prefix for addresses in the control region (P1 space). H2E, for example, is equivalent to ^X7FFE002E.
P(ipr)	<p>The OpenVMS I64 software implementation of an Alpha internal processor register whose name is <code>ipr</code>. See the <i>Alpha Architecture Reference Manual</i> for the names and descriptions of these processor registers. Not all Alpha internal processor registers are implemented on OpenVMS I64.</p> <p>This syntax is also used to refer to Intel Itanium application and control registers using meaningful names, where <code>ipr</code> is the name of the Intel Itanium register. For example, you can refer to Intel Itanium register CR20 using either of the following:</p> <p>P(IFA) P(CR.IFA)</p> <p>See the <i>Intel® IA-64 Architecture Software Developer's Manual, Volume 2: IA-64 System Architecture</i> manual for the names of the application and control registers.</p>
PC	The OpenVMS I64 software implementation of a program counter register, formed by the union of the IP (instruction bundle pointer) and the slot offset (PSR.ri).

Symbol	Description
pid:Rn	General register <i>n</i> in the process specified by process ID <i>pid</i> .
PS	The processor status register.
Pn	Predicate register <i>n</i> where <i>n</i> can range from 0 to 63 (decimal).
Q	The last value displayed. The value of <i>Q</i> is set by every command that causes DELTA or XDELTA to display the contents of memory or the value of an expression.
Rn	General register <i>n</i> where <i>n</i> can range from 0 to 127 (decimal).
Xn	<p>Base register <i>n</i>, where <i>n</i> can range from 0 to 15 (decimal). These registers are used for storing values, most often the base addresses of data structures in memory.</p> <p>For XDELTA only, X14 and X15 contain the addresses of two command strings that XDELTA stores in memory. See the Execute Command String (;E) command for more information.</p> <p>For XDELTA only, registers X4 and X5 contain specific addresses. X4 contains the address of the location that contains the PCB address of the current process on the current processor. The address that X4 contains is that of the per-CPU database for the current processor. X5 contains SCH\$GL_PCBVEC, the symbolic address of the start of the PCB vector, and the list of PCB slots.</p>

Table 2.2. DELTA/XDELTA Symbols for OpenVMS Alpha systems

Symbol	Description
.	The address of the current location. The value of this symbol is set by the Open Location and Display Contents (/), Open Location and Display Instruction (!), and the Open Location and Display Indirect (TAB) commands.
FPn	Floating point register <i>n</i> , where <i>n</i> can range from 0 to 31 (decimal).
FPCR	The floating point control register.
G	^XFFFFFFFF80000000, the prefix for system space addresses.
H	^X7FFE0000, the prefix for addresses in the control region (P1 space). H2E, for example, is equivalent to ^X7FFE002E.
PC	The program counter register.
pid:PC	The program counter in the process specified by process ID <i>pid</i> .
PS	The processor status register.
Q	The last value displayed. The value of <i>Q</i> is set by every command that causes DELTA or XDELTA to display the contents of memory or the value of an expression.
pid:Rn	General register <i>n</i> in the process specified by process ID <i>pid</i> .
Rn	General register <i>n</i> , where <i>n</i> can range from 0 to 31 (decimal).
Xn	<p>Base register <i>n</i>, where <i>n</i> can range from 0 to 15 (decimal). These registers are used for storing values, most often the base addresses of data structures in memory.</p> <p>For XDELTA only, X14 and X15 contain the addresses of two command strings that XDELTA stores in memory. See the Execute Command String (;E) command for more information.</p> <p>For XDELTA only, registers X4 and X5 contain specific addresses. X4 contains the address of the location that contains the PCB address of the current process on the</p>

Symbol	Description
	current processor. The address that X4 contains is that of the per-CPU database for the current processor. X5 contains SCH\$GL_PCBVEC, the symbolic address of the start of the PCB vector, and the list of PCB slots.

Table 2.3. DELTA/XDELTA Symbols for OpenVMS VAX systems

Symbol	Description
.	The address of the current location. The value of this symbol is set by the Open Location and Display Contents (/), Open Location and Display Instruction (!), and the Open Location and Display Indirect (TAB) commands.
G	^X80000000, the prefix for system space addresses. G2E, for example, is equivalent to ^X8000002E.
H	^X7FFE0000, the prefix for addresses in the control region (P1 space). H2E, for example, is equivalent to ^X7FFE002E.
Pn	The internal processor register at processor address n, where n can range from 0 to 3F (hexadecimal). See the <i>VAX Architecture Reference Manual</i> for a description of these processor registers.
Q	The last value displayed. The value of Q is set by every command that causes DELTA or XDELTA to display the contents of memory or the value of an expression.
Rn	General register n, where n can range from 0 to F (hexadecimal). RF+4 is the processor status longword (PSL), RE is the stack pointer, and RF is the program counter (PC).
Xn	Base register n, where n can range from 0 to F (hexadecimal). These registers are used for storing values, most often the base addresses of data structures in memory. For XDELTA only, XE and XF contain the addresses of two command strings that XDELTA stores in memory. See the Execute Command String (;E) command for more information. For XDELTA only, registers X4 and X5 contain specific addresses. X4 contains the address of the location that contains the PCB address of the current process on the current processor. The address that X4 contains is that of the per-CPU database for the current processor. X5 contains SCH\$GL_PCBVEC, the symbolic address of the start of the PCB vector, and the list of PCB slots.

2.2. Floating Point Register Support

On OpenVMS Alpha, floating point registers can be accessed from DELTA and from XDELTA but only if floating point arithmetic is enabled in the current process. On OpenVMS I64, floating point registers FP6 through FP11 are always available. The other floating point registers are available if floating point arithmetic is enabled in the current process.

DELTA runs in the context of a process. On OpenVMS Alpha, access to floating-point registers is enabled as soon as the first floating point instruction in the code being examined is executed. Access is disabled as soon as that image completes execution. On OpenVMS I64, floating-point registers are always available to DELTA.

Table 2.4 shows these relationships:

Table 2.4. Floating Point Register Support by Platform

	Alpha	I64
XDELTA	No access	FP6—FP11
DELTA	FPn if FP access is enabled	Always available

When the system enters XDELTA, it may not be obvious which process is the current process. If the current process happens to have floating point enabled (because a floating point instruction has executed and the image containing the floating point instruction is still executing), then you can access the floating point registers. Otherwise, you cannot. XDELTA checks the FEN (floating point enable) IPR (internal processor register) to see whether it needs to provide access to floating point registers.

2.3. Forming Numeric Expressions

Expressions are combinations of numbers, symbols that have numeric values, and arithmetic operators.

On all platforms, DELTA and XDELTA store and display all numbers in hexadecimal. They also interpret all numbers as hexadecimal.

Expressions are formed using regular (infix) notation. Both DELTA and XDELTA ignore operators that trail the expression. The following is a typical expression (in hexadecimal):

G4A32+24

DELTA and XDELTA evaluate expressions from left to right. No operator takes precedence over any other.

DELTA and XDELTA recognize five binary arithmetic operators, one of which also acts as a unary operator. They are listed in Table 2.5.

Table 2.5. Arithmetic Operators

Operator	Action
+ or SPACE	Addition
-	Subtraction when used as a binary operator, or negation when used as a unary operator
*	Multiplication
%	Division
@	Arithmetic shift

The following example shows the arguments required by the arithmetic-shift operator:

$n @ j$

In this example, n is the number to be shifted, and j is the number of bits to shift it. If j is positive, n is shifted to the left; if j is negative, n is shifted to the right. Argument j must be less than 20_{16} and greater than -20_{16} . Bits shifted beyond the limit of the longword are lost; therefore, the result must fit into a longword.

Note

Do not enter unnecessary spaces, as DELTA/XDELTA treats the space as an additional operator.

Chapter 3. Debugging Programs

When you use DELTA or XDELTA, there are no prompts, few symbols, and one error message. You move through program code by referring directly to address locations. This chapter provides directions for the following actions:

- Referencing addresses
- Referencing registers, the PSL or PS, and the stack
- Interpreting the error message
- Debugging kernel mode code under certain conditions
- Debugging an installed, protected, shareable image
- Using XDELTA on multiprocessor computers
- Debugging code when single-stepping fails (Alpha only)
- Debugging code that does not match the compiler listings (I64 and Alpha only)

For examples of DELTA debugging sessions on various OpenVMS platforms, see Appendix A for I64, Appendix B for Alpha, and Appendix C for VAX.

3.1. Referencing Addresses

When using DELTA or XDELTA to debug programs, you move through the code by referring to addresses. To help you identify address locations within your program, use a list file and a map file. The list file (`.LIS`) lists each instruction and its offset value from the base address of the program section. The full map file (`.MAP`) lists the base addresses for each section of your program. To determine the base address of a device driver program, see the *OpenVMS VAX Device Support Manual*.

Once you have the base addresses of the program sections, locate the instruction in the list file where you want to start the debugging work. Add the offset from the list program to the base address from the map file. Remember that all calculations of address locations are done in hexadecimal. You can use DELTA/XDELTA to do the calculations for you with the `=` command.

To make address referencing easier, you can use offsets to a base address. Then you do not have to calculate all address locations. First, place the base address into a base register. Then move to a location using the offset to the base address stored in the register.

Whenever DELTA/XDELTA displays an address, it will display a relative address if the offset falls within the permitted range (see the `;X` command in Chapter 4).

3.1.1. Referencing Addresses (I64 and Alpha Only)

On I64 and Alpha, to reference addresses during a DELTA debug session, use the following OpenVMS Alpha example as a guide. The example uses a simple C program (`HELLO.C`). You can also use the same commands in an XDELTA debug session.

```
#include <stdio.h>
main()
{
    printf("Hello world\n");
}
```

The following procedure generates information to assist you with the address referencing:

1. Use the `/LIST` and `/MACHINE_CODE` qualifiers to compile the program and generate the list file containing the Alpha machine instructions.

To generate the list file for the previous example, use the following command:

```
$ cc/list/machine_code hello
```

The compiler will generate the following Alpha code in the machine code portion of the listing file:

```
        .PSECT $CODE, OCTA, PIC, CON, REL, LCL, SHR, -
        EXE, NORD, NOWRT
0000  main::                                ; 000335
0000      LDA  SP, -32(SP)                    ; SP, -32(SP)
0004      LDA  R16, 48(R27)                   ; R16, 48(R27) ; 000337
0008      STQ  R27, (SP)                     ; R27, (SP)   ; 000335
000C      MOV  1, R25                         ; 1, R25     ; 000337
0010      STQ  R26, 8(SP)                    ; R26, 8(SP)  ; 000335
0014      STQ  FP, 16(SP)                    ; FP, 16(SP)
0018      LDQ  R26, 32(R27)                   ; R26, 32(R27) ; 000337
001C      MOV  SP, FP                        ; SP, FP     ; 000335
0020      LDQ  R27, 40(R27)                   ; R27, 40(R27) ; 000337
0024      JSR  R26, DECC$GPRINTF              ; R26, R26
0028      MOV  FP, SP                        ; FP, SP     ; 000338
002C      LDQ  R28, 8(FP)                    ; R28, 8(FP)
0030      LDQ  FP, 16(FP)                    ; FP, 16(FP)
0034      MOV  1, R0                         ; 1, R0
0038      LDA  SP, 32(SP)                    ; SP, 32(SP)
003C      RET  R28                          ; R28
```

Notice the statement numbers on the far right of some of the lines. These numbers correspond to the source line statement numbers from the listing file as shown next:

```
335 main()
336 {
337     printf("Hello world\n");
338 }
```

2. Use the `/MAP` qualifier with the link command to generate the full map file (`.MAP` file). To produce a debuggable image, make sure that either `/DEBUG` or `/TRACEBACK` (the default) is also specified with the link command.

To generate the map file for the example program, use the following command:

```
$ LINK/MAP/FULL HELLO
```

3. See the Program Section Synopsis of the map file. Locate the code section that you want to debug and its base address.

For the example program, the map file is `HELLO.MAP`. A portion of the Program Section Synopsis is shown below. The `$CODE` section of the program has a base address of 20000.

+-----+					
! Program Section Synopsis !					
+-----+					
Psect Name	Module Name	Base	End	Length	
-----	-----	---	---	-----	
\$LINKAGE		00010000	0001007F	00000080	(128.)
	HELLO	00010000	0001007F	00000080	(128.)
\$CODE		00020000	000200BB	000000BC	(188.)
	HELLO	00020000	000200BB	000000BC	(188.)

4. See the list file for the location where you want to start debugging. First find the source line statement number. Next find that statement number in the machine code listing portion of the list file. This is the specific instruction where you want to start debugging.

For the example program, source statement 337 is the following:

```
printf("Hello world\n");
```

Search the machine code listing for statement 337. The first occurrence is the instruction at offset 4 from the start of `main::` and the base of the `$CODE` PSECT.

5. Enable DELTA using the following commands:

```
$ DEFINE LIB$DEBUG SYS$LIBRARY:DELTA
$ RUN/DEBUG HELLO
```

6. If you want to store the base address in a base register, use the **;X** command to load the base register.

For the example program, use the following DELTA/XDELTA command to store the base address of 20000 in base register 0.

```
20000,0;X
```

7. Now you can move to specific address locations.

For example, if you want to place a breakpoint at offset 4, you would calculate the address as 20000 (base address) plus 4 (offset), or 20004, and specify the **;B** command as follows:

```
20004;B
```

Alternatively, if you stored the base address in the base register, you could use the address expression `X0+4` (or `X0 4`, where the `+` sign is implied) to set the breakpoint as follows:

```
X0+4;B
```

Reverse this technique to find an instruction displayed by DELTA/XDELTA in the `.LIS` file, as follows:

1. Note the address of the instruction you want to locate in the `.LIS` file.

For example, DELTA/XDELTA displays the following instruction at address 20020:

```
20020! LDQ R27, #X0028(R27)
```

The following steps allow you to find this instruction in the `.LIS` file.

2. See the `.MAP` file, and identify the psect and module where the address of the instruction is located. Check the base address value and the end address value of each psect and module. When the instruction address is between the base and end address values, record the psect and module names.

In the example, the instruction address is located in the `HELLO` module (`$CODE PSECT`). The address, 20020, is between the base address 20000 and the end address 200BB.

3. Subtract the base address from the instruction address. Remember that all calculations are in hexadecimal and that you can use the `DELTA/XDELTA =` command to do the calculations. The result is the offset.

For example, subtract the base address of 20000 from the instruction address 20020. The offset is 20.

4. See the `.LIS` file. Look up the module and then find the correct psect. Look for the offset value you calculated in the previous step.

In the example, there are two psects and one module but only one `$CODE` psect. Look up the instruction at offset 20, and you will find the following in the `.LIS` file:

```
0020          LDQ  R27, 40(R27)          ; R27, 40(R27)          ; 000337
```

3.1.2. Referencing Addresses (VAX Only)

On VAX, to reference addresses during a DELTA debug session, use the following example as a guide. The example uses a simple VAX MACRO program (`EXAMPLE.MAR`). You can also use the same commands in an XDELTA debugging session.

```
0000  1  .title example
0000  2
0000  3  .entry  start  ^M<r3,r4>
0002  4  clr1   r3
0004  5  movl   #5,r4
0007  6  10$:   addl   r4,r3
000A  7  sobgtr  r4,10$
000D  8  ret
000E  9
000E 10  .end    start
```

The following procedure generates information to assist you with address referencing:

1. Use the `/LIST` qualifier to assemble the program and generate the list file.

To generate the list file for the previous example, use the following command:

```
$ MACRO/LIST EXAMPLE
```

2. Use the `/MAP` qualifier with the link command to generate the full map file (`.MAP` file). Make sure that the default `/DEBUG` or `/TRACEBACK` qualifier is active for your link command. If not, specify `/DEBUG` or `/TRACEBACK` along with the `/MAP` qualifier.

To generate the map file for the example program, use the following command:

```
$LINK/MAP EXAMPLE
```

3. See the Program Section Synopsis of the map file, locate the section that you want to debug, and look up the base address.

For the example program, the map file is `EXAMPLE.MAP`. A portion of the Program Section Synopsis is shown below. The first section of the program has a base address of 200.

+-----+				
! Program Section Synopsis !				
+-----+				
Psect Name	Module Name	Base	End	Length
-----	-----	---	---	-----
. BLANK .		00000200	0000020D	0000000E (14.)
	EXAMPLE	00000200	0000020D	0000000E (14.)

- See the list file for the location of the specific instruction where you want to start debugging.

For the example program, start with the second instruction (`MOVL #5,R4`) with an offset of 4.

- Enable DELTA using the following commands:

```
$ DEFINE LIB$DEBUG SYS$LIBRARY:DELTA
$ RUN/DEBUG EXAMPLE
```

- If you want to store the base address in a base register, use the `;X` command to load the base register.

For the example program, use the following DELTA/XDELTA command to store the base address 200 in base register 0.

```
200,0;X Return
```

- Now you can move to specific address locations.

For example, if you want to place a breakpoint at the second instruction (`MOVL #5,R4`), you would calculate the address as 200 (base address) plus 4 (offset), or 204, and specify the `;B` command as follows:

```
204;B Return
```

Alternatively, if you stored the base address in the base register, you could use the address expression `X0+4` (or `X0 4`, where the `+` sign is implied), as follows:

```
X0+4;B Return
```

Reverse this technique to find an instruction displayed by DELTA/XDELTA in the `.LIS` file, as follows:

- Note the address of the instruction you want to locate in the `.LIS` file.

For example, DELTA/XDELTA displays the following instruction at address 020A:

```
20A! sobgtr r4,00000207
```

The following steps allow you to find the instruction at location 207:

- See the `.MAP` file and identify the PSECT and MODULE where the address of the instruction is located. Check the base address value and the end address value of each PSECT and MODULE. When the instruction address is between the base and end address values, record the PSECT and MODULE names.

In the example, the instruction address is located in the EXAMPLE module (.BLANK. psect). The address instruction, 207, is between the base address 200 and the end address 20D.

3. Subtract the base address from the instruction address. Remember that all calculations are in hexadecimal and that you can use the DELTA/XDELTA = command to do the calculations. The result is the offset.

For the example, subtract the base address 200 from the instruction address 207. The offset is 7.

4. See the .LIS file. Look up the MODULE and then find the correct PSECT. Look for the offset value you calculated in the previous step.

In the example, there is only one PSECT and MODULE. Look up the instruction at offset 7. The program is branching to the following instruction:

```
10$:    addl r4,r3
```

3.2. Referencing Registers

When using DELTA or XDELTA to debug programs, you can view the contents of registers. The following sections describe the types of registers that are referenced by each OpenVMS platform.

3.2.1. Referencing Registers (I64 Only)

On I64, you can reference the following kinds of registers: integer, floating, application, branch, control, special purpose, and software equivalents of special OpenVMS symbolic locations.

Table 3.1 lists the Intel Itanium registers and symbols by which they are identified.

Table 3.1. Intel Itanium Registers and their Associated Symbols

Register	Symbol
General	R0 through R127
Floating	FP0 through FP127
Branch	BR0 through BR7
Predicate	P0 through P63
Application	AR16 (RSC), AR17 (BSP), AR18 (BSPSTORE), AR19 (RNAT), AR25 (CSD), AR26 (SSD), AR32 (CCV), AR36 (UNAT), AR64 (PFS), AR65 (LC), AR66 (EC)
Control	CR0 (DCR), CR1 (ITM), CR2 (IVA), CR8 (PTA), CR16 (IPSR), CR17 (ISR), CR19 (IIP), CR20 (IFA), CR21 (ITIR), CR22 (IIPA), CR23 (IFS), CR24 (IIM), CR25 (IHA), CR65 (IVR)

In addition, there is a program counter (PC) register, which is obtained from the hardware IP register and the `ri` field of the PSR register.

3.2.2. Referencing Registers (Alpha Only)

On Alpha, to view the contents of the 32 integer registers, the program counter (PC), the stack pointer (SP), the processor status (PS), the 32 floating point registers, the floating point control register (FPCR),

and the internal processor registers (IPRs), use the same DELTA/XDELTA commands that you use to view the contents of any memory location. These commands include /, LINEFEED, and ESC. The symbols for identifying these registers follow:

- Integer registers are referenced by the symbol R and a decimal number from 0 to 31. For example, register 1₁₀ is R1₁₀ and register 10₁₀ is R10₁₀. (Decimal notation differs from the original implementation on VAX which uses hexadecimal notation.)
- PC is referenced symbolically by PC.
- PS is referenced symbolically by PS.
- FP is referenced by R29.
- SP is referenced by R30.
- Floating point registers are referenced by FP and a decimal number from 0 to 31. For example, floating point register 1₁₀ is FP1₁₀ and floating point register 10₁₀ is FP10₁₀.
- FPCR is treated like any other floating point register except, to explicitly open it, you specify FPCR/.
- Internal processor registers (IPRs) are accessed symbolically, for example, P(ASTEN). For IPR names, see the *Alpha Architecture Reference Manual*.

Floating point registers can be accessed from DELTA and from XDELTA but only if floating point arithmetic is enabled in the current process.

DELTA runs in the context of a process. Access to floating point registers is enabled as soon as the first floating point instruction in the code being examined is executed. Access is disabled as soon as that image completes execution.

When the system enters XDELTA, some process is the current process, and that current process may not be obvious. If that process happens to have floating point enabled at the time (because a floating point instruction had executed and the image containing the floating point instruction was still executing), then you can access the floating point registers. Otherwise, you cannot. XDELTA checks the FEN (floating point enable) IPR (internal processor register) to see if it needs to provide access to floating point registers.

3.2.3. Referencing Registers (VAX Only)

On VAX, to view the contents of the 16 general registers (including the program counter and the stack pointer) and the processor status longword (PSL), use the same DELTA/XDELTA commands as you use to view the contents of any memory location (for example, the /, LINEFEED, and the ESC commands). The symbols used to identify the locations of the registers and PSL are as follows:

- The general registers are referred to by the symbol R and a hexadecimal number from 0₁₆ to F₁₆ representing the number of the register. For example, general register 1₁₀ is R1₁₆ and general register 10₁₀ is RA₁₆. The stack pointer is located in general register 14₁₀, RE₁₆. The program counter is in general register 15₁₀, RF₁₆.
- Upon entry to DELTA or XDELTA, the PSL is stored in the longword directly following the longword representing general register F₁₆. Reference it by using the general register F₁₆ symbol plus along word (RF+4).

3.3. Interpreting the Error Message

When you make an error entering a command in DELTA or XDELTA, you get the `Eh?` error message. This is the only error message generated by DELTA and XDELTA. It is displayed under the following circumstances:

- You entered characters that DELTA/XDELTA does not recognize
- You entered a command incorrectly
- You exceeded the limits of the command (for example, trying to set another breakpoint when all breakpoints are used)
- You attempted to display a particular memory address and one or more of the following is true:
 - Location is not a valid memory address
 - You have no privilege to read the address
 - The process to which the read applies does not exist (DELTA only)
- You attempted to change a particular memory address (including setting a breakpoint) and one or more of the following is true:
 - The location is not a valid memory address
 - You have no privilege to write to the address
 - The process to which the write applies does not exist (DELTA only)

On I64, the error message is also displayed if you are unable to step over a subroutine call due to no write access to the address of the next instruction.

On Alpha, the error message is also displayed if you are unable to single-step or proceed due to no write access to the address of the next instruction.

3.4. Debugging Kernel Mode Code Under Certain Conditions

Some programs exist which, while running in process space, change mode to kernel and raise IPL. Typically, this code is debugged with both DELTA and XDELTA. DELTA is used to debug the kernel mode code at IPL zero. XDELTA is used to debug the code at elevated IPL. (DELTA does not work at elevated IPL.)

Before you can debug such code with XDELTA, you must complete some setup work.

3.4.1. Setup Required (I64 and Alpha Only)

On I64 and Alpha, some setup work is required before you can debug kernel mode code that runs in process space at an elevated IPL. Before you access XDELTA, do the following:

1. Ensure that page faults do not occur at elevated IPL by locking into memory (or the working set) the code that runs at elevated IPL.

2. Make the code writable. (By default, code pages are read only.) To do this, modify the code psect attributes in the link options file or set the affected code pages to writable with \$SETPRT.
3. Make code pages copy-on-reference (CRF). You can do this when you make the code writable. If you modify the link options file, set the code psect attributes to be WRT, NOSHR. If you use \$SETPRT, it automatically makes the pages CRF.

3.4.2. Setup Required (VAX Only)

On VAX, some setup work is required before you can debug kernel mode code that runs in process space at an elevated IPL. Before you access XDELTA, do the following:

1. Ensure that page faults do not occur at elevated IPL by locking into memory (or the working set) the code that runs at elevated IPL.
2. Make the code writable if you plan to do anything more than single-step through your code (such as set breakpoints, step-overs, and so forth). (By default, code pages are read only.) To make the code writable, modify the code psect attributes in the link options file or set the affected code pages to writable with \$SETPRT.

3.4.3. Accessing XDELTA

After you set up the code for debugging, you are ready to access XDELTA. The most convenient method is to invoke INI\$BRK from the code at elevated IPL. This causes a trap into XDELTA. You can then step out of the INI\$BRK routine into the code to be debugged.

3.5. Debugging an Installed, Protected, Shareable Image

Some shareable images, such as user-written system services, must be linked and installed in a way that precludes debugging with DELTA unless you take further steps. Those steps are described in this section.

Typically, a user-written system service is linked and installed in such a way that the code is shared in a read-only global section, the data is copy-on-reference, and the default code psects are read-only and shareable. Such a shareable image is installed with the Install utility using a command like the following:

```
INSTALL> myimage.exe /share/protect/open/header
```

Other qualifiers can also be used.

When installed in this way, the shareable image code is read-only. However, to debug a user-written system service with DELTA, to single-step and to set breakpoints, the code must either be writable or DELTA must be able to change the code page protection to make it writable. Neither is possible when the code resides in a read-only global section.

Therefore, to debug a user-written system service, you must link and install it differently. In linking the image, the code psects must be set to writable and, preferably, to non-shareable (to force the code pages to be copy-on-reference). Multiple processes accessing this code through the global section will each have their own private copy. You can do this in the link options file by adding a line such as the following for each code psect:

```
PSECT=$CODE$, NOSHR, WRT
```

Then, the image must be installed writable with the `/WRITE` qualifier and without the `/RESIDENT` qualifier, as follows:

```
INSTALL> myimage.exe /share/protect/open/header/write
```

After you have installed the image in this way, you can use DELTA to set breakpoints in the shareable image code and single-step through it.

3.6. Using XDELTA on Multiprocessor Computers

On multiprocessor computers, only one processor can use XDELTA at a time. If a second processor attempts to enter XDELTA when another processor has already entered it, the second processor waits until the first processor has exited XDELTA. If the processor using XDELTA sets a breakpoint, other processors are aware of the breakpoint. Therefore, when the code with the XDELTA breakpoint is executed on another processor, that processor will enter XDELTA and stop at the specified breakpoint.

On Alpha and VAX systems, XDELTA uses its own system control block (SCB) to direct all interrupt handling to an error handling routine in XDELTA. Therefore, an error encountered by XDELTA does not affect any other processors that share the standard system SCB. On I64 systems, the implementation is different, but the outcome is the same: XDELTA avoids causing errors that could lead to unintended effects to other processors.

On VAX, when a breakpoint is taken by a processor in a multiprocessor environment, the processor's physical identification number is displayed on the XDELTA breakpoint message line as a 2-digit hexadecimal number. The following is an example of a breakpoint message in a multiprocessor environment:

```
1 BRK AT 00000400 ON CPU 03
00000400/movl #5,r4
```

On I64 and Alpha, the processor's physical identification number is similarly displayed but the number is decimal instead of hexadecimal with no leading zeros. For example:

```
BRK 1 AT 20000 ON CPU 2
20000! LDL R1, (R2)
```

3.7. Debugging Code When Single-Stepping Fails (Alpha Only)

On Alpha, the use of the `S` command to single-step occasionally fails and the error message `Eh?` is displayed. This can happen either when you are single-stepping through code or when you have stopped at a breakpoint. In each case, it fails because XDELTA does not have write access to the next instruction. Directions on how to continue debugging for both cases follow:

- You are single-stepping through your code and your single-step fails.

You can set other breakpoints and proceed with the `;P` command. If this occurs at a `JSR` or `BSR` instruction, you can first use the `O` command and then either single-step (with the `S` command) or proceed (with the `;P` command).

- You have stopped at a breakpoint and your attempt to single-step fails.

You can delete the breakpoint and then proceed with the `;P` command. If this occurs at a JSR or BSR instruction, it may be possible to first use the `O` command and then either single-step (with the `S` command) or proceed (with the `;P` command).

3.8. Debugging Code that Does Not Match the Compiler Listings (I64 and Alpha Only)

There are two cases when the code in your image does not exactly match your compiler listings. As long as you understand why these differences exist, they should not interfere with your debugging. The explanations follow:

- The compilers generate listings with mnemonics that replace some of the Alpha assembly language instructions. This makes the listings easier to read but can initially cause confusion because the code does not exactly match the code in your image. In every case, there is a 1-to-1 correlation between the line of code in your image and the line of code in your listing.
- In certain situations, the linker can modify the instructions in your image so that they do not exactly match your compiler listings. On Alpha, for example, the linker can replace JSR instructions and the call setup to use a BSR instruction for better performance. On I64, the linker sometimes generates code and performs jumps and calls.

Chapter 4. DELTA/XDELTA Commands

This chapter describes how to use each DELTA and XDELTA command to debug a program. It also describes which commands are used only with DELTA. Table 4.1 provides a summary of the DELTA/XDELTA commands that are common to OpenVMS I64 and Alpha, and VAX systems. Table 4.2 provides a summary of the DELTA/XDELTA commands that are available only on OpenVMS I64 and Alpha. Table 4.3 provides a summary of the DELTA/XDELTA commands that are available only on OpenVMS I64.

Many commands in this chapter include an example. The program used for all the examples, except those illustrating commands available only on OpenVMS I64 and Alpha, is listed in Appendix C.

Command Usage Summary

DELTA and XDELTA use the same commands, with the following exceptions:

- Only DELTA uses the EXIT and ;M commands and arguments that specify a process identification.
- XDELTA defines some base registers that DELTA does not (see Chapter 2).
- On I64 and Alpha, only DELTA uses the ;I command.

For all OpenVMS platforms, differences are noted in command descriptions.

Enter the LINEFEED, ESC, TAB, and RETURN commands by pressing the corresponding key.

Table 4.1. DELTA/XDELTA Command Summary (All platforms)

Command	Description
[	Set Display Mode
/	Open Location and Display Contents in Prevailing Width Mode
!	Open Location and Display Contents in Instruction Mode
LINEFEED	Close Current Location, Open Next
ESC	Open Location and Display Previous Location
TAB	Open Location and Display Indirect Location
"	Open Location and Display Contents in ASCII Mode
RETURN	Close Current Location
;B	Breakpoint
;P	Proceed from Breakpoint
;G	Go
S	Step Instruction
O	Step Instruction over Subroutine
;D 'string'	Deposit ASCII String
;E	Execute Command String
;X	Load Base Register
=	Display Value of Expression
;M ¹	Set All Processes Writable (available only on DELTA)

Command	Description
;M ²	Set All Processes Writable; also, set selected registers of other processes writable (available only on DELTA)
;L	Lists Names and Locations of Loaded Executive Images
EXIT	Exit from DELTA debugging session

¹VAX specific²I64 and Alpha specific

The commands in Table 4.2 are available only on OpenVMS I64 and Alpha.

Table 4.2. DELTA/XDELTA Command Summary (I64 and Alpha Only)

Command	Description
;D	Dumps a region of memory
;Q	Validate queue
;C	Force system to bug check and crash
;W	Locate and display the executive image that contains the specified address
;I	Locate and display information about the current main image that contains the specified address; also display information about all shareable images activated by the current main image (available only on DELTA)
;H	Display on video terminal or at hard copy terminal
\string\	Display the ASCII text string enclosed in backslashes

The commands in Table 4.3 are available only on OpenVMS I64.

Table 4.3. DELTA/XDELTA Command Summary (I64 Only)

Command	Description
;T	Display the address of the interrupt stack frame.

[(left angle bracket)—Set Display Mode

[(left angle bracket) — Sets the width mode of displays produced by DELTA/XDELTA commands.

Synopsis

[mode

Argument

mode

Specifies the display mode as follows:

Mode	Meaning
B	Byte mode. Subsequent open and display location commands display the contents of one byte of memory.

Mode	Meaning
L	Longword mode. Subsequent open and display location commands display the contents of a longword of memory. This is the default mode.
W	Word mode. Subsequent open and display location commands display the contents of one word of memory.

On I64 and Alpha, the following modes are also available.

Mode	Meaning
A	Address display of 32-bit/64-bit. Subsequent address displays will be 64 bits.
Q	Quadword mode. Subsequent open and display location commands display the contents of a quadword of memory.

Description

The Set Display Mode command changes the prevailing display width to byte, word, longword, or quadword. The default display width is longword on Alpha and VAX, quadword on I64. The display mode remains in effect until you enter another Set Display Mode command.

Example

```
R0/    00000001    ❶
[B      01        ❷
R0/    01         ❸
```

- ❶ Contents of general register 0 (R0) are displayed using the `/` command. The display is the default mode, longword.
- ❷ Display mode is changed to byte mode using the `[B` command.
- ❸ Contents of R0 are displayed in byte mode. The least significant byte is displayed.

/ (forward slash)—Open Location and Display Contents in Prevailing Width Mode

`/` (forward slash) — Opens a location and displays its contents in the prevailing display mode.

Synopsis

```
[pid:] [start-addr-exp] [end-addr-exp] / current-contents [new-exp]
```

Arguments

[pid]

The internal process identification (PID) of a process you want to access. If you specify zero or do not specify a PID, the default process is the current process. This argument cannot be used with XDELTA.

If you use the *pid* argument, every time you use this command during the debugging session the contents of the same process are displayed, unless you specify a different *pid*.

You can obtain the internal PID of processes by running the System Dump Analyzer utility (SDA). Use the SDA command `SHOW SUMMARY` to determine the external PID. Then use the SDA command `SHOWPROCESS/INDEX` to determine the internal PID. For more information about using SDA commands, see your operating system's *VMS System Dump Analyzer Utility Manual*.

Note

The register examples in the descriptions of *start-addr-exp* and *end-addr-exp* apply to both VAX and Alpha register. (Alpha register numbers are displayed in decimal, and VAX register numbers are displayed in hexadecimal.)

[start-addr-exp]

The address of the location to be opened, or the start of a range of addresses to be opened. If not specified, the address displayed is that currently specified by the symbol **Q** (last quantity displayed). Use the following syntax to display a single address location:

```
start-addr-exp/
```

You can also specify a register for this parameter. For example, if you want to view the contents of general register 3 (R3), enter the following DELTA/XDELTA command:

```
R3/
```

[end-addr-exp]

The address of the last location to be opened. Use the following syntax to display a range of address locations:

```
start-addr-exp,end-addr-exp/
```

You can also specify a range of registers. For example, if you want to view the contents of general registers 3 through 5, enter the following DELTA/XDELTA command:

```
R3,R5/
```

If you specify an address expression for *end-addr-exp* that is less than *start-addr-exp*, DELTA/XDELTA displays the contents of *start-addr-exp* only.

current-contents

You do not specify this parameter. It is a hexadecimal value, displayed by DELTA/XDELTA, of the contents of the location (or range of locations) you specified with the *pid* argument and the address expression. It is displayed in the prevailing width display mode.

[new-exp]

An expression, the value of which is deposited into the location just displayed. If you specify *new-exp* after a range of locations, the new value is placed only in the last location (specified by *end-addr-exp*).

When you specify *new-exp*, terminate the command by pressing the **Return** key.

If you want to deposit a new value into a location in another process (that is, you specified a PID other than the current process), you must have already set the target process to be writable using the **WM** command.

If the value you deposit is longer than the last location where it will be deposited, the new value overwrites subsequent locations. For example, the values at address locations 202 and 204 are as follows:

```
202/ 05D053D4
204/ C05405D0
```

If you deposited the value `FFFFFFFF` at address 202, the overflow value would overwrite the value stored at address location 204, as follows:

```
202/ 05D053D4 FFFFFFFFFF Return
204/ C054FFFF
```

Description

The Open Location and Display Contents command opens the location or range of locations at *start-addr-exp* and displays *current-contents*, the contents of that location, in hexadecimal format. You can place a new value in the location by specifying an expression. A new value overwrites the last value displayed.

To display a range of locations, give the *start-addr-exp* argument as the first address in the range, followed by a comma, followed by the last address in the range (the *end-addr-exp* argument). For example, if you want to display all locations from 402 to 4F0, the command is as follows:

```
402,4F0/
```

This command changes the current address (`.` symbol) to the contents of the opened location. A subsequent Close Location command does not change the current address. However, a subsequent Close Current Location and Open Next command (ESC or LINEFEED) executes as follows:

- Writes any *new-exp* specified
- Closes the location opened by the `/` command
- Adds the number of bytes (defined by the prevailing display width mode) to the address just opened with the `/` command
- Changes the current address to the new value
- Opens the new location and displays the contents

The display mode remains hexadecimal until the next Open Location and Display Contents in Instruction Mode (`!`) command or Open Location and Display Contents in ASCII Mode (`"`) command.

In DELTA, not XDELTA, processes having the CMKRNL privilege can examine the address space of any existing process. Use *pid* to specify the internal PID of the process you want to examine. For example, use the following command to view address location 402 in the process with a PID of 00010010:

```
00010010:402/
```

On I64 and Alpha, DELTA also permits the examination of general purpose registers in another process. The PID specifies the internal PID of the process you want to examine. For example, use the following command to examine R5 in the process with a PID of 00010010:

```
00010010:R5/
```

Example

```
R0,R9/00000001
R1/00000000
R2/00000226
R3/7FF2AD94
R4/000019B4
R5/00000000
R6/7FF2AA49
R7/8001E4DD
R8/7FFED052
R9/7FFED25A
```

Contents of all the general registers R0 through R9 are displayed.

! (exclamation mark)—Open Location and Display Contents in Instruction Mode

! (exclamation mark) — Displays an instruction and its operands.

Synopsis

```
[pid:] [start-addr-exp] [end-addr-exp]!
```

Arguments

[pid]

The internal process identification (PID) of a process you want to access. If you specify zero, or do not specify any PID, the default process is the current process. This argument cannot be used with XDELTA.

Subsequent open location and display contents commands, issued after using the *pid* argument, display the contents of the location of the specified process until you specify another PID with this command.

You can obtain the internal PID of processes by running the System Dump Analyzer utility (SDA). Use the SDA command SHOW SUMMARY to determine the external PID. Then use the SDA command SHOW PROCESS/INDEX to determine the internal PID. For more information about SDA commands, see your operating system's *VMS System Dump Analyzer Utility Manual*.

[start-addr-exp]

The address of the instruction, or the first address of the range of instructions, to display. If you do not specify this parameter, the address displayed is that currently specified by Q (last quantity displayed). When you want to view just one location, the syntax is as follows:

```
start-addr-exp!
```

[end-addr-exp]

The address of the last instruction in the range to display. When you want to view several instructions, the syntax is as follows:

```
start-addr-exp,end-addr-exp!
```

Each location within the range is displayed with the address, a slash (/), and the machine instruction.

Description

The Open Location and Display Contents in Instruction Mode command displays the contents of a location or range of locations as a machine instruction. DELTA/XDELTA does not make any distinction between reasonable and unreasonable instructions or instruction streams.

This command does not allow you to modify the contents of the location. The command sets a flag that causes subsequent Close Current Location and Display Next (LINEFEED) and Open Location and Display Indirect Location (TAB) commands to display MACRO instructions. You can clear the flag by using the Open Location and Display Contents (/) command, which displays the contents of the location as a hexadecimal number, or Open Location and Display Contents in ASCII Mode ("), which displays the contents of the location in ASCII.

When an address appears as an instruction's operand, DELTA/XDELTA sets the Q symbol to that address. Then enter ! again to go to the address specified in the instruction operand. DELTA/XDELTA changes Q only for operands that use program-counter or branch-displacement addressing modes; Q is not altered for operands that use literal and register addressing modes. This feature is useful for branches that follow.

Examples

The following examples illustrate the command on each OpenVMS platform.

I64 example:

```
G0BF5D60!      add      r33 = 0008, r33 ;;      ❶
80BF5D62!      nop.i    000000 ;;              ❷
80BF5D70!      ld4      r2 = [r2] ;;
80BF5D71!      nop.m    000000
80BF5D72!      sxt4     r2 = r2 ;;
80BF5D80!      cmp.eq   p14, p0 = r2, r0
80BF5D81!      nop.f    000000
80BF5D82! (p14) br.cond.dpnt.few.clr 0000030 ;;
80BF5D90!      ld8      r14 = [r2], 008 ;;
80BF5D91!      nop.m    000000
80BF5D92!      mov      b7 = r14 ;;
80BF5DA0!      ld8      r1 = [r2]
```

- ❶ The instruction at the base address G0BF5D60 is displayed using the ! command. XDELTA displays an add instruction.
- ❷ After typing a LINEFEED command, XDELTA displays the next instruction location and the instruction at that address, and so on.

Alpha example:

```
30000!      LDA      SP, #XFFE0 (SP)      ❶
00030004!   BIS      R31, R31, R18        ❷
```

- ❶ The instruction at address 30000 is displayed using the ! command. DELTA/XDELTA displays a LDA instruction. Note that unlike on a VAX computer, an absolute address never appears in an instruction operand. So the value of Q has no use after an instruction display.
- ❷ After typing a LINEFEED command, DELTA/XDELTA displays the next instruction location and the instruction at that address.

VAX example:

```
69B!  
BRB      0000067A ❶  
!  
CLRQ     - (SP) ❷
```

- ❶ The instruction at address 69B is displayed using the **!** command. DELTA/XDELTA displays a branch instruction and sets Q (last address location displayed) to the branch address 67A.
- ❷ The instruction at address 67A is displayed using the **!** command. The value of Q is used as the address location.

" (double quote)—Open Location and Display Contents in ASCII

" (double quote) — Displays the contents of a location as an ASCII string.

Synopsis

```
[pid:] start-addr-exp [end-addr-exp]"
```

Arguments

[pid]

The internal process identification (PID) of a process you want to access. If you specify zero, or do not specify any PID, the default process is the current process. This argument cannot be used with XDELTA.

Subsequent open location and display contents commands issued after using the *pid* argument, display the contents of the location of the specified process until you specify another PID with this command.

You can obtain the internal PID of processes by running the System Dump Analyzer utility (SDA). Use the SDA command **SHOW SUMMARY** to determine the external PID. Then use the SDA command **SHOW PROCESS/INDEX** to determine the internal PID. For more information about SDA commands, see your operating system's *VMS System Dump Analyzer Utility Manual*.

[start-addr-exp]

The address of the location, or the start of a range of locations, to be displayed. If you want to view one location, the syntax is as follows:

```
start-addr-exp"
```

[end-addr-exp]

The last address within a range of locations to be viewed. If you want to view a series of locations, the syntax is as follows:

```
start-addr-exp,end-addr-exp"
```

Description

The Open Location and Display Contents in ASCII command opens the location or range of locations at *start-addr-exp* and displays the contents in ASCII format. This command does not change the width of the display (byte, word, longword) from the prevailing mode. If the prevailing mode is word mode, two ASCII characters are displayed; if byte mode, one character is displayed.

The display mode remains ASCII until you enter the next Open Location and Display Contents command (/) or Open Location and Display Contents in Instruction Mode command (!). These commands change the display mode to hexadecimal or instruction, respectively.

You can modify the contents of the locations, starting at *start-addr-exp*, with the Deposit ASCII string (') command.

Example

```
235FC2 [W/415A ❶  
235FC2" ZA      ❷ Linefeed ❸  
235FC4/PP
```

- ❶ The current display mode is word (displays one word in hexadecimal).
- ❷ The " command changes the prevailing display mode to ASCII but does not affect the width of the display.
- ❸ The next Close Current Location, Open Next command (LINEFEED), determines the address of the location to open by adding the width, in bytes, to the value contained in the symbol . (the current address). Then it opens the number of bytes equal to the width of the prevailing display mode, which in this example is two bytes.

The ASCII representation of the contents of the location presents the bytes left to right, while the hexadecimal representation presents them right to left.

' (single quote)—Deposit ASCII String

' (single quote) — Deposits the ASCII string at the current address.

Synopsis

' string '

Arguments

string

The string of characters to be deposited.

Description

The Deposit ASCII String command deposits *string* at the current location (.) in ASCII format. The second apostrophe is required to terminate the string. All characters typed between the first and second apostrophes are entered as ASCII character text. Avoid embedding an apostrophe (') within the string you want to deposit.

When you want to use key commands (LINEFEED, RETURN, ESC, or TAB), press the key. These commands are entered as text.

This command stores the characters in 8-bit bytes and increments the current address (.) by one for each character stored.

This command does not change the prevailing display mode.

Example

```
7FFE1600/'R0/ Linefeed Linefeed'
```

The ASCII string “R0/ LINEFEED LINEFEED” is stored at address 7FFE1600. This string, if subsequently executed with the **;E** command, examines the contents of general register 0 (the command R0/), then examines two subsequent registers (using two LINEFEED commands).

= (equal sign)—Display Value of Expression

= (equal sign) — Evaluates an expression and displays its value.

Synopsis

expression =

Argument

expression

The expression to be evaluated.

Description

The Display Value of Expression command evaluates an expression and displays its value in hexadecimal. The expression can be any valid DELTA/XDELTA expression. See Section 2.1 for a description of DELTA/XDELTA expressions.

All calculations and displays are in hexadecimal in the prevailing length mode.

Note

Because DELTA and XDELTA treat the space as an addition operator, do not enter an unnecessary space.

Example

```
FF+1=00000100 ❶  
A-1=00000009 ❷
```

- ❶ FF₁₆ and 1₁₆ are added together. DELTA/XDELTA displays the sum in hexadecimal.
- ❷ 1₁₆ is subtracted from A₁₆. DELTA/XDELTA displays the result in hexadecimal.

\string\—Immediate mode text display command (I64 and Alpha Only)

\string\ — Displays the ASCII text string enclosed in backslashes.

Synopsis

\string\

Description

This mode is useful when creating your own predefined command strings. Use the backslash to begin and end an ASCII text string. Follow the ending backslash with a terminator. When DELTA or XDELTA encounters the ending backslash and terminator, it prints the ASCII text string.

ESC (Escape key)—Open Location and Display Previous Location

ESC (**E**scape key)—Open Location and Display Previous Location — Opens the previous location and displays its contents.

Synopsis

ESC

Description

The Open Location and Display Previous Location command decrements the location counter (.) by the width (in bytes) of the prevailing display mode, opens that many bytes, and displays the contents on a new line. The address of the location is displayed on the new line in the prevailing mode, followed by a slash (/) and the contents of that address.

On VAX, this command is ignored if the prevailing display mode is instruction mode (set by the ! command).

On all platforms, use this command to move backwards through a series of locations. Set the address where you want to start (for example, with the /command). Then press the **ESC** key repeatedly to display each preceding location. **ESC** is echoed as a dollar sign (\$) on the terminal.

On keyboards without a separate **ESC** key, press **Ctrl/3** or the escape key sequence that you defined on your keyboard. The **ESC** key on LK201 keyboards (VT220, VT240, VT340, and workstation key boards) generates different characters and cannot be used for the ESC command. You must use **Ctrl/3**.

Example

```
R1/00000000 ❶ $ ❷ ESC  
R0/00000001
```

- ❶ The contents of general register 1 are displayed using the / command.
- ❷ The contents of general register 0, the location prior to general register 1, are displayed by pressing **ESC**.

EXIT—Exit from DELTA Debugging Session

EXIT — Terminates the DELTA debugging session. Use with DELTA only.

Synopsis

EXIT

Description

Use the EXIT command to terminate a DELTA debugging session. You cannot use EXIT in XDELTA.

You may have to enter EXIT twice, such as when your program terminates execution by the \$EXIT system service or by the **Return** key (to DCL).

LINEFEED (Linefeed key or Ctrl/J)—Close Current Location, Open Next Location

LINEFEED (**Linefeed** key or **Ctrl/J**) — Closes the currently open location and opens the next location, displaying its contents.

Synopsis

LINEFEED

Description

The Close Current Location Open Next command closes the currently open location, then opens the next and displays its contents. This command accepts no arguments, and thus can only be used to open the next location. It is useful for examining a series of locations one after another. First, set the location where you want to start (for example, with the **/** or **(!)** command). Then, press the **LINEFEED** key repeatedly to examine each successive location.

The **LINEFEED** command displays the contents of the next location in the prevailing display mode and display width. If the current display mode is hexadecimal (the **/** command was used) and the display width is word, the next location displayed is calculated by adding a word to the current location. Its contents are displayed in hexadecimal. If the current display mode is instruction, the next location displayed is the next instruction, and the contents are displayed as a MACRO instruction.

On keyboards without a separate **Linefeed** key, press **Ctrl/J**. The **Linefeed** key on LK201 keyboards (VT220, VT240, VT340, and workstation key boards) generates different characters and cannot be used for the LINEFEED command. You must use **Ctrl/J**.

This command is useful for displaying a series of machine instructions, a series of register values, or a series of values on the stack or in memory.

The values in the symbol **Q** and the symbol **.** are changed automatically.

Examples

The following examples illustrate the command on each OpenVMS platform.

I64 example:

```
G0BF5D60!      add      r33 = 0008, r33 ;;    ❶
80BF5D62!      nop.i    000000 ;;            ❷
80BF5D71!      nop.m    000000
80BF5D72!      sxt4     r2 = r2 ;;
80BF5D80!      cmp.eq   p14, p0 = r2, r0
80BF5D81!      nop.f    000000
80BF5D82! (p14) br.cond.dpnt.few.clr 0000030 ;;
```

```
80BF5D90!      ld8      r14 = [r2], 008 ;;
80BF5D91!      nop.m    000000
80BF5D92!      mov      b7 = r14 ;;
80BF5DA0!      ld8      r1 = [r2]
```

- ❶ The instruction at the base address G0BF5D60 is displayed using the ! command. XDELTA displays an add instruction.
- ❷ Ten successive instructions are displayed by pressing the **Linefeed** key twelve times. The LINEFEED command is not echoed on the terminal.

Alpha example:

```
30000!      LDA      SP, #XFFE0 (SP) ❶
00030004!   BIS      R31, R31, R18   ❷
00030008!   STQ      R27, (SP)
0003000C!   BIS      R31, R31, R19
00030010!   STQ      R26, #X0008 (SP)
00030014!   BIS      R31, #X04, R25
```

- ❶ Instruction at address 30000 is displayed using the ! command.
- ❷ Five successive instructions are displayed by pressing the **Linefeed** key five times. The LINEFEED command is not echoed on the terminal.

VAX example:

```
6B9!
CLRQ      -(SP) ❶ Linefeed ❷
000006BB/CLRQ      -(SP)      Linefeed
000006BD/PUSHL     X1+002E     Linefeed
000006C1/PUSHAL    X1+003A     Linefeed
000006C5/CLRQ      -(SP)      Linefeed
000006C7/PUSHL     #00
```

- ❶ Instruction at address 6B9 is displayed using the ! command.
- ❷ Five successive instructions are displayed by pressing the Linefeed key five times. The LINEFEED command is not echoed on the terminal.

RETURN (Return or Enter key)—Close Current Location

RETURN (**Return** or **Enter** key) — Closes a location that has been opened by one of the open location and display contents commands.

Synopsis

RETURN

Description

If you have opened a location with one of the open location and display contents commands (/ , LINEFEED, ESC, TAB, !, or "), press the **Return** key to close the location. Use this command to make sure that a specific location has not been left open with the possibility of being overwritten.

You also press the **Return** key to terminate the following DELTA/XDELTA commands:

- ;X
- ;E
- ;G
- ;P
- ;B
- ;M
- 'string'
- ;L
- EXIT (DELTA only)

On I64 and Alpha, the same is true for the commands that are specific to this implementation, as follow:

- ;Q
- ;C
- ;D
- ;H
- ;I
- ;T (I64 only)
- ;W
- \string\

On all platforms, you can also use the **Return** key as an ASCII character in a quoted string. See the Deposit ASCII String command ' (single quote)—Deposit ASCII String (').

TAB (Tab key)—Open Location and Display Indirect Location

TAB (**Tab** key) — Opens the location addressed by the contents of the current location and displays its contents.

Synopsis

TAB

Description

The Open Location and Display Indirect Location command opens the location addressed by the contents of the current location and displays the contents of the addressed location on a new line. The display is in the prevailing display mode. This command is useful for examining data structures that have been placed in a queue, or the operands of instructions.

To execute this command, press the **Tab** key.

This command changes the current address (.) to the location displayed.

This command does not affect the display mode.

Examples

The following examples illustrate the command on each OpenVMS platform.

I64 and Alpha, and VAX example:

```
10000/00083089      ❶  
00010004/00000000    ❷  
00010008/00030000    ❸  
00030000/23DEFFFE0
```

- ❶ The contents of location 10000 are displayed using the `/` command.
- ❷ The subsequent two locations are displayed using the `LINEFEED` command.
- ❸ After displaying the contents of location 10008 (30000), the `TAB` command is used to display the contents of location 30000.

VAX example:

```
69B!  
BRB      0000067A      ❶ Tab  
0000067A/CLRQ      - (SP) ❷
```

- ❶ The instruction at 69B is displayed using the `!` command. DELTA/XDELTA displays a branch instruction.
- ❷ The instruction at the address referred to by the branch instruction is displayed by pressing the **Tab** key. DELTA/XDELTA displays the instruction at address 67A.

;B—Breakpoint

;B — Shows, sets, and clears breakpoints.

Synopsis

[addr-exp] [n] [display-addr-exp] [cmd-string-addr] **;B**

Arguments

[addr-exp]

The address where you want the breakpoint.

[n]

The number to assign to the breakpoint. If you omit a number, DELTA/XDELTA assigns the first unused number to the breakpoint; if all numbers are in use, DELTA/XDELTA displays the error message, `Eh?`.

On VAX, for XDELTA, the range is from 2 to 8. For XDELTA, breakpoint 1 is reserved for `INI$BRK`. For DELTA, the range is from 1 to 8.

On I64 and Alpha, for XDELTA, the range is from 1 to 8. For DELTA, the range is from 1 to 8.

[display-addr-exp]

The address of a location, the contents of which are to be displayed in hexadecimal in the prevailing width mode when the breakpoint is encountered. Omit this argument by specifying zero or two consecutive commas. If omitted, DELTA/XDELTA displays only the instruction that begins at the specified address.

[cmd-string-addr]

The address of the string of DELTA/XDELTA commands to execute when this breakpoint is encountered. **;**E****—Execute Command String DELTA/XDELTA displays the information requested before executing the string of commands associated with complex breakpoints. You must have previously deposited the string of commands using the **'** command or have coded the string into an identifiable location in your program. If omitted, DELTA/XDELTA executes no commands automatically and waits for you to enter commands interactively.

Description

The breakpoint command shows, sets, and clears breakpoints. The action of this command depends on the arguments used with it. Each action is described below.

Displaying Breakpoints

To show all the breakpoints currently set, enter **;**B****. For each breakpoint, DELTA/XDELTA displays the following information:

- Number of the breakpoint
- Address of the breakpoint
- Address of a location the contents of which will be displayed when the breakpoint is encountered
- Address of the command string associated with this breakpoint (for complex breakpoints, the section called “Setting Complex Breakpoints”)

Setting Simple Breakpoints

To set a breakpoint, enter an address expression followed by **;**B****. Then press the **Return** key, as follows:

```
addr-exp;B Return
```

DELTA/XDELTA sets a breakpoint at the specified location and assigns it the first available breakpoint number.

When DELTA/XDELTA reaches the breakpoint, it completes the following actions:

- Suspends instruction execution.
- Sets a flag to change the display mode to instruction mode. Any subsequent Close Current Location, Open Next (LINEFEED) commands, and Open and Display Indirect Location (TAB) commands will display locations as machine instructions.

- On VAX, the following message is displayed, listing the number of the breakpoint, the address of the breakpoint, and the instruction stored at the breakpoint location:

```
n BRK at address
address/decoded-instruction
```

On I64 and Alpha, the format of the display differs slightly, as shown in the following example:

```
Brk n at address [on CPU] [new mode =]
[new IPL =]
address!decoded-instruction
```

- On I64 and Alpha systems, if the interrupt priority level (IPL) has changed, the new IPL is printed (XDELTA only). Also on I64 and Alpha systems, if the processor mode has changed, the new mode is printed (both XDELTA and DELTA).

If you are using XDELTA in a multiprocessor environment, the CPUID of the processor where the break was taken is also displayed.

On VAX, the CPU ID is displayed as a 2-digit hexadecimal number.

On I64 and Alpha, the CPU ID is displayed as a decimal number with no leading zeros.

On all platforms, after the breakpoint message is displayed, you can enter other DELTA/XDELTA commands. You can reset the flag that controls the mode in which instructions are displayed by entering the Open Location and Display Contents (/) command.

Setting a Breakpoint and Assigning a Number to It

To set a breakpoint and assign it a number, enter the address where you want the breakpoint, a comma, a single digit for the breakpoint number, a semicolon (;), the letter B, and then press the **Return** key.

For example, if you wanted to set breakpoint 4 at address 408, the command is as follows:

```
408,4;B Return
```

DELTA/XDELTA sets a breakpoint at the specified location and assigns it the specified breakpoint number.

Clearing Breakpoints

To clear a breakpoint, enter zero (0), followed by a comma, the number of the breakpoint to remove, a semicolon (;), the letter B, and then press the **Return** key. DELTA/XDELTA clears the specified breakpoint. For example, if you wanted to clear breakpoint 4, the command is as follows:

```
0,4;B Return
```

On VAX, when using XDELTA, do not clear breakpoint 1. If you do, any calls to INI\$BRK in your program will not result in entry into XDELTA.

Setting Complex Breakpoints

On all platforms, a complex breakpoint completes one or more of the following actions:

- Always displays the next instruction to be executed

- Optionally displays the contents of another, specified location
- Optionally executes a string of DELTA/XDELTA commands stored in memory

To use the complex breakpoint, you must first create the string of DELTA commands you want executed. Then deposit those commands at a memory location with the Deposit ASCII String command (**'**).

To set a complex breakpoint, use the following syntax:

```
addr-exp,n,display-addr-exp,cmd-string-addr;B
```

Example

```
;B
1  00000690
2  00000699    ❶
0,2;B          ❷
;B
1  00000690    ❸
;P             ❹
```

- ❶ Two breakpoints have already been set and are displayed. Using **;B**, DELTA/XDELTA displays each breakpoint number and the address location of each breakpoint.
- ❷ Breakpoint 2 is cleared.
- ❸ Current breakpoints are displayed. Because breakpoint 2 has been cleared, DELTA/XDELTA displays just breakpoint 1.
- ❹ Program execution is continued using the **;P** command.

Displaying Breakpoints in a Multithreaded Application

To support the debugging of multithreaded applications, DELTA has the capability of displaying a thread ID at a breakpoint. When DELTA reaches a breakpoint in a multithreaded application, DELTA displays the thread ID and stops the execution of all other threads. (When DELTA reaches a breakpoint in a single-threaded application, the display and behavior is the same as in the past; DELTA displays the address and stops program execution.)

In the following example, a breakpoint is set in a multithreaded application with 30000;B and is followed by the **;P** (Proceed from Breakpoint) command. The breakpoint is taken. Because it is a multithreaded application, the thread ID is included in the display.

```
30000;B ;P
Brk 1 at 30000 on Thread 12
00030000! LDA SP,#XFF80(SP)
```

;C—Force System to Bugcheck and Crash (I64 and Alpha Only)

;C — Force the system to bugcheck and crash.

Synopsis

```
;C
```


Description

The **;C** command forces the system to bugcheck and crash. You can do this from wherever you are in your debugging session. Although this command is for use primarily with XDELTA, you can also use it with DELTA, but only in kernel mode. When you issue this command, the following message is generated:

```
BUG$_DEBUGCRASH, Debugger forced system crash
```

;D—Dump (I64 and Alpha Only)

;D — Dumps a region of memory.

Synopsis

addr_exp length **;D**

Arguments

addr-exp

The starting address of the dump.

length

The length of bytes to dump.

Description

On I64 and Alpha systems, the **;D** command dumps a region of memory. The display is in a format similar to the DCL DUMP command.

Example

```
G,200;D
Dump of 80000000 for 0000200 bytes
00840008 80000200 0000241F 00E8401D .@...$. : 80000000
00840008 80000200 00002400 0004401D .@...$. : 80000010
00840008 80000200 00000001 0000001D ..... : 80000020
00000000 00000000 00000000 00000000 ..... : 80000030
00040000 00203008 00202400 0260100B ..`..$. ..0 : 80000040
90000A00 40038004 10700001 00000001 .....p....@ : 80000050
00800070 00000200 00001418 04200810 .. .....p... : 80000060
00000000 00000000 00000000 00000000 ..... : 80000070
00000000 00000000 00000000 00000000 ..... : 80000080
00000000 00000000 00000000 00000000 ..... : 80000090
00000000 00000000 00000000 00000000 ..... : 800000A0
00000000 00000000 00000000 00000000 ..... : 800000B0
00000000 00000000 00000000 00000000 ..... : 800000C0
00000000 00000000 00000000 00000000 ..... : 800000D0
00000000 00000000 00000000 00000000 ..... : 800000E0
00000000 00000000 00000000 00000000 ..... : 800000F0
```

❶
❷
❸

```

00040000 00040000 00300580 02090001 .....0..... : 80000100
00840008 80000200 00000001 0000001D ..... : 80000110
00840008 80000200 00000001 0000001D ..... : 80000120
00840008 80000200 00002400 0004401D .@...$. : 80000130
00840008 80000200 0000241C 0128401D .@()..$. : 80000140
84000804 40006200 02000580 060D0800 .....b. @. : 80000150
20000000 00000200 00002400 0000C81D .....$. : 80000160
50000178 00000200 00000001 0000001D .....x..P : 80000170
07000A00 00005501 08002100 44000802 ...D.!...U..... : 80000180
00840008 80000200 00000001 0000001D ..... : 80000190
00840008 80000200 00002400 0004401D .@...$. : 800001A0
00840008 80000200 00002400 0004401D .@...$. : 800001B0
00840008 80000200 00002400 0004401D .@...$. : 800001C0
00840008 80000200 00002400 0004401D .@...$. : 800001D0
00840008 80000200 00002400 0004401D .@...$. : 800001E0
00840008 80000200 00002400 0004401D .@...$. : 800001F0
FFFFFFFF 8 ④

```

- ❶ The DUMP command is issued.
- ❷ The dump output summarizes the operation.
- ❸ The memory dump is displayed. The output is in the same format as the DCL DUMP command.
- ❹ The starting location of the dump is printed.

;**E**—Execute Command String

;**E** — Executes a string of DELTA/XDELTA commands stored in memory.

Synopsis

address-expression **;**E****

Arguments

address-expression

The address of the string of DELTA/XDELTA commands to execute.

Description

The Execute Command String command executes a string of DELTA/XDELTA commands. Load the ASCII text command string to a specific location in memory using the Deposit ASCII String command (') or code the string in your program into an identifiable location.

If you want DELTA/XDELTA to proceed with program execution after it executes the string of commands, end the command string with the **;**P**** command. If you want DELTA/XDELTA to wait for you to enter a command after it executes the string of commands, end the command string with a null byte (a byte containing 0).

XDELTA, but not DELTA, provides two command strings in memory.

On Alpha, the addresses of these command strings are stored in base registers X14 and X15. The string addressed by X14 displays the physical page number (PFN) database for the PFN in X0. The string addressed by X15 copies the PFN in R0 to base register X0. It then displays the PFN database for that PFN.

On VAX, the addresses of these command strings are stored in base registers XE and XF. The string addressed by XE displays the physical page number (PFN) database for the PFN in X0. The string addressed by XF copies the PFN in R0 to base register X0. It then displays the PFN database for that PFN.

You can use the command strings provided with XDELTA to obtain the following information:

- Specified PFN
- PFN state and type
- PFN reference count
- PFN backward link or working-set-list index
- PFN forward link or share count
- Page table entry (PTE) address that points to the PFN
- PFN backing-store address
- On VAX, the virtual block number in the process swap image, the block to which the page's entry in the SWPVBN array points
- On Alpha, the virtual page number in process swap image, the collection of blocks containing the page as pointed to by the PFN database

Example

```
7FFE1600,0;X      ❶
7FFE1600           ❷
X0;E              ❸
R0/00000001        ❹
R1/00000000
R2/00000000
```

- ❶ The address (7FFE1600) where an ASCII string is stored is placed into base register 0 using **;X**.
- ❷ DELTA/XDELTA displays the value in X0.
- ❸ The command string stored at address 7FFE1600, which is to examine the contents of R0, R1, and R2 (R0/ **Linefeed Linefeed**), is executed with **;E**.
- ❹ DELTA/XDELTA executes the commands and displays the contents of R0, R1, and R2.

;G—Go

;G — Continues program execution.

Synopsis

address-expression **;G**

Arguments

address-expression

The address at which to continue program execution.

Description

The Go command places the address you specified in *address-expression* into the PC and continues execution of the program at that address. It is useful when you want to ignore specific lines of code or return to a previous program location to repeat execution.

Example

```
6A2;G
```

Program execution is started at address 6A2.

;H—Video Terminal Display Command (I64 and Alpha Only)

;H — Specifies the display mode, either hard copy terminal mode or DEC-CRT.

Synopsis

```
;H
```

Description

The **;H** command enables you to choose the display mode of DELTA/XDELTA output. You can display output either in hard copy terminal mode or DEC-CRT mode. The default display is DEC-CRT mode. You can toggle back and forth from one display mode to the other by repeating the **;H** command.

;I—List Current Main Image and Its Shareable Images (I64 and Alpha Only)

;I — Lists information about the current main image and all shareable images that were activated, including those that were installed /RESIDENT.

Synopsis

```
;I
```

Description

The **;I** command peruses the image control block (IMCB) list and displays information about the current main image and all shareable images that were activated, including those that were installed /RESIDENT. The **;I** command differs from the **;L** command which displays information about the loadable image database.

The display of the **;I** command is similar to the **;L** command display. It shows the image name, the starting and ending addresses, the symbol vector address, and some flags. The command is useful for debugging shareable images. For example, the display enables you to determine where LIBRTL is mapped.

The field flags are M, S, and P. The flag M indicates the main image; S or P indicates images that are installed as shareable or protected, respectively.

Unlike the **;L** command, which only works from kernel mode or when you have CMEXEC or CMKRNL privileges, the **;I** command works from any mode. However, to modify the IMCB database, you must be in executive or kernel mode.

For resident main and shareable images, the **;I** command also includes an entry for each resident code section and each compressed data section, which shows the base and end address for each section.

The **;I** command is implemented only for DELTA.

Example

```
$ define lib$debug delta
$ run/debug hello
OpenVMS Alpha DELTA Version 1.5
Brk 0 at 00020040
00020040!      LDA      SP, #XFFD0 (SP) ;i
Image Name      Base      End      Symbol-Vector  Flags
HELLO           00010000 000301FF
DECC$SHR        00032000 001233FF 00106B90      S
DPML$SHR        0012C000 001AC5FF 0019DED0      S
LIBRTL          001AE000 0025E7FF 00240790      S

Resident Code Sections:
LIBOTS          8015A000 801BBA00
                00124000 0012A1FF 00128000      S

Resident Code Sections:
                801BC000 801C2C00

Compressed Data Sections:
                00124000 00124A00
                00126000 00126800
                00128000 00128600
                0012A000 0012A200
SYS$PUBLIC_VECTORS 80401C98 80403028 80401C98
DELTA           00260000 002943FF 00260000
SYS$BASE_IMAGE  8040C5B0 804163E0 8040C5B0
```

;L—List Names and Locations of Loaded Executive Images

;L — Lists the names and virtual addresses of all loaded executive images.

Synopsis

[sequence number] **;L**

Argument

[sequence number]

On I64 and Alpha, specifies a single executive image.

Description

Use the **;L** command when you are debugging code that resides in system space. Although you use this command mostly with XDELTA, you can use it with DELTA if your process has change-mode-to-executive (CMEXEC) privilege and you are running a program in executive mode.

This command lists the names and locations of the loaded modules of the executive. A loading mechanism maps a number of images of the executive into system space. The **;L** command lists the currently loaded images with their starting and ending virtual addresses. If you enter **;L** before all the executive images are loaded (for example, at an XDELTA initial breakpoint), only those images that have been loaded will be displayed.

On Alpha, this command displays additional information and provides a second use, based on the additional information. For each loaded executive image that is sliced into discontinuous image sections, the display shows the sequence number for the executive image and the base and ending addresses of each image section. A second use of this command is to display the base and ending addresses of a single image if you specify its sequence number.

Examples

The following examples illustrate the command on each platform.

The following I64 example shows the names, the starting and ending virtual addresses, and the sequence number for the specified loaded executive image. Images are split into image sections, showing the name and the base, link, and ending address of each respective section. In these examples, sequence number 24 selects the `PROCESS_MANAGEMENT`; sequence number selects `SYSS$PUBLIC_VECTORS`; and sequence number 32 selects `RMS`.

```
24;L
Seq# LDRISD   Image Name           Base      End      Link      End
0024 83881B80 PROCESS_MANAGEMENT
      0 83881C70 Read Write           83203800 83203808 00010000 00010008
      1 83881CB8 Read           Execute      805AF300 806E4D70 00014000 00149A70
      2 83881D00 Read           83203A00 83230C78 0014C000 00179278
      3 83881D48 Read Write      83230E00 8323C120 0017C000 00187320
      4 83881D90 Read Write      8323C200 8323C214 00188000 00188014
      7 83881E68 Read Write      8323C400 8323C414 00194000 00194014
      8 83881EB0 Read Write      8323C600 8323C604 00198000 00198004
      9 83881EF8 Read Write      8323C800 83240660 0019C000 0019FE60
0;L
Seq# LDRISD   Image Name           Base      End      Link      End
0000 83868580 SYSS$PUBLIC_VECTORS
      0 83868670 Read           Execute      80000000 80000070 00010000 00010070
      1 838686B8 Read           83000000 830000B0 00014000 000140B0
      2 83868700 Read Write      83000200 83000218 00018000 00018018
      3 83868748 Read           83000400 83008788 0001C000 00024388
      Symbol Vector      83000400
32;L
Seq# LDRISD   Image Name           Base      End      Link      End
0032 83885500 RMS
      0 838855E0 Read Write      832B5800 832B5F40 00010000 00010740
      1 83885628 Read           Execute      8014E900 8014FAE0 00014000 000151E0
      2 83885670 Read           Execute      8098D100 80B9C8A0 00018000 002277A0
```

3	838856B8	Read	832B6000	832EC400	00228000	0025E400
4	83885700	Read Write	832EC400	832EFAE8	00260000	002636E8
5	83885748	Read Write	832EFC00	832EFC14	00264000	00264014
6	83885790	Read Write	832EFE00	832EFE50	00268000	00268050
9	83885868	Read Write	832F0000	832F0014	00274000	00274014
A	838858B0	Read Write	832F0200	832F0204	00278000	00278004
B	838858F8	Read Write	832F0400	832F3DC0	0027C000	0027F9C0

The following Alpha example shows the names, the starting and ending virtual addresses, and the sequence numbers for all the loaded executive images. Only one image, EXEC_INIT.EXE, was not split into image sections. For every image that was split into image sections, it also shows the name and the base and ending address of each section.

```
;L
Seq#  Image Name                      Base      End
0012  EXEC_INIT.EXE                   8080C000  80828000
0010  SYS$CPU_ROUTINES_0101.EXE
      Nonpaged read only              80038000  8003A200
      Nonpaged read/write             80420200  80420A00
      Initialization                  80808000  80808400
000E  ERRORLOG.EXE
      Nonpaged read only              8002E000  80036600
      Nonpaged read/write             8041BE00  80420200
      Initialization                  80804000  80804800
000C  SYSTEM_SYNCHRONIZATION.EXE
      Nonpaged read only              80024000  8002C800
      Nonpaged read/write             8041A000  8041BE00
      Initialization                  80800000  80800800
      .      .      .      .
      .      .      .      .
      .      .      .      .
0002  SYS$BASE_IMAGE
      Nonpaged read only              80002000  80009400
      Nonpaged read/write             80403000  80414C00
      Fixup                           80620000  80620600
      Symbol Vector                   8040B010  80414560
0000  SYS$PUBLIC_VECTORS.EXE
      Nonpaged read only              80000000  80001C00
      Nonpaged read/write             80400000  80403000
      Fixup                           8061E000  8061E200
      Symbol Vector                   80401BF0  80402ED0
```

The following Alpha example illustrates the use of the sequence number with the **;L** command to display information about one image. In this example, the sequence number C for the SYSTEM_SYNCHRONIZATION.EXE module is specified with the **;L** command. (It is not necessary to specify the leading zeros in the command.) The resulting display shows only the SYSTEM_SYNCHRONIZATION.EXE module (whose sequence number is 000C). The display includes the names of the image sections within the module and their base and ending addresses.

```
C;L
Seq#  Image Name                      Base      End
000C  SYSTEM_SYNCHRONIZATION.EXE
      Nonpaged read only              80024000  8002C800
      Nonpaged read/write             8041A000  8041BE00
      Initialization                  80800000  80800800
```

VAX example, showing the names and the starting and ending virtual addresses of the three executive images that are loaded in memory.

```
;L
PRIMITIVE_IO.EXE           800EAA00  800EBC00
SYSTEM_SYNCHRONIZATION.EXE 800EBC00  800ED400
SYSTEM_PRIMITIVES.EXE      800ED400  800F1000
```

;M—Set All Processes Writable

;M — Sets the address spaces of all processes to be writable or read-only by your DELTA process. This command can be used only with DELTA. Use of this command requires CMKRNL privilege. On Alpha, this command also sets writable the general purpose registers of other processes, if, after issuing the **;M** command, you specify another process with any command that takes the PID argument, such as the **/** command.

Synopsis

n ;M

Argument

n

Specifies your process privileges for reading and writing at other processes. If 0, your DELTA process can only read locations in other processes; if 1, your process can read or write any location in any process. If not specified, DELTA returns the current value of the M (modify) flag (0 or 1).

Description

The Set All Processes Writable command is useful for changing values in the running system.

Note

Use this activity very carefully during time sharing. It affects all processes on the system. For this reason, your process must have change-mode-to-kernel (CMKRNL) privilege to use this command. It is safest to use this command only on a standalone system.

;P—Proceed from Breakpoint

;P — Continues program execution following a breakpoint.

Synopsis

;P

Description

The Proceed from Breakpoint command continues program execution at the address contained in the PC of the program. Program execution continues until the next breakpoint or until program completion.

Note

If DELTA/XDELTA does not have write access to the target of a JSR instruction, you cannot use the **S** or **;P** command at the JSR instruction. First, you must use the **O** command; then you can use the **S** or **;P** command.

Example

The following examples illustrate the command on each OpenVMS platform.

I64 example:

```
G0BF5D60,0;X      ❶
G0BF5D60
X0+60;B
  1 00000060      ❷
;P                ❸
Brk 1 at X0+00000060 on CPU 0  ❹
X0+00000060!          alloc    r53 = ar.pfs, 18, 08, 00 (New IPL = 0) -
                                (New mode = USER)
```

- ❶ Set the base register.
- ❷ Set a breakpoint at address X0+00000060 using **;B**.
- ❸ Program execution is continued using the **;P** command.
- ❹ Program execution halts at breakpoint 1. DELTA/XDELTA displays the breakpoint message (the breakpoint number and the address) and the instruction.

Alpha example:

```
;B
  1 00030010      ❶
;P                ❷
Brk 1 at 00030010
00030010!          STQ          R26, #X0008 (SP)  ❸
```

- ❶ Current breakpoints are displayed using **;B** (breakpoint 1 at address 30010).
- ❷ Program execution is continued using the **;P** command.
- ❸ Program execution halts at breakpoint 1. DELTA/XDELTA displays the breakpoint message (the breakpoint number and the address) and the instruction.

VAX example:

```
;B
2 00000699      ❶
;P                ❷
2 BRK AT 00000699
00000699/BSBB    000006A2  ❸
```

- ❶ Current breakpoints are displayed using **;B** (breakpoint 2 at address 699).
- ❷ Program execution is continued using the **;P** command.
- ❸ Program execution halts at breakpoint 2. DELTA/XDELTA displays the breakpoint message (the breakpoint number and the address) and the instruction.

;Q—Validate Queue (I64 and Alpha Only)

;Q — Analyzes absolute and self-relative longword queues and displays the results of the analysis.

Synopsis

queue_header_address [queue_type];Q

Argument

queue_header_address

The queue header must be at least longword aligned.

[queue_type]

A queue type of zero (the default) represents an absolute queue. A queue type of 1 indicates a self-relative queue.

Description

The validate queue function is similar to the one in the OpenVMS System Dump Analyzer Utility. It can analyze both absolute and self-relative longword queues and display the results of the analysis. This function identifies various problems in the queue headers and invalid backward links for queue entries and evaluates the readability of both. For valid queues, it tells you the total number of entries. For invalid queues, it tells you the queue entry number and the address that is invalid and why.

Example

```
FFFFFFFF8000F00D;Q      !Absolute at GF00D
GF00D,0;Q               !Absolute at GF00D
GF00,1;Q                !Self-relative at GF00
```

;T—Display Interrupt Stack Frame on XDELTA (I64 Only)

;T — XDELTA only; displays contents of an interrupt stack frame.

Synopsis

addr_exp ;T

Arguments

addr-exp

The address of the stack frame. This is an optional argument. If not specified, the ;T command without any argument displays the interrupt stack frame with which XDELTA was invoked.

Description

On I64 systems, the XDELTA ;T command displays the contents of an interrupt stack frame.

Example

In the following example, the **;T** command displays the machine state at the time of the exception.

```
;T
* Exception Frame Display: *
Exception taken at IP FFFFFFFF.8063D830, slot 01
from Kernel mode Exception Frame at FFFFFFFF.89DA1CE0
Trap Type    00000080 (External Interrupt)
IVT Offset   00003000 (External Interrupt)
External Interrupt Vector 00000000
* = Value read directly from the register rather than the frame

Control Registers:
CR0  Default Control Register (DCR)          00000000.00007F00
CR1  Interval Timer Match Register (ITM)      * 0000C6F7.31F82D5B
CR2  Interruption Vector Address (IVA)        * FFFFFFFF.801D0000
CR8  Page Table Address (PTA)                * FFFFFFFF.7FFF013D
CR16 Processor Status Register (IPSR)         00001210.0A026010
CR17 Interrupt Status Register (ISR)          00000200.00000000
CR19 Instruction Pointer (IIP)                FFFFFFFF.8063D830
CR20 Faulting Address (IFA)                  FFFFFFFF.88580078
CR21 TLB Insertion Register (ITIR)           00000000.00000334
CR22 Instruction Previous Address (IIPA)       FFFFFFFF.8063D830
CR23 Function State (IFS)                    80000000.00000FA7
CR24 Instruction immediate (IIM)              FFFFFFFF.88580078
CR25 VHPT Hash Address (IHA)                 FFFFFFFF.7FFF5860
CR64 Local Interrupt ID (LID)                * 00000000.00000000
CR66 Task Priority Register (TPR)             * 00000000.00010000
CR68 External Interrupt Req Reg 0 (IRR0)      * 00000000.00000000
CR69 External Interrupt Req Reg 1 (IRR1)      * 00000000.00000000
CR70 External Interrupt Req Reg 2 (IRR2)      * 00000000.00000000
CR71 External Interrupt Req Reg 3 (IRR3)      * 00020000.00000000
CR72 Interval Time Vector (ITV)              * 00000000.000000F1
CR73 Performance Monitoring Vector (PMV)      * 00000000.000000FB
CR74 Corrected Machinecheck Vector (CMCV)     * 00000000.00010000
CR80 Local Redirection Register 0 (LRR0)      * 00000000.00010000
CR81 Local Redirection Register 1 (LRR1)      * 00000000.00010000

Application Registers:
AR0  Kernel Register (KR0)                   * 00000000.20570000
AR1  Kernel Register (KR1)                   * 00000000.60000000
AR2  Kernel Register (KR2)                   * 00000000.00000000
AR3  Kernel Register (KR3)                   * 00000000.00000000
AR4  Kernel Register (KR4)                   * 00000000.00000000
AR5  Kernel Register (KR5)                   * 0000C6F7.31F82D5B
AR6  Kernel Register (KR6)                   * FFFFFFFF.84C3E000
AR7  Kernel Register (KR7)                   * FFFFFFFF.89D4B000
AR16 Register Stack Config Reg (RSC)          00000000.00000000
AR17 Backing Store Pointer (BSP)              FFFFFF802.A3EAC300
AR18 Backing Store for Mem Store (BSPSTORE)   FFFFFF802.A3EAC300
AR19 RSE NaT Collection Register (RNAT)       00000000.00000000
AR32 Compare/Exchange Comp Value Reg (CCV)    FFFFFFFF.84132680
AR36 User NaT Collection Register (UNAT)      00000000.00000000
AR40 Floating-point Status Reg (FPSR)         0009804C.0270033F
AR44 Interval Time Counter (ITC)              * 0000C6FB.A91997B5
AR64 Previous Function State (PFS)            00000000.00000FA7
AR65 Loop Count Register (LC)                 00000000.00000000
AR66 Epilog Count Register (EC)               00000000.00000000
```

Processor Status Register (IPSR):

AC = 0 MFL= 1 MFH= 0 IC = 1 I = 1 DT = 1
 DFL= 0 DFH= 0 RT = 1 CPL= 0 IT = 1 MC = 0 RI = 1

Interrupt Status Register (ISR):

Code 00000000 X = 0 W = 0 R = 0 NA = 0 SP = 0
 RS = 0 IR = 0 NI = 0 SO = 0 EI = 1 ED = 0

Branch Registers:

B0 FFFFFFFF.8063C570
 B1 00000000.00000000
 B2 00000000.00000000
 B3 00000000.00000000
 B4 00000000.00000000
 B5 00000000.00000000
 B6 FFFFFFFF.80001580
 B7 FFFFFFFF.806F4D30

Region Registers:

RR0 * 00000000.00000035
 RR1 * 00000000.00000030
 RR2 * 00000000.00000030
 RR3 * 00000000.00000030
 RR4 * 00000000.00000030
 RR5 * 00000000.00000030
 RR6 * 00000000.00000030
 RR7 * 00000000.00000335

Floating Point Registers:

F6 00000000.0001003E.00000000.0000FCBE
 F7 00000000.0001003E.00000000.00000040
 F8 00000000.0001003E.00000000.003F2F80
 F9 00000000.00010003.80000000.00000000
 F10 00000000.0000FFFB.80000000.00000000
 F11 00000000.0000FFFB.80000000.00000000

FPSR 0009804C.0270033F

Miscellaneous Registers:

Processor Identifier (CPUID 0,1) GenuineIntel
 (CPUID 3) 00000000.1F010504
 Interrupt Priority Level (IPL) 00000003
 Stack Align 000002D0
 NaT Mask 001C
 PPrev Mode 00
 Previous Stack 00
 Interrupt Depth 00
 Preds 00000000.FF65CCA3
 Nats 00000000.00000000
 Context 00000000.FF61CEA3

General Registers:

R0 00000000.00000000	GP FFFFFFFF.8442E200	R2 FFFFFFFF.84132688
R3 FFFFFFFF.8442E200	R4 FFFFFFFF.8442E200	R5 00000000.00000001
R6 FFFFFFFF.84C3E000	R7 00000000.00000000	R8 00000000.00000003
R9 00000000.00000009	R10 00000000.00000008	R11 00000000.00000000
SP FFFFFFFF.89DA0D18	TP 00000000.00000000	R14 00000000.00000001
R15 FFFFFFFF.8401BD90	R16 FFFFFFFF.84017508	R17 FFFFFFFF.84009E98
R18 FFFFFFFF.84C3F274	R19 00000000.00000000	R20 FFFFFFFF.84009E00
R21 FFFFFFFF.84132627	R22 FFFFFFFF.84C3E01C	R23 00000000.0000000F
R24 00000000.00011F90	R25 00000000.00000003	R26 00000000.00000000
R27 FFFFFFFF.84132668	R28 FFFFFFFF.8416D7C8	R29 FFFFFFFF.89DA1FB0
R30 00000000.7FF2E318	R31 00000000.00000000	

Interrupted Frame RSE Backing Store , Size = 39 registers

FFFFF802.A3EAC300: FFFFFFFF.84C3E080 (R32)
 FFFFF802.A3EAC308: E0000000.00000000 (R33)
 FFFFF802.A3EAC310: FFFFFFFF.84132628 (R34)
 FFFFF802.A3EAC318: FFFFFFFF.88598080 (R35)
 FFFFF802.A3EAC320: 00000000.00000001 (R36)
 FFFFF802.A3EAC328: FFFFFFFF.806029A0 (R37)
 FFFFF802.A3EAC330: 00000000.FF65C563 (R38)
 FFFFF802.A3EAC338: 00000000.00000000 (R39)
 FFFFF802.A3EAC340: FFFFFFFF.8442E200 (R40)
 FFFFF802.A3EAC348: FFFFFFFF.806029C0 (R41)
 FFFFF802.A3EAC350: FFFFFFFF.8442E200 (R42)

```
FFFFF802.A3EAC358: FFFFFFFF.88598080 (R43)
FFFFF802.A3EAC360: FFFFFFFF.84191000 (R44)
FFFFF802.A3EAC368: 00000000.00000009 (R45)
FFFFF802.A3EAC370: FFFFFFFF.8416D7C8 (R46)
FFFFF802.A3EAC378: FFFFFFFF.8442E200 (R47)
FFFFF802.A3EAC380: 00000000.00000000 (R48)
FFFFF802.A3EAC388: FFFFFFFF.84132668 (R49)
FFFFF802.A3EAC390: 00000000.00000008 (R50)
FFFFF802.A3EAC398: 00000000.00000000 (R51)
FFFFF802.A3EAC3A0: 00000000.7FF2E318 (R52)
FFFFF802.A3EAC3A8: 00000000.00000000 (R53)
FFFFF802.A3EAC3B0: 00000000.00000FB2 (R54)
FFFFF802.A3EAC3B8: FFFFFFFF.84132627 (R55)
FFFFF802.A3EAC3C0: 00000000.00000003 (R56)
FFFFF802.A3EAC3C8: FFFFFFFF.89DA1FB0 (R57)
FFFFF802.A3EAC3D0: FFFFFFFF.801D9BD0 (R58)
FFFFF802.A3EAC3D8: FFFFFFFF.806029C0 (R59)
FFFFF802.A3EAC3E0: 00000000.00000001 (R60)
FFFFF802.A3EAC3E8: FFFFFFFF.89DA1FB0 (R61)
FFFFF802.A3EAC3F0: FFFFFFFF.8442E200 (R62)
FFFFF802.A3EAC400: 00000000.00000003 (R63)
FFFFF802.A3EAC408: FFFFFFFF.8063C570 (R64)
FFFFF802.A3EAC410: 00000000.00000008 (R65)
FFFFF802.A3EAC418: 00000000.00000008 (R66)
FFFFF802.A3EAC420: FFFFFFFF.84132668 (R67)
FFFFF802.A3EAC428: FFFFFFFF.8416D7C8 (R68)
FFFFF802.A3EAC430: 00000000.00000008 (R69)
FFFFF802.A3EAC438: FFFFFFFF.8416DAA0 (R70)
```

;W—List Name and Location of a Single Loaded Image (I64 and Alpha Only)

;W — Lists information about an image that contains the address you supplied.

Synopsis

address-expression **;W**

sequence number offset **;W**

Arguments

address-expression

An address contained within an executive image or a user image.

sequence number

The identifier assigned to an executive image.

offset

The distance from the base address of the image.

Description

The **;W** command is used for debugging code that resides in system or user space. You can use this command with XDELTA for debugging an executive image. You can also use this command with DELTA.

To examine the executive image list, you must be running in executive mode or your process must have change-mode-to-executive (CMEXEC) privilege.

This command can be used in two ways. In the first way, if you supply an address that you are trying to locate, the command lists the name of the executive or user image that contains the address, its base and ending addresses, and the offset of the address from the base of the image. For any executive image that has been sliced, it also displays its sequence number. The offset can be used with the link map of the image to locate the actual code or data. This offset is saved in the value Q.

In the second way, if you supply the sequence number of a sliced executive image and an offset, the command computes and displays the address in memory. The address is saved in the value Q.

Examples

The first form of the command takes a system space address as a parameter and attempts to locate that address within the loaded executive images. This command works for both sliced and unsliced loadable executive images. The output is very similar to **;L**, except the offset is displayed for you, as shown in the following example:

```
80026530;W
Seq#  Image Name                               Base      End      Image Offset
000C  SYSTEM_SYNCHRONIZATION.EXE
      Nonpaged read only                       80024000  8002C800  00002530
```

The second form of the command takes a loadable executive image sequence number and an image offset from the map file as parameters. The output, again, is very similar to **;L**, except that the system space address that corresponds to the image offset is displayed, as shown in the following example:

```
C,2530;W
Seq#  Image Name                               Base      End      Address
000C  SYSTEM_SYNCHRONIZATION.EXE
      Nonpaged read only                       80024000  8002C800  80026530
```

;X—Load Base Register

;X — Places an address in a base register.

Synopsis

address-expression n [y] **;X**

Arguments

address-expression

The address to place in the base register.

n

The number of the base register.

[y]

On I64 and Alpha, a parameter for modifying the default offset of 10000_{16} . The valid range is 1 to FFFFFFFF.

Description

On I64 and Alpha, to place an address in a base register, enter:

- An expression followed by a comma (,), or
- A number from 0 to 15_{10} , or optionally, a number from 1 to FFFFFFFF, a semicolon (;)
- The letter X.

On VAX, to place an address in a base register, enter an expression followed by a comma (,), a number from 0 to F_{16} , a semicolon (;), and the letter X.

On all platforms, DELTA/XDELTA places the address in the base register. DELTA/XDELTA confirms that the base register is set by displaying the value deposited in the base register.

For example, the following command places the address 402 in base register 0. DELTA/XDELTA then displays the value in the base register to verify it.

```
402,0;X Return  
00000402
```

Whenever DELTA/XDELTA displays an address, it will display a relative address if the address falls within the computer's valid range for an offset from a base register. The relative address consists of the base register identifier (Xn), followed by an offset. The offset gives the address location in relation to the address stored in the base register.

For example, if base register 2 contains 800D046A, the address that would be displayed is X2+C4, the base register identifier followed by the offset.

Relative addresses are computed for both opened and displayed locations and for addresses that are instruction operands.

If you have defined several base registers, the offset will be relative to the closest base register. If an address falls outside the valid range, it is displayed as a hexadecimal value.

On I64, the default offset is 10000_{16} , which can be modified.

On Alpha, the default offset is 10000_{16} , which can be modified.

On VAX, the default offset is 2000_{16} bytes. It cannot be modified.

Examples

The following examples illustrate the command on each platform.

I64 example:

```

G0BF5D60,0,200;X 1
;X
0 80BF5D60 00000200
4 8392A900
5 83009DE0
13 FFFFF802 06C00000
14 830937F015 83093700
G0BF5D60,0,200;X ❶
;X
0 80BF5D60 00000200
4 8392A900
5 83009DE0
13 FFFFF802 06C00000
14 830937F0
15 83093700 ❷

```

- ❶ Set the base register, with an offset.
- ❷ The `;X` command with no arguments displays the existing base register values. Offset values are also displayed, if their value is other than the default offset.

Alpha example:

```

30000,0;X ❶
00030000
30070,1,200;X ❷
00030070
;X ❸
0 00030000
1 00030070 00000200
S ❹
X0+00000004! BIS R31,R31,R18
x1+10! STQ FP,#X0020(SP) ❺

```

- ❶ The base address of the program (determined from the map file) is virtual address 30000. The base address is stored in base register 0 with `;X`, using the default offset. DELTA/XDELTA displays the value in base register 0 just loaded, 30000.
- ❷ The address of a subroutine, 30070, is stored in base register 1, specifying a new offset of 200 (to override the default value of 100000). Note that this command could also have been expressed as "x0+70,1,200;X". DELTA/XDELTA displays the value in base register 1 just loaded, 30070.
- ❸ The `;X` command is used to display the current base registers. Note that for those not using the default offset, the offset is also displayed.
- ❹ The `S` command is used to execute the first instruction in the main routine. DELTA/XDELTA displays the address of the next instruction, 30004, as x0+00000004 and then displays the instruction at that address.
- ❺ The instruction at offset 10 from base register 1 is displayed in instruction mode using the `!` command.

VAX example:

```

00000664/CLRQ -(SP)
200,1;X ❶
00000200 ❷

X1 490!
CMPL R0,#000009A8 ❸

```



```
X1 499!  
BSBB      X1+04A2
```

④

- ❶ The base address of the program (determined from the map file) is virtual address 200. The base address is stored in base register 1 with ;X.
- ❷ DELTA/XDELTA displays the value in base register 1 just loaded, 200.
- ❸ The instruction at offset 490 is displayed in instruction mode using the ! command. The address reference is X1+490 (the + sign is implied when not specified). DELTA/XDELTA displays the instruction at address X1+490.
- ❹ The instruction at offset 499 is displayed. This instruction is a branch instruction. DELTA/XDELTA displays the address of the branch in offset notation.

O—Step Instruction over Subroutine

O — Executes one instruction, steps over a subroutine by executing it, and displays the instruction to which the subroutine returns control.

Synopsis

o

Description

The Step Instruction over Subroutine command executes one instruction and displays the address of the next instruction. If the instruction executed is a call to a subroutine, the subroutine is executed and the next instruction displayed is the instruction to which the subroutine returns control. Use this command to do single-step instruction execution excluding single-stepping of instructions within subroutines. If you want to do single-step execution of all instructions, including those in subroutines, use the S command.

This command sets a flag to change the display mode to instruction mode. Any subsequent Close Current Location, Open Next (LINEFEED) commands and Open and Display Indirect Location (TAB) commands will display locations as machine instructions. The Open Location and Display Contents (/) command clears the flag, causing the display mode to revert to longword, hexadecimal mode.

On I64, the subroutine call instruction is br.call.

On Alpha, the subroutine call instructions are JSR and BSR.

On VAX, the subroutine call instructions are BSBB, BSBW, JSB, CALLG, and CALLS.

On all platforms, if you set a breakpoint in the subroutine and enter the O command, program execution breaks at the subroutine breakpoint. When you enter a Proceed command (;P), and program execution returns to the instruction to which the subroutine returns control, a message is displayed, as follows:

On I64 and Alpha systems:

```
Step-over at nnnnnnnn  
instruction
```

On VAX systems:

```
STEPOVER BRK AT nnnnnnnn  
instruction
```

The message informs you that program execution has returned from a subroutine.

If you are using XDELTA in a multiprocessor environment, the CPU ID of the processor where the break was taken is also displayed.

On I64 and Alpha, the CPU ID is displayed as a decimal number with no leading zeros.

On VAX, the CPU ID is displayed as a 2-digit hexadecimal number.

Examples

The following examples illustrate the command on each OpenVMS platform.

I64 example:

```
X0+00000380! mov      r7 = r23S      ❶
X0+00000381! nop.f      000000S
X0+00000382! br.call.sptk.many b0 = 0000E30 O ❷
X0+00000390! mov      r29 = r41S      ❸
X0+00000391! mov      r1 = r40S
```

- ❶ Program execution is currently at Base Register X0, plus offset 00000380. The instruction at X0+380 is a Move Application Register instruction. Step execution is then continued using the **S** command.
- ❷ Program execution is stopped at Base Register X0, plus offset 00000381. The instruction at offset 00000381 is a No Operation instruction. Step execution is then continued using the **S** command.
- ❸ Program execution is stopped at offset 00000382. The instruction at 00000382 is a "br.call" instruction. Execution is continued using the **O** command, thus skipping the routine(s) being called.

Alpha example:

```
30040;B      ❶
30070;B      ❷
;B
1 00030040
2 00030070
;P      ❸
Brk 1 at 00030040
00030040! LDA R27,#XFFC8(R2) O ❹
00030044! BSR R26,#X00000A O ❺
Brk 2 at 00030070
00030070! LDA SP,#XFFD0(SP) ;P ❻
Step-over at 30048
00030048! LDQ R26,#X0048(R2) S ❼
0003004C! BIS R31,R31,R17 ❼
```

- ❶ A simple breakpoint is set in the main routine at address 30040, just prior to the subroutine call.
- ❷ A simple breakpoint is set in the subroutine at address 30070. The breakpoints are displayed using the **;B** command.
- ❸ Program execution continues using **;P**.
- ❹ Program execution stops at breakpoint 1. DELTA/XDELTA displays the breakpoint message and the instruction at the breakpoint address. The **O** command is used to single-step (DELTA/XDELTA recognizes that this is not a call instruction and turns it into a single-step instead).
- ❺ The next instruction is a subroutine call (BSR). The subroutine is stepped over using the **O** command.
- ❻ Ordinarily, the step-over would continue execution at the instruction following the subroutine call. However, in this case, program execution stops at breakpoint 2 inside the subroutine at address 30070. Program execution continues with the **;P** command.

- ⑦ The subroutine completes execution. DELTA/XDELTA displays a step-over break message that indicates that the **O** command has been completed, returning control at address 30048.

VAX example:

```

6D5;B                                ❶
;P                                  ❷
1 BRK AT 000006D5
000006D5/CALLS      #0C,@#7FFEDE00
;P                                  ❸
        PID= 0006      LOGINTIME= 12:50:29.45
2 BRK AT 00000699
00000699/BSBB      000006A2
;P                                  ❹
1 BRK AT 000006D5
000006D5/CALLS      #0C,@#7FFEDE00
;P                                  ❺
        PID= 0007      LOGINTIME= 12:50:37.08
2 BRK AT 00000699
00000699/BSBB      000006A2
O                                  ❻
1 BRK AT 000006D5
000006D5/CALLS      #0C,@#7FFEDE00
;P                                  ❼
        PID= 0008      LOGINTIME= 12:50:45.64
STEPOVER BRK AT 0000069B
0000069B/BRB      X1+047A          ❽

```

- ❶ One breakpoint has been set at address 699 in the main routine. A simple breakpoint is set at 6D5 using **;B**. This breakpoint is in a subroutine.
- ❷ Program execution continues using **;P**.
- ❸ Program execution stops at breakpoint 1, which is in the subroutine. DELTA/XDELTA displays the breakpoint message and the instruction at the new breakpoint. Program execution continues using **;P**.
- ❹ The subroutine completes and displays some output. Program execution continues until breakpoint 2. DELTA/XDELTA displays the breakpoint message and the breakpoint 2 instruction. Program execution continues with the **;P** command.
- ❺ Program execution stops at breakpoint 1. Program execution continues with the **;P** command. The subroutine completes execution and displays the output.
- ❻ Program execution stops at breakpoint 2. The subroutine is stepped over to the next instruction using the **O** command.
- ❼ Program execution stops at breakpoint 1 in the subroutine. Program execution continues using the **;P** command.
- ❽ The subroutine completes execution and displays output. DELTA/XDELTA displays a STEPOVER break message that states the **O** command has been completed, returning control at address 69B.

S—Step Instruction

S — Executes one instruction and displays the next. If the executed instruction is a call to a subroutine, it steps into the subroutine and displays the next instruction to be executed in the subroutine.

Synopsis

S

Description

The Step Instruction command executes one instruction and displays the next instruction (in instruction mode) and its address. Use this command to single-step instructions, including single-stepping all instructions in subroutines. If you want to exclude single-stepping instructions in subroutines, use the **O** command.

The instruction displayed has not yet been executed. This command sets a flag to change the display mode to instruction mode. Any subsequent Close Current Location, Open Next (LINEFEED) commands and Open and Display Indirect Location (TAB) commands will display locations as machine instructions. The Open Location and Display Contents (/) command clears the flag, causing the display mode to revert to longword, hexadecimal mode.

On I64, if the instruction is a br.call instruction, Step moves to the subroutine called by these instructions and displays the first instruction within the subroutine.

On Alpha, if the instruction being executed is a JSR or BSR instruction, Step moves to the subroutine called by these instructions and displays the first instruction within the subroutine.

Note

If DELTA/XDELTA does not have write access to the target of a JSR instruction, you cannot use the **S** or **;P** command at the JSR instruction. First, you must use the **O** command; then you can use the **S** or **;P** command.

On VAX, if the instruction being executed is a BSBB, BSBW, JSB, CALLG, or CALLS instruction, Step moves to the subroutine called by these instructions and displays the first instruction within the subroutine.

On Alpha and VAX, in general, you move to the instruction where you want to start single-step execution by placing a breakpoint at that instruction and typing **;P**. Then press **S** to execute the first instruction and display the next one.

Examples

I64 example:

```
X0+00000061!      mov      r52 = b0 S      ❶
X0+00000062!      mov      r40 = r1 S      ❷
X0+00000070!      st8       [r12] = r0 ;;  ❸
```

- ❶ Program execution has been stopped at base register X0 plus offset 00000061. The instruction at this address is a Move Branch Register. Step execution is continued using the **S** command.
- ❷ Program execution is now stopped at base register X0 plus offset 00000062. The instruction at this address is a Move Application Register. Step execution is then continued using the **S** command.
- ❸ The instruction at offset 00000070 is displayed.

Alpha example:

```
0003003C!      BLBC      R0, #X000006 S      ❶
00030040!      LDQ       R16, #X0050 (R2) S    ❷
00030044!      BIS       R31, R31, R17 S      ❸
00030048!      LDQ       R26, #X0040 (R2)
```

- ❶ Step program execution is started at address 3003C. The instruction at 3003C is a conditional branch instruction. Step execution is continued using the **S** command.
- ❷ Because the condition (BLBC) was not met, program execution continued at the next instruction at address 30040. Had the branch been taken, execution would have continued at address 30058. The second **S** command causes the LDQ instruction to be executed.
- ❸ The instruction at address 30044 is displayed. The **S** command is executed.

OpenVMS VAX example:

00000690/CMPL	R0, #000009A8	S	❶
00000697/BEQL	0000069D	S	❷
00000699/BSBB	000006A2	S	❸
000006A2/PUSHL	R2		❹

- ❶ Step program execution is started at address 690. The instruction at 690 is executed and the next instruction is displayed. Step execution is continued using **S**.
- ❷ At address 697, there is a branch instruction to the instruction at address 69D. However, because the condition (BEQL) is not met, program execution continues at the next instruction. The next **S** command is executed.
- ❸ At address 699, there is a branch instruction to the instruction at address 6A2, a subroutine. The next **S** command is executed.
- ❹ Program execution moves to the subroutine.

Appendix A. Sample DELTA Debug Session on I64

This appendix gives an example of how you would use DELTA to debug a program executing on OpenVMS I64. The example C program named LOG uses the system service `SYS$GETJPIW` to obtain the PID, process name, and login time of each process. To run the example program without error, you need WORLD privilege.

Note

Although this example debugging session demonstrates using the DELTA debugger, you could use most of the commands in the example in an XDELTA debugging session as well.

This appendix consists of two sections:

- Section A.1 shows the source and machine listing files for the example C program.
- Section A.2 shows the example DELTA debugging session and explains the various commands used and information provided.

A.1. Listing File for C Example Program

This section shows the listing file for the C program, LOG, in two parts:

- Section A.1.1—C source code
- Section A.1.2—Machine code

See Section A.2 for the corresponding sample debugging session using this program.

A.1.1. Source Listing for I64 Debugging Example

Example A.1 shows the C source code for the example file, LOG.

Example A.1. Listing File for LOG: C Source Code

```
1  #include <descrip.h>
973 #include <jpidef.h>
1378 #include <ssdef.h>
5641 #include <starlet.h>
9024 #include <stdio.h>
0606 #include <stdlib.h>
2406
22407 void print_line(unsigned long int pid,
22408     char *process_name,
22409     unsigned long int *time_buffer);
22410
22411 typedef struct {
22412     unsigned short int il3_buffer_len;
22413     unsigned short int il3_item_code;
22414     void *il3_buffer_ptr;
22415     unsigned short int *il3_return_len_ptr;
22416 } item_list_3;
22417
```

```
22418 #define NUL '\0'
22419
22420 main(void)
22421 {
22422     static char name_buf[16];
22423     static unsigned long int pid, time_buf[2];
22424     static unsigned short int name_len;
22425
22426     unsigned short int pidadr[2] = {-1, -1};
22427     unsigned long int ss_sts;
22428     item_list_3 jpi_itmlst[] = {
22429 /* Get login time */
22430 { sizeof(time_buf),
22431  JPI$_LOGINTIM,
22432  (void *) time_buf,
22433  NULL
22434 },
22435
22436 /* Get process name */
22437 { sizeof(name_buf) - 1,
22438  JPI$_PRCNAM,
22439  (void *) name_buf,
22440  &name_len
22441 },
22442
22443 /* Get process ID (PID) */
22444 { sizeof(pid),
22445  JPI$_PID,
22446  (void *) &pid,
22447  NULL
22448 },
22449
22450 /* End of list */
22451 { 0,
22452  0,
22453  NULL,
22454  NULL
22455 }
22456 };
22457
22458 /*
22459  * While there's more GETJPI information to process and a
22460  * catastrophic error has not occurred then
22461  *   If GETJPI was successful then
22462  *     NUL terminate the process name string and
22463  *   print the information returned by GETJPI
22464  */
22465
22466     while((ss_sts = sys$getjpiw(0, &pidadr, 0, &jpi_itmlst, 0, 0,
22467 0)) != SS$_NOMOREPROC &&
22468 ss_sts != SS$_BADPARAM &&
22469 ss_sts != SS$_ACCVIO) {
22470         if (ss_sts == SS$_NORMAL) {
22471             *(name_buf + name_len) = NUL;
22472             print_line(pid, name_buf, time_buf);
22473         }
22474     }
```



```
22475     exit(EXIT_SUCCESS);
22476 }
22477
22478 void print_line(unsigned long int pid,
22479     char *process_name
22480     unsigned long int *time_buffer)
22481 {
22482     static char ascii_time[12];
22483
22484     struct dsc$descriptor_s time_dsc = {
22485         sizeof(ascii_time) - 1,
22486         DSC$K_DTYPE_T,
22487         DSC$K_CLASS_S,
22488         ascii_time
22489         1
22490     unsigned short int time_len;
22491
22492 /*
22493 Convert the logged in time to ASCII and NUL terminate it
22494 */
22495     sys$asctim(&time_len, &time_dsc, time_buffer, 1);
22496     *(ascii_time + time_len) = NUL;
22497
22498 /*
22499 Output the PID, process name and logged in time
22500 */
22501     printf("\n\tPID= %08.8X\t\tPRCNAM= %s\tLOGINTIM= %s",
22502         pid,
22503         process_name,
22504         ascii_time);
22505
22506     return;
22507 }
```

A.1.2. Machine Code Listing for I64 Debugging Example

Example A.2 through Example A.4 show machine code listings for the procedures in the example program, LOG.

Example A.2. Listing File for LOG: Machine Code _MAIN Procedure

```
.psect $CODE$, CON, LCL, SHR, EXE, NOWRT, NOVEC, NOSHORT
.proc    __MAIN
        .align 32
.global  __MAIN
.personality DECC$$SHELL_HANDLER
.handlerdata
__MAIN:    // 02242
        { .mii 002C00F2EB40      0000      alloc    r45 = rspfs, 6, 9, 8, 0
010800C00080      0001      mov      r2 = sp // r2 = r12
0120000A0380      0002      mov      r14 = 80 ;;
        }
        { .mmi 010028E183C0      0010      sub      r15 = sp, r14 ;; // r15 =
r12, r14
0080C0F00380      0011      ld8      r14 = [r15]
010800F00300      0012      mov      sp = r15 ;; // r12 = r15
        }
        { .mii 000008000000      0020      nop.m    0
```

```

000188000B00      0021      mov      r44 = rp    // r44 = br0
010800100B80      0022      mov      r46 = gp ;; // r46 = r1
    }
:
    { .mii 010802E00040      0100      mov      gp = r46    // r1 = r46
00015405A000      0101      mov.i    rspfs = r45
000E00158000      0102      mov      rp = r44 ;; // br0 = r44
    }
    { .mbb 010800CA0300      0110      adds     sp = 80, sp // r12 = 80, r12
000108001100      0111      br.ret.sptk.many rp // br0
004000000000      0112      nop.b    0 ;;
    }
    .endp    __MAINRoutine Size: 288 bytes,      Routine Base: $CODE$ + 0000

```

Example A.3. Listing File for LOG: Machine Code MAIN Procedure

```

.proc    MAIN
.align 32
.global  MAIN
MAIN:    // 022420
    { .mii
002C00A22A00      0120      alloc    r40 = rspfs, 0, 10, 7, 0
010800C00080      0121      mov      r2 = sp    // r2 = r12
012000080380      0122      mov      r14 = 64 ;;
    }
    { .mmi
010028E183C0      0130      sub      r15 = sp, r14 ;; // r5 = r12, r14
0080C0F00380      0131      ld8      r14 = [r15]
010800F00300      0132      mov      sp = r15 ;; // r12 = r15
    }
    { .mii
000008000000      0140      nop.m    0
0001880009C0      0141      mov      r39 = rp    // r39 = br0
010800100A40      0142      mov      r41 = gp ;; // r41 = r1
    }
    .
    .
    .
    { .mbb
01C4321401C0      0280      cmp4.eq pr7, pr6 = ss_sts, r33 // pr7, pr6 =
    r32, r33
008600018007      0281      (pr7)   br.cond.dpnt.many L$12
004000000000      0282      nop.b    0 ;;
    }
    .
    .
    .
    { .mib
0080C2B00AC0      0320      ld8.mov out1 = [r43], name_buf
012000100B00      0321      add      out2 = @gprel(time_buf), gp // r44 =
    @gprel(time_buf), r1
00A000001000      0322      br.call.sptk.many rp = PRINT_LINE ;; // br0 =
    PRINT_LINE
    }
    { .bbb
0091FFFDD000      0330      br.sptk.many L$10    // 022473
004000000000      0331      nop.b    000400000000      0332      nop.b    0 ;;
    }

```

```

.
.
.
{ .mii
000008000000    0370    nop.m    0
000E0014E000    0371    mov      rp = r39      // br0 = r39
010800C80300    0372    adds     sp = 64, sp ;;    // r12 = 64, r12
}
{ .bbb
000108001100    0380    br.ret.sptk.many rp    // br0
004000000000    0381    nop.b    0
004000000000    0382    nop.b    0 ;;
}
.endp    MAIN
Routine Size: 624 bytes,    Routine Base: $CODE$ + 0120

```

Example A.4. Listing File for LOG: Machine Code PRINT_LINE Procedure

```

.proc    PRINT_LINE
.align 32
.global  PRINT_LINE
PRINT_LINE:    // 022478
{ .mii
002C0091A9C0    0390    alloc    r39 = rspfs, 3, 6, 4, 0
010800C00080    0391    mov      r2 = sp    // r2 = r12
012000020380    0392    mov      r14 = 16 ;;
}
{ .mmi
010028E183C0    03A0    sub      r15 = sp, r14 ;;    // r15 = r12, r14
0080C0F00380    03A1    ld8      r14 = [r15]
010800F00300    03A2    mov      sp = r15 ;;    // r12 = r15
}
.
.
.
{ .mmi
012000100B00    0490    add      out3 = @ltoffx(ascii_time), gp ;; //r44
= @ltoffx(ascii_time), r1
0080C2C00B00    0491    ld8.mov  out3 = [r44], ascii_time
012000008640    0492    mov      ai = 4 ;;    // r25 = 4
}
{ .bbb
00A000001000    04A0    br.call.sptk.many rp = DECC$TXPRINTF // br0 =
DECC$TXPRINTF
004000000000    04A1    nop.b    0
004000000000    04A2    nop.b    0 ;;
}
{ .mii
010802800040    04B0    mov      gp = r40    // r1 = r40
00015404E000    04B1    mov.i    rspfs = r39    // 022506
000E0014C000    04B2    mov      rp = r38 ;;    // br0 = r38
}
{ .mbb
010800C20300    04C0    adds     sp = 16, sp // r12 = 16, r12
000108001100    04C1    br.ret.sptk.many rp // br0
004000000000    04C2    nop.b    0 ;;
}
.endp    PRINT_LINE

```

Routine Size: 320 bytes, Routine Base: \$CODE\$ + 0390

The .MAP file for the sample program is shown in Example A.5. Only the Program Section Synopsis with the psect, module, base address, end address, and length are listed.

Example A.5. .MAP File for the Sample Program

+-----+				
! Program Section Synopsis !				
+-----+				
Psect Name	Module/Image	Base	End	Length
-----	-----	----	----	-----
\$BSS\$		00010000	0001001F	00000020 (32.)
	LOG	00010000	0001001F	00000020 (32.)
\$CODE\$		00020000	0002061F	00000620 (1568.)
	LOG	00020000	000204CF	000004D0 (1232.)
	<Linker>	000204D0	0002061F	00000150 (336.)
\$LITERAL\$		00030000	00030058	00000059 (89.)
	LOG	00030000	00030058	00000059 (89.)
\$READONLY\$		00030060	00030087	00000028 (40.)
	LOG	00030060	00030087	00000028 (40.)
\$LINK\$		00040000	00040000	00000000 (0.)
	LOG	00040000	00040000	00000000 (0.)
\$LINKER UNWIND\$		00040000	00040047	00000048 (72.)
	LOG	00040000	00040047	00000048 (72.)
\$LINKER UNWINFO\$		00040048	000400B7	00000070 (112.)
	LOG	00040048	000400B7	00000070 (112.)
.sbss		00050000	00050013	00000014 (20.)
	LOG	00050000	00050013	00000014 (20.)
\$LINKER SDATA\$		00060000	000600CF	000000D0 (208.)
	<Linker>	00060000	000600CF	000000D0 (208.)

A.2. Example DELTA Debugging Session on I64

The DELTA debugging session on OpenVMS I64 for the sample program is shown in the three example segments that follow.

DELTA Debugging Session Example on I64 - Part 1

In the first part of the example session, DELTA is enabled and the LOG program is invoked. The example shows version information displayed by DELTA and the use of several key DELTA commands, including **!**, **;B**, and **;P**.

The callout list following the example provides details for this example segment.

Example A.6. DELTA Debugging Session on I64 - Part 1

```

$ DEFINE LIB$DEBUG SYS$SHARE:DELTA                                ❶
$ RUN/DEBUG LOG                                                    ❷
hp OpenVMS Industry Standard 64 DELTA Debugger                  ❸
  Brk 0 at 00020000
00020000!      alloc      r45 = ar.pfs, 0F, 08, 00 20000,1;X
00020000
X1 280!      cmp4.eq      p7, p6 = r32, r33 .;B                    ❹

```

```

X1 322!          br.call.sptk.many b0 = 0000070 ;; .;B      ⑤
;P
Brk 1 at X1+00000280                                     ⑥
X1+00000280!     cmp4.eq      p7, p6 = r32, r33 R32/00000000 00000001 ;P
Brk 2 at X1+00000322
X1+00000322!     br.call.sptk.many b0 = 0000070 ;; O
                PID= 37E00401      PRCNAM= SWAPPER LOGINTIM= 00:00:00.00 ⑦

```

- ① DELTA is enabled as the debugger.
- ② The example program LOG is invoked with DELTA.
- ③ DELTA displays a banner and the first executable instruction. The base address of the program (determined from the .MAP file) is virtual address 20000. The base address is placed in base register 1 with the ;X command. Now, references to an address can use the address offset notation. For example, a reference to the first instruction in routine *main* is X1+0120. Also, DELTA displays some address locations as offsets to the base address.
- ④ The instruction at address 20280 is displayed in instruction mode using the ! command. Its address location is expressed as the base address plus an offset. In the listing file, the offset is 280. (This is the point where the return status from SYS\$GETJPIW is checked.) The base address in base address register X1 is 20000. The address reference, then, is X1+280. Note that the + sign is implied when not specified.

A simple breakpoint is set at that address using the ;B command. The address reference for ;B is the dot (.) symbol, representing the current address. (X1+280;B would have produced the same thing.)

- ⑤ The same commands (that is, the ! command to view the instructions and the ;B command to set a breakpoint) are repeated for the instruction at offset 322. (This is the point at which the *print_line* function is called.)
- ⑥ Program execution halts at the first breakpoint. DELTA displays the breakpoint message (Brk 1 at X1+00000280) with the breakpoint number 1 and the address at which the break occurred. The virtual address is 20280, which is the base address (20000) plus the offset 280. DELTA then displays the instruction in instruction mode (cmp4.eq p7, p6 = r32, r33). The contents of general register 32 are displayed with the forward slash (/) command (register 32 contains the value of the *ss_sts* variable). DELTA displays the contents of R32, which is 1. Program execution continues using the ;P command.
- ⑦ The function *print_line* is executed and the output (PID, process name, and login time) is displayed.

DELTA Debugging Session Example on I64 - Part 2

In the second part of the example session, program execution continues and DELTA stops at the next breakpoint and displays information. User interaction allows DELTA to continue subsequent breakpoints. Use of the O command is demonstrated to halt program execution and step over a routine call.

The callout list following the example provides details for this example segment.

Example A.7. DELTA Debugging Session on I64 - Part 2

```

X1+00000330!     br.many      1FFFE00 ;P      ①
Brk 1 at X1+00000280
X1+00000280!     cmp4.eq      p7, p6 = r32, r33 ;P
Brk 2 at X1+00000322
X1+00000322!     br.call.sptk.many b0 = 0000070 ;; O      ②
                PID= 37E00407      PRCNAM= CLUSTER_SERVER LOGINTIM= 13:48:49.48
X1+00000330!     br.many      1FFFE00 ;P
Brk 1 at X1+00000280

```

```

X1+00000280!    cmp4.eq      p7, p6 = r32, r33
;B
1 X1+00000280
2 X1+00000322
0,1;B
;B 2 X1+00000322
;P
Brk 2 at X1+00000322
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; O
                PID= 37E00408   PRCNAM= CONFIGURE      LOGINTIM= 13:48:52.06
X1+00000330!    br.many      1FFFEE0 ;P
Brk 2 at X1+00000322
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; O
                PID= 37E00409   PRCNAM= USB$UCM_SERVER LOGINTIM= 13:48:54.80
X1+00000330!    br.many      1FFFEE0 ;P
Brk 2 at X1+00000322
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; X1 491! ld8 r44 = [r44]
Linefeed
X1+00000492!    mov          r25 = 000004 ;; Linefeed
X1+000004A0!    br.call.sptk.many b0 = 0000150 .;B
;B
1 X1+000004A0
2 X1+00000322
;P
Brk 1 at X1+000004A0
X1+000004A0!    br.call.sptk.many b0 = 0000150 O
                PID= 37E0040A   PRCNAM= LANACP      LOGINTIM= 13:48:54.84
X1+000004B0!    mov          r1 = r40 ;P
Brk 2 at X1+00000322
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; ;P
Brk 1 at X1+000004A0
X1+000004A0!    br.call.sptk.many b0 = 0000150 O
                PID= 37E0040C   PRCNAM= FASTPATH_SERVER LOGINTIM= 13:48:55.01
X1+000004B0!    mov          r1 = r40 ;P
Brk 2 at X1+00000322
X1+00000322!    br.call.sptk.many b0 = 0000070 ;;
;B
1 X1+000004A0
2 X1+00000322
0,2;B
0,1;B
;B
;P
PID= 37E0040D   PRCNAM= IPCACP LOGINTIM= 13:48:55.05
PID= 37E0040E   PRCNAM= ERRFMT LOGINTIM= 13:48:55.14
PID= 37E0040F   PRCNAM= CACHE_SERVER LOGINTIM= 13:48:55.19
PID= 37E00410   PRCNAM= OPCOM LOGINTIM= 13:48:55.24
PID= 37E00411   PRCNAM= AUDIT_SERVER LOGINTIM= 13:48:55.31
PID= 37E00412   PRCNAM= JOB_CONTROL LOGINTIM= 13:48:55.39
PID= 37E00414   PRCNAM= SECURITY_SERVER LOGINTIM= 13:48:55.84
PID= 37E00415   PRCNAM= ACME_SERVER LOGINTIM= 13:48:55.88
PID= 37E00416   PRCNAM= SMISERVER LOGINTIM= 13:49:02.26
PID= 37E0041E   PRCNAM= NETACP LOGINTIM= 13:49:04.54
PID= 37E0041F   PRCNAM= EVL LOGINTIM= 13:49:05.68
PID= 37E00420   PRCNAM= REMACP LOGINTIM= 13:49:13.39
PID= 37E00424   PRCNAM= TCPIP$INETACP LOGINTIM= 13:50:05.71
PID= 37E00425   PRCNAM= TCPIP$PORTM_1 LOGINTIM= 13:50:08.40
PID= 37E00426   PRCNAM= TCPIP$FTP_1 LOGINTIM= 13:50:08.77

```

```
PID= 37E0042A  PRCNAM= LATACP  LOGINTIM= 13:50:12.00  
PID= 37E008E5  PRCNAM= SYSTEM  LOGINTIM= 13:32:01.42  
PID= 37E008E7  PRCNAM= JNELSON  LOGINTIM= 13:41:17.48$
```

- ❶ Program execution continues with the **;P** command. DELTA stops at the next breakpoint.
- ❷ The **O** command halts program execution at the instruction where the function returns control (br.many 1FFFEE0). (This is the point at which control passes to checking the conditions of the while loop.) Program execution continues with **;P**.
- ❸ Breakpoint 2 is encountered. DELTA displays the breakpoint message and the instruction. The function is executed with the **O** command and the function output is displayed. The next instruction where the function returns control is displayed. Program execution continues with the **;P** command.
- ❹ Breakpoint 2 is encountered again. DELTA displays the breakpoint message and the instruction. The function is executed with the **O** command and the function output is displayed. The next instruction where the function returns control is displayed. Program execution continues with the **;P** command.
- ❺ Breakpoint 2 is encountered again. The instruction at offset 491 (located in *print_line*) is displayed using the **!** command. This instruction is part of the setup for the call to the *printf* function.
- ❻ Successive address locations are displayed by pressing the Linefeed key (**Ctrl/J**) twice. These instructions are the remainder of the setup and the call to *printf*.
- ❼ A breakpoint at X1+4A0 (the current address) is set using the **;B** command. This breakpoint is in the function *print_line*. The dot (.) symbol represents the current address. Note that breakpoint 1 was cleared earlier and is now reused by DELTA for the new breakpoint.
- ❽ Program execution continues with the **;P** command.
- ❾ Program execution stops at the new breakpoint 1, which is in the *print_line* function. DELTA displays the breakpoint message and the instruction at the new breakpoint. The **O** command halts program execution at the instruction where the function returns control, stepping over the routine call. Program execution is continued with the **;P** command.
- ❿ Program execution stops at breakpoint 1 in the *print_line* function. Program execution is continued using a combination of the **O** and **;P** commands.

Appendix B. Sample DELTA Debug Session on Alpha

This appendix gives an example of how you would use DELTA to debug a program executing on OpenVMS Alpha. The example C program named LOG uses the system service SYSS\$GETJPIW to obtain the PID, process name, and login time of each process. To run the example program without error, you need WORLD privilege.

Note

Although this example debugging session demonstrates using the DELTA debugger, you could use most of the commands in the example in an XDELTA debugging session as well.

This appendix consists of two sections:

- Section B.1 shows the source and machine listing files for the example C program
- Section B.2 shows the example DELTA debugging session and explains the various commands used and information provided.

B.1. Listing File for C Example Program

This section shows the listing file for the C program, LOG, in two parts:

- Section B.1.1—C source code
- Section B.1.2—Machine code

See Section B.2 for the corresponding sample debugging session using this program.

B.1.1. Source Listing for Alpha Debugging Example

Example B.1 shows the C source code for the example file, LOG.

Example B.1. Listing File for LOG: C Source Code

```
1      #include <descrip.h>
434    #include <jpidef.h>
581    #include <ssdef.h>
1233   #include <starlet.h>
3784   #include <stdio.h>
4117   #include <stdlib.h>
4345
4346   void print_line(unsigned long int pid, char *process_name,
4347     unsigned long int *time_buffer);
4348
4349   typedef struct {
4350     unsigned short int il3_buffer_len;
4351     unsigned short int il3_item_code;
4352     void *il3_buffer_ptr;
4353     unsigned short int *il3_return_len_ptr;
4354     } item_list_3;
4355
4356   #define NUL '\0'
```

```
4357
4358 main()
4359 {
4360 static char name_buf[16];
4361 static unsigned long int pid, time_buf[2];
4362 static unsigned short int name_len;
4363
4364 unsigned short int pidadr[2] = {-1, -1};
4365 unsigned long int ss_sts;
4366 item_list_3 jpi_itmlst[] = {
4367     /* Get's login time */
4368     {sizeof(time_buf),
4369      JPI$_LOGINTIM,
4370      (void *) time_buf,
4371      NULL},
4372
4373     /* Get's process name */
4374     {sizeof(name_buf) - 1,
4375      JPI$_PRCNAM,
4376      (void *) name_buf,
4377      &name_len},
4378
4379     /* Get's process ID (PID) */
4380     {sizeof(pid),
4381      JPI$_PID,
4382      (void *) &pid,
4383      NULL},
4384
4385     /* End of list */
4386     {0,
4387      0,
4388      NULL,
4389      NULL}
4390 };
4391
4392 /*
4393 While there's more GETJPI information to process and a catastrophic
4394 error has not occurred then
4395 If GETJPI was successful then
4396     NUL terminate the process name string and
4397     print the information returned by GETJPI
4398 */
4399
4400 while(
4401     (ss_sts = sys$getjpiw(0, &pidadr, 0, &jpi_itmlst, 0, 0,
4402     0)) != SS$_NOMOREPROC &&
4403     ss_sts != SS$_BADPARAM &&
4404     ss_sts != SS$_ACCVIO)
4405 {
4406     if (ss_sts == SS$_NORMAL)
4407     {
4408         *(name_buf + name_len) = NUL;
4409         print_line(pid, name_buf, time_buf);
4410     }
4411     exit(EXIT_SUCCESS);
4412 }
4413
```

```
4414 void print_line(unsigned long int pid, char *process_name,
4415   unsigned long int *time_buffer)
4416   {
4417   static char ascii_time[12];
4418
4419   struct dsc$descriptor_s time_dsc = {
4420       sizeof(ascii_time) - 1,
4421       DSC$K_DTYPE_T,
4422       DSC$K_CLASS_S,
4423       ascii_time
4424   };
4425   unsigned short int time_len;
4426
4427   /*
4428   Convert the logged in time to ASCII and NUL terminate it
4429   */
4430   sys$asctim(&time_len, &time_dsc, time_buffer, 1);
4431   *(ascii_time + time_len) = NUL;
4432
4433   /*
4434   Output the PID, process name and logged in time
4435   */
4436   printf("\n\tPID= %08.8X\t\tPRCNAM= %s\tLOGINTIM= %s", pid,
4437     process_name, ascii_time);
4438
4439   return;
4440   )
4441   __main(void *p1, void *p2, void *p3, void *p4, void *p5, void *p6)
4442   {
4443       void decc$exit(int);
4444       void decc$main(void *, void *, void *, void *, void *, void *, int
4445         *, void **, void **);
4445       int status;
4446       int argc;
4447       void *argv;
4448       void *envp;
4449
4450       decc$main(p1, p2, p3, p4, p5, p6, &argc, &argv, &envp);
4451
4452       status = main4453
4453
4454
4455
4456
4457           );
4458
4459       decc$exit(status);
4460   }
```

B.1.2. Machine Code Listing for Alpha Debugging Example

Example B.2 shows the machine code listing for the example program.

Example B.2. Listing File for LOG: Machine Code

```

.PSECT $CODE, OCTA, PIC, CON, REL, LCL, SHR, -
      EXE, NORD, NOWRT
0000 print_line::                                ; 004414
0000     LDA     SP, -80(SP)                      ; SP, -80(SP)
0004     MOV     1, R19                          ; 1, R19          ; 004430
0008     STQ     R27, (SP)                       ; R27, (SP)       ; 004414
000C     MOV     4, R25                          ; 4, R25          ; 004430
0010     STQ     R26, 32(SP)                     ; R26, 32(SP)     ; 004414
0014     STQ     R2, 40(SP)                      ; R2, 40(SP)
0018     STQ     R3, 48(SP)                      ; R3, 48(SP)
001C     STQ     R4, 56(SP)                      ; R4, 56(SP)
0020     STQ     FP, 64(SP)                     ; FP, 64(SP)
0024     MOV     SP, FP                          ; SP, FP
0028     MOV     R27, R2                        ; R27, R2
002C     STL     R17, process_name               ; R17, 16(FP)
0030     LDQ     R0, 40(R2)                      ; R0, 40(R2)      ; 004419
0034     MOV     R16, pid                       ; R16, R3         ; 004414
0038     LDQ     R26, 48(R2)                    ; R26, 48(R2)     ; 004430
003C     LDA     R16, time_len                  ; R16, 8(FP)
0040     LDQ     R4, 32(R2)                     ; R4, 32(R2)      ; 004423
0044     LDA     R17, time_dsc                  ; R17, 24(FP)     ; 004430
0048     STQ     R0, time_dsc                   ; R0, 24(FP)      ; 004419
004C     LDQ     R27, 56(R2)                    ; R27, 56(R2)     ; 004430
0050     STL     R4, 28(FP)                     ; R4, 28(FP)      ; 004419
0054     JSR     R26, SYS$ASCTIM                ; R26, R26        ; 004430
0058     LDL     R0, time_len                   ; R0, 8(FP)       ; 004431
005C     MOV     pid, R17                      ; R3, R17         ; 004436
0060     LDQ     R27, 88(R2)                    ; R27, 88(R2)
0064     MOV     R4, R19                        ; R4, R19
0068     LDQ     R26, 80(R2)                    ; R26, 80(R2)
006C     MOV     4, R25                        ; 4, R25
0070     ZEXTW   R0, R0                         ; R0, R0          ; 004431
0074     ADDQ    R4, R0, R0                     ; R4, R0, R0
0078     LDQ_U   R16, (R0)                     ; R16, (R0)
007C     MSKBL   R16, R0, R16                  ; R16, R0, R16
0080     STQ_U   R16, (R0)                     ; R16, (R0)
0084     LDQ     R16, 64(R2)                    ; R16, 64(R2)     ; 004436
0088     LDL     R18, process_name              ; R18, 16(FP)
008C     JSR     R26, DECC$GPRINTF              ; R26, R26
0090     MOV     FP, SP                         ; FP, SP          ; 004439
0094     LDQ     R28, 32(FP)                    ; R28, 32(FP)
0098     LDQ     R2, 40(FP)                     ; R2, 40(FP)
009C     LDQ     R3, 48(FP)                     ; R3, 48(FP)
00A0     LDQ     R4, 56(FP)                     ; R4, 56(FP)
00A4     LDQ     FP, 64(FP)                     ; FP, 64(FP)
00A8     LDA     SP, 80(SP)                     ; SP, 80(SP)
00AC     RET     R28                           ; R28
Routine Size: 176 bytes,      Routine Base: $CODE + 0000
00B0 main::                                ; 004358
00B0     LDA     SP, -144(SP)                   ; SP, -144(SP)
00B4     MOV     48, R17                       ; 48, R17         ; 004366
00B8     STQ     R27, (SP)                     ; R27, (SP)       ; 004358
00BC     STQ     R26, 64(SP)                   ; R26, 64(SP)
00C0     STQ     R2, 72(SP)                     ; R2, 72(SP)
00C4     STQ     R3, 80(SP)                     ; R3, 80(SP)
00C8     STQ     R4, 88(SP)                     ; R4, 88(SP)

```

```

00CC      STQ      R5, 96(SP)          ; R5, 96(SP)
00D0      STQ      R6, 104(SP)         ; R6, 104(SP)
00D4      STQ      R7, 112(SP)         ; R7, 112(SP)
00D8      STQ      R8, 120(SP)         ; R8, 120(SP)
00DC      STQ      FP, 128(SP)         ; FP, 128(SP)
00E0      MOV      SP, FP              ; SP, FP
00E4      MOV      R27, R2             ; R27, R2
00E8      LDA      SP, -16(SP)          ; SP, -16(SP)
00EC      LDQ      R26, 40(R2)          ; R26, 40(R2) ; 004366
00F0      LDQ      R18, 64(R2)          ; R18, 64(R2)
00F4      LDA      R16, jpi_itmlst     ; R16, 16(FP)
00F8      JSR      R26, OTS$MOVE       ; R26, R26
00FC      LDA      R6, jpi_itmlst     ; R6, 16(FP) ; 004401
0100      LDQ      R3, -64(R2)          ; R3, -64(R2) ; 004370
0104      LDA      R7, pidadr          ; R7, 8(FP) ; 004401
0108      LDQ      R0, 32(R2)           ; R0, 32(R2) ; 004364
010C      MOV      2472, R8             ; 2472, R8 ; 004401
0110      STL      R0, pidadr           ; R0, 8(FP) ; 004364
0114      LDA      R3, time_buf         ; R3, 16(R3) ; 004370
0118      MOV      R3, R5              ; R3, R5
011C      STL      R5, 20(FP)           ; R5, 20(FP) ; 004366
0120      LDA      R4, 8(R3)            ; R4, 8(R3) ; 004376
0124      STL      R4, 32(FP)           ; R4, 32(FP) ; 004366
0128      LDA      R17, 24(R3)          ; R17, 24(R3)
012C      STL      R17, 36(FP)          ; R17, 36(FP)
0130      LDA      R19, 28(R3)          ; R19, 28(R3)
0134      STL      R19, 44(FP)          ; R19, 44(FP)
0138 L$6:                                     ; 004400
0138      LDQ      R26, 48(R2)          ; R26, 48(R2) ; 004401
013C      CLR      R16                  ; R16
0140      LDQ      R27, 56(R2)          ; R27, 56(R2)
0144      MOV      R7, R17              ; R7, R17
0148      STQ      R31, (SP)           ; R31, (SP)
014C      CLR      R18                  ; R18
0150      MOV      R6, R19              ; R6, R19
0154      CLR      R20                  ; R20
0158      CLR      R21                  ; R21
015C      MOV      7, R25               ; 7, R25
0160      JSR      R26, SYS$GETJPIW     ; R26, R26
0164      CMPEQ    ss_sts, 20, R16      ; R0, 20, R16 ; 004402
0168      CMPEQ    ss_sts, R8, R17      ; R0, R8, R17 ; 004401
016C      CMPEQ    ss_sts, 12, R18      ; R0, 12, R18 ; 004403
0170      BIS      R17, R16, R17        ; R17, R16, R17 ; 004401
0174      BIS      R17, R18, R18        ; R17, R18, R18
0178      BNE      R18, L$10            ; R18, L$10 ; 004400
017C      CMPEQ    ss_sts, 1, R0        ; R0, 1, R0 ; 004405
0180      BEQ      R0, L$6              ; R0, L$6
0184      MOV      R4, R17              ; R4, R17 ; 004408
0188      LDQ_U    R19, 24(R3)          ; R19, 24(R3) ; 004407
018C      MOV      R5, R18              ; R5, R18 ; 004408
0190      LDA      R27, -96(R2)         ; R27, -96(R2)
0194      EXTWL    R19, R3, R19         ; R19, R3, R19 ; 004407
0198      ADDQ     R4, R19, R19         ; R4, R19, R19
019C      LDQ_U    R22, (R19)           ; R22, (R19)
01A0      MSKBL    R22, R19, R22        ; R22, R19, R22
01A4      STQ_U    R22, (R19)           ; R22, (R19)
01A8      LDL      R16, 28(R3)          ; R16, 28(R3) ; 004408
01AC      BSR      R26, print_line     ; R26, print_line

```

```

01B0      BR      L$6                ; L$6                ; 004405
01B4      NOP                                ;
01B8 L$10:                                ; 004400
01B8      LDQ      R26, 80(R2)        ; R26, 80(R2)        ; 004411
01BC      CLR      R16                ; R16
01C0      LDQ      R27, 88(R2)        ; R27, 88(R2)
01C4      MOV      1, R25             ; 1, R25
01C8      JSR      R26, DECC$EXIT     ; R26, R26
01CC      MOV      FP, SP             ; FP, SP            ; 004412
01D0      LDQ      R28, 64(FP)        ; R28, 64(FP)
01D4      MOV      1, R0              ; 1, R0
01D8      LDQ      R2, 72(FP)         ; R2, 72(FP)
01DC      LDQ      R3, 80(FP)         ; R3, 80(FP)
01E0      LDQ      R4, 88(FP)         ; R4, 88(FP)
01E4      LDQ      R5, 96(FP)         ; R5, 96(FP)
01E8      LDQ      R6, 104(FP)        ; R6, 104(FP)
01EC      LDQ      R7, 112(FP)        ; R7, 112(FP)
01F0      LDQ      R8, 120(FP)        ; R8, 120(FP)
01F4      LDQ      FP, 128(FP)        ; FP, 128(FP)
01F8      LDA      SP, 144(SP)        ; SP, 144(SP)
01FC      RET      R28                ; R28
Routine Size: 336 bytes,      Routine Base: $CODE + 00B0
0200 __main::                                ; 004441
0200      LDA      SP, -48(SP)         ; SP, -48(SP)
0204      MOV      9, R25             ; 9, R25            ; 004450
0208      STQ      R27, (SP)          ; R27, (SP)        ; 004441
020C      STQ      R26, 24(SP)        ; R26, 24(SP)
0210      STQ      R2, 32(SP)         ; R2, 32(SP)
0214      STQ      FP, 40(SP)         ; FP, 40(SP)
0218      MOV      SP, FP             ; SP, FP
021C      LDA      SP, -32(SP)        ; SP, -32(SP)
0220      MOV      R27, R2            ; R27, R2
0224      LDA      R0, argc            ; R0, 16(FP)        ; 004450
0228      LDQ      R26, 48(R2)        ; R26, 48(R2)
022C      LDA      R1, argv            ; R1, 12(FP)
0230      STQ      R0, (SP)           ; R0, (SP)
0234      LDA      R0, envp            ; R0, 8(FP)
0238      STQ      R1, 8(SP)          ; R1, 8(SP)
023C      LDQ      R27, 56(R2)        ; R27, 56(R2)
0240      STQ      R0, 16(SP)         ; R0, 16(SP)
0244      JSR      R26, DECC$MAIN     ; R26, R26
0248      LDA      R27, -96(R2)       ; R27, -96(R2)    ; 004452
024C      BSR      R26, main           ; R26, main
0250      LDQ      R27, 40(R2)        ; R27, 40(R2)    ; 004459
0254      MOV      status, R16        ; R0, R16
0258      MOV      1, R25             ; 1, R25
025C      LDQ      R26, 32(R2)        ; R26, 32(R2)
0260      JSR      R26, DECC$EXIT     ; R26, R26
0264      MOV      FP, SP             ; FP, SP            ; 004460
0268      LDQ      R28, 24(FP)        ; R28, 24(FP)
026C      LDQ      R2, 32(FP)         ; R2, 32(FP)
0270      LDQ      FP, 40(FP)         ; FP, 40(FP)
0274      LDA      SP, 48(SP)         ; SP, 48(SP)
0278      RET      R28                ; R28
Routine Size: 124 bytes,      Routine Base: $CODE + 0200

```

The .MAP file for the sample program is shown in Example B.3. Only the Program Section Synopsis with the psect, module, base address, end address, and length are listed.

Example B.3. .MAP File for the Sample Program

+-----+ ! Program Section Synopsis ! +-----+									
Psect Name	Module Name		Base		End	Length			
-----	-----		----		---	-----			
\$LINKAGE	00010000	000100FF	00000100	(	256.)	LOG	00010000	000100FF	00000100 (256.)
\$LITERAL	00010100	00010158	00000059	(	89.)	LOG	00010100	00010158	00000059 (89.)
\$READONLY	00010160	00010160	00000000	(	0.)	LOG	00010160	00010160	00000000 (0.)
\$INIT	00020000	00020000	00000000	(	0.)	LOG	00020000	00020000	00000000 (0.)
\$UNINIT	00020000	0002002F	00000030	(	48.)	LOG	00020000	0002002F	00000030 (48.)
\$CODE	00030000	0003027B	0000027C	(	636.)	LOG	00030000	0003027B	0000027C (636.)

B.2. Example DELTA Debugging Session on Alpha

The DELTA debugging session on OpenVMS Alpha for the sample program is shown in the three example segments that follow.

B.2.1. DELTA Debugging Session Example on Alpha - Part 1

In the first part of the example session, DELTA is enabled and the LOG program is invoked. The example shows version information displayed by DELTA and the use of the ;B and ;P commands.

The callout list following the example provides details for this example segment.

Example B.4. DELTA Debugging Session on Alpha- Part 1

```

$ DEFINE LIB$DEBUG SYS$LIBRARY:DELTA          ❶
$ RUN/DEBUG LOG                                ❷
Alpha/VMS DELTA Version 1.5                    ❸
Brk 0 at 00030200
00030200!   LDA          SP, #XFFD0 (SP)   30000,1;X
X1 164! CMPEQ      R0, #X14, R16 .;B        ❹

X1 1AC! BSR        R26, #XFFFF94 .;B        ❺

```

- ❶ DELTA is enabled as the debugger.
- ❷ The example program LOG is invoked with DELTA.
- ❸ DELTA displays a version number and the first executable instruction. The base address of the program (determined from the map file) is virtual address 30000. The base address is placed in base register 1 with ;X. Now references to an address can use the address offset notation. For example, a reference to the first instruction is X1+200 (or the base address 30000 + offset 200). Also, DELTA displays some address locations as offsets to the base address.
- ❹ The instruction at address 30164 is displayed in instruction mode using !. Its address location is expressed as the base address plus an offset. In the listing file, the offset is 164. (This is the point where the return status from SYSS\$GETJPIW is checked.) The base address in base address register X1 is 30000. The address reference, then, is X1+164. Note the + sign is implied when not specified.

A simple breakpoint is set at that address using the ;B command. The address reference for ;B is the . symbol, representing the current address. X1+164;B would have done the same thing.

- ❺ The ! command to view the instruction and ;B to set a breakpoint are repeated for the instruction at offset 1AC. (This is the point at which the print_line function is called.)

B.2.2. DELTA Debugging Session Example on Alpha - Part 2

In the second part of the example session, program execution continues with ;P, then halts at the first breakpoint and displays information. User interaction allows DELTA to continue subsequent breakpoints.

The callout list following the example provides details for this example segment.

Example B.5. DELTA Debugging Session on Alpha - Part 2

```

;P
Brk 1 at 00030164
X1+00000164!      CMPEQ      R0,#X14,R16  R0/ 00000001 ;P
Brk 2 at 000301AC
X1+000001AC!      BSR        R26,#XFFFF94 O
      PID= 00000021      PRCNAM= SWAPPER LOGINTIM= 00:00:00.00
X1+000001B0!      BR         R31,#XFFFFE1 ;P
Brk 1 at 00030164
X1+00000164!      CMPEQ      R0,#X14,R16 R0/ 00000001 ;P
Brk 2 at 000301AC
X1+000001AC!      BSR        R26,#XFFFF94 O
      PID= 00000024      PRCNAM= ERRFMT  LOGINTIM= 16:24:01.03
X1+000001B0!      BR         R31,#XFFFFE1 ;P
Brk 1 at 00030164
X1+00000164!      CMPEQ      R0,#X14,R16
;B
  1 00030164
  2 000301AC
0,1;B
;B
  2 000301AC
;P
Brk 2 at 000301AC
X1+000001AC!      BSR        R26,#XFFFF94 O
      PID= 00000025      PRCNAM= OPCOM   LOGINTIM= 16:24:02.56
X1+000001B0!      BR         R31,#XFFFFE1 ;P
Brk 2 at 000301AC
X1+000001AC!      BSR        R26,#XFFFF94 O
      PID= 00000026      PRCNAM= AUDIT_SERVER LOGINTIM=16:24:03.66
X1+000001B0!      BR         R31,#XFFFFE1 ;P
Brk 2 at 000301AC
X1+000001AC!      BSR        R26,#XFFFF94 X1 84! LDQ   R16,#X0040(R2)

```

- ❶ The ;P command lets you proceed from the breakpoint.
- ❷ Program execution halts at the first breakpoint. DELTA displays the breakpoint message (Brk 1 at 00030164) with the breakpoint number 1 and the virtual address. The virtual address is 30164, which is the base address (30000) plus the offset 164. DELTA then displays the instruction in instruction mode (CMPEQ R0,#X14,R16). The contents of the general register 0 are displayed with the / command. DELTA displays the contents of R0, which is 1. Program execution continues using the ;P command.
- ❸ The function print_line is executed, and the output (PID, process name, and login time) is displayed.
- ❹ The O command halts program execution at the instruction where the function returns control (BR R31,#XFFFFE1). (This is the point at which control passes to checking the conditions of the while loop.) Program execution continues with ;P.

- ⑤ Breakpoint 2 is encountered. DELTA displays the breakpoint message, and the instruction. The function is executed with the **O** command and the function output is displayed. The next instruction where the function returns control is displayed. Program execution continues with the **;P** command.
- ⑥ Breakpoint 2 is encountered again. DELTA displays the breakpoint message, and the instruction. The function is executed with the **O** command and the function output is displayed. The next instruction where the function returns control is displayed. Program execution continues with the **;P** command.
- ⑦ Breakpoint 2 is encountered again. The instruction at offset 84 (in `print_line`) is displayed using **!**. This instruction is part of the setup for the call to the `printf` function.

B.2.3. DELTA Debugging Session Example on Alpha - Part 3

In the third part of the example session, successive address locations are specified when the user presses **Linefeed**. Another breakpoint is set, and program execution continues. DELTA stops at the break point, and the **;O** command is used to halt execution and step over a routine call. Program execution continues through more breakpoints to a final exit.

The callout list following the example provides details for this example segment.

Example B.6. DELTA Debugging Session Example on Alpha - Part 3

Linefeed	①
X1+00000088! LDL R18, #X0010 (FP) Linefeed	
X1+0000008C! JSR R26, (R26) .;B	②
; B	
1 0003008C	
2 000301AC	
; P	③
Brk 1 at 0003008C	④
X1+0000008C! JSR R26, (R26) O	
PID= 00000027 PRCNAM= JOB_CONTROL LOGINTIM= 16:24:06.83	
X1+00000090! BIS R31, FP, SP ;P	
Brk 2 at 000301AC	
X1+000001AC! BSR R26, #XFFFF94 ;P	
Brk 1 at 0003008C	⑤
X1+0000008C! JSR R26, (R26) O	
PID= 00000028 PRCNAM= NETACP LOGINTIM= 16:24:22.86	
X1+00000090! BIS R31, FP, SP ;P	
Brk 2 at 000301AC	
X1+000001AC! BSR R26, #XFFFF94	
; B	
1 0003008C	
2 000301AC	
0, 2; B	
0, 1; B	
; B	
; P	
PID= 00000029 PRCNAM= EVL LOGINTIM= 16:24:26.67	
PID= 0000002A PRCNAM= REMACP LOGINTIM= 16:24:38.21	
PID= 0000002B PRCNAM= LATACP LOGINTIM= 16:24:43.18	

```
PID= 0000004C      PRCNAM= GODDARD  LOGINTIM= 07:40:49.34
PID= 0000002D      PRCNAM= SYMBIONT_0001  LOGINTIM= 16:25:47.54
PID= 0000002F      PRCNAM= MCCORMICK      LOGINTIM= 16:27:45.27
Exit 00000001
8002228C!          ADDL              R15,SP,SP  EXIT
```

⑥
⑦
⑧

- ❶ Successive address locations are displayed by pressing the Linefeed key two times. These instructions are the remainder of the setup and the call to printf.
- ❷ A breakpoint at X1+8C (the current address) is set using the **;B** command. This breakpoint is in the function print_line. The . symbol represents the current address. Note that breakpoint 1 was cleared earlier and is now reused by DELTA for the new breakpoint.
- ❸ Program execution continues with the **;P** command.
- ❹ Program execution stops at the new breakpoint 1, which is in the print_line function. DELTA displays the breakpoint message and the instruction at the new breakpoint. The **O** command halts program execution at the instruction where the function returns control, stepping over the routine call. Note the **O** command must be used in this case, as opposed to the **;P** command, because the printf function resides in read-only protected memory. Program execution is continued with the **;P** command.
- ❺ Program execution stops at breakpoint 1 in the print_line function. Program execution is continued using a combination of the **O** and **;P** commands.
- ❻ All current process login times are displayed.
- ❼ Final exit status is displayed.
- ❽ The DELTA EXIT command is entered to terminate the debugging session and leave DELTA.

Appendix C. Sample DELTA Debug Session on VAX

This appendix provides an example of how you would use DELTA to debug a program executing on OpenVMS VAX. The example program, named LOGINTIM, uses the system service `SYS$GETJPI` to obtain the login times of each process. To run the example program without error, you need `WORLD` privilege.

Note

Although this example debugging session demonstrates using the DELTA debugger, you could use most of the commands in the example in an XDELTA debugging session as well.

This appendix consists of two sections:

- Section C.1 shows the source and machine listing files for the example program
- Section C.2 shows the example DELTA debugging session and explains the various commands used and information provided.

C.1. Listing Files for Example Program

This section shows the listing files for the example program, LOGINTIM, in two parts:

- Section C.1.1—Listing file for example source code
- Section C.1.2—Map file program section synopsis

See Section C.2 for the corresponding sample debugging session using this program.

C.1.1. Source Listing for VAX Debugging Example

The `.LIS` file for the DELTA debugging example on OpenVMS VAX is shown in Example C.1. Only the offsets and source code are shown.

Example C.1. Program for Getting LOGINTIMs

```
0000 1 ;++
0000 2 ; This sample program uses the wildcard feature of GETJPI to get
0000 3 ; LOGINTIM for each active process. It outputs the PID and LOGINTIM
0000 4 ; for each and exits when there are NOMOREPROCs.
0000 5 ;--
0000 6 ;
0000 7 ;
0000 8 ; Data areas.
0000 9 ;
0000 10 DEVNAM: .ASCID /SYS$OUTPUT/           ;Output device specifier
000E
0012 11
0012 12 CHAN:  .LONG 0                       ;Assigned output channel
0016 13
0016 14 ITMLST:                             ;Item list for GETJPI call
```

```

0016 15      .WORD  8                ; Byte length of output buffer
0018 16      .WORD  JPI$_LOGINTIM    ; Specify LOGINTIM item code
001A 17      .ADDRESS      TIME      ; Address of output buffer
001E 18      .LONG  0                ; Not interested in return length
0022 19      .LONG  0                ;Item list terminator
0026 20
0026 21 TIME: .QUAD  0                ;Buffer to hold LOGINTIM
002E 22
002E 23 OUTLEN: .LONG  0                ;FAO buffer length
0032 24 OUTBUF: .LONG  1024            ;FAO buffer descriptor
0036 25      .ADDRESS BUF
003A 26 BUF:   .BLKB  1024            ;FAO buffer
043A 27
043A 28 CTRSTR: .ASCID  *!/!_PID= !XW!_LOGINTIME= !%T* ;FAO control string
0448
0454
045E 29
045E 30 PIDADR: .LONG  -1              ;Wildcard PID control longword
0462 31
0462 32 ;++
0462 33 ; Start of program.
0462 34 ;--
0462 35 S:      .WORD  0                ;Entry mask
0464 36      $ASSIGN_S  DEVNAM,CHAN    ;Assign output channel
0475 37      MOVAB  TIME,R2            ;Load pointer to LOGINTIM
047A 38                                ;output buffer
047A 39 LOOP:   $GETJPI_S  ITMLST=ITMLST,-;Get LOGINTIM for a process
047A 40                                PIDADR=PIDADR
0490 41      CMPL  R0,#SS$_NOMOREPROC ;Are we done?
0497 42      BEQL  5$                ;If EQL yes
0499 43      BSBB  GOT_IT              ;Process data for this process
049B 44      BRB   LOOP                ;Look for another process
049D 45
049D 46 5$:     MOVZBL #SS$_NORMAL,R0  ;Set successful completion code
04A1 47      RET                      ;Return, no more processes
04A2 48
04A2 49 GOT_IT: $FAO_S  CTRSTR,-        ;Format the output data
04A2 50                                OUTLEN,-
04A2 51                                OUTBUF,-
04A2 52                                PIDADR,R2
04B9 53      $QIOW_S  CHAN=CHAN,-      ;Output to SYS$OUTPUT
04B9 54                                FUNC=#IO$_WRITEVBLK,-
04B9 55                                P1=BUF,-
04B9 56                                P2=OUTLEN
04DC 57      RSB                      ;Done with this process data
04DD 58
04DD 59      .END S

```

C.1.2. Map File for VAX Debugging Example

The .MAP file is shown in Example C.2. Only the Program Section Synopsis with the PSECT, MODULE, base address, end address, and length are listed.

Example C.2. LOGINTIM Program .Map File

+-----+ ! Program Section Synopsis ! +-----+				
Psect Name	Module Name	Base	End	Length
-----	-----	----	----	-----
. BLANK .		00000200	000006E2	000004E3 (1251.)
	.MAIN.	00000200	000006E2	000004E3 (1251.)

C.2. Example DELTA Debugging Session on VAX

The DELTA debugging session on OpenVMS VAX for the sample program is shown in the four example segments that follow.

C.2.1. DELTA Debugging Session Example on VAX - Part 1

In the first part of the example session, DELTA is enabled and the LOGINTM program is invoked. The example shows version information displayed by DELTA and the use of the **;B** and **;P** commands.

The callout list following the example provides details for this example segment.

Example C.3. DELTA Debugging Session Example on VAX - Part 1

```

$ DEFINE LIB$debugging SYS$LIBRARY:DELTA      ❶
$ RUN/debugging LOGINTIM                      ❷
DELTA Version 6.0
00000664/CLRQ      -(SP) 200,1;X              ❸
00000200                                                  ❹
X1 490!CMPL      R0,#000009A8 .;B              ❺
X1 499!BSBB      X1+04A2 .;B                    ❻

```

- ❶ DELTA is enabled as the debugger.
- ❷ The example program LOGINTIM is invoked with DELTA.
- ❸ DELTA displays a version number and the first executable instruction. The base address of the program (determined from the map file) is virtual address 200. The base address is placed in base register 1 with **;X**. Now references to an address can use the address offset notation. For example, a reference to the first instruction is X1+464 (or base address 200 + offset 464). Also, DELTA displays some address locations as offsets to the base address.
- ❹ DELTA displays the value in base register 1, just loaded 200.
- ❺ The instruction at address 690 is displayed in instruction mode using **!**. Its address location is expressed as the base address plus an offset. In the listing file, the offset is 490. The base address in base register X1 is 200. The address reference, then, is X1+490. (Note that the + sign is implied when not specified.)

A simple breakpoint is set at that address using the **;B** command. The address reference for **;B** is the **.** symbol, representing the current address. X1+490;B would have done the same thing.

- ❻ The same commands (**!** command to view the instruction and **;B** to set a breakpoint) are repeated for the instruction at offset 499. When DELTA displays the instruction (BSBB GOT_IT), it displays the destination of the branch (GOT_IT) as the address location. DELTA displays the value as an offset to base register 1.

C.2.2. DELTA Debugging Session Example on VAX - Part 2

In the second part of the example session, program execution begins. DELTA halts at the first breakpoint and displays information. User interaction allows DELTA to continue to the next breakpoint.

The callout list following the example provides details for this example segment.

Example C.4. DELTA Debugging Session Example on VAX - Part 2

```

;P                                     ❶
X1+0490/CMPL      R0,#000009A8 R0/00000001 ;P   ❷
2 BRK AT 00000699
X1+499/BSBB      X1+04A2 O                     ❸
          PID=  0000      LOGINTIME=  00:00:00.00  ❹
X1+049B/BRB      X1+047A ;P                     ❺
1 BRK AT 00000690
X1+0490/CMPL      R0,#000009A8 R0/00000001 ;P   ❻
2 BRK AT 00000699
X1+0499/BSBB      X1+04A2 O                     ❼
          PID=  0001      LOGINTIME=  00:00:00.00  ❽
X1+049B/BRB      X1+047A ;P                     ❾
1 BRK AT 00000690
X1+0490/CMPL      R0,#000009A8                 ❻
;B                                     ❼
1  00000690
2  00000699                               ❽

```

- ❶ Program execution begins with the **;P** command.
- ❷ Program execution halts at the first breakpoint. DELTA displays the breakpoint message (1 BRK AT 00000690) with the breakpoint number 1 and the virtual address. The virtual address is 00000690, which is the base address (200) plus the offset 490. DELTA then displays the instruction in instruction mode (CMPL R0,#000009A8). The contents of general register 0 are displayed with the **/** command. DELTA displays the contents of R0, which is 1. Program execution continues using the **;P** command.
- ❸ Program execution halts at breakpoint 2. DELTA displays the breakpoint message, then the instruction. Step-instruction execution, excluding instructions in subroutines, is initiated with **O**.
- ❹ The subroutine GOT_IT is executed, and the output (PID and login time) is displayed.
- ❺ The **O** command halts program execution at the instruction where the subroutine returns control (BRB LOOP). DELTA displays the instruction in instruction mode (BRB X1+047A), where X1+047A is the address of the first instruction in LOOP. Program execution continues with **;P**.
- ❻ Breakpoint 1 is encountered again; DELTA displays the breakpoint message and the instruction. The contents of R0 are examined (**/** command) and program execution continues (**;P**).
- ❼ Breakpoint 2 is encountered again; DELTA displays the breakpoint message and the instruction. The subroutine is stepped over again with the **O** command. The subroutine is executed, and the output is displayed. The instruction where the subroutine returns control is displayed. Program execution continues (**;P** command).
- ❽ Breakpoint 1 is encountered; DELTA displays the breakpoint message and the instruction.
- ❾ All breakpoints in the program are listed with the **;B** command.
- ❽ DELTA displays the breakpoints (by breakpoint number) and the address locations.

C.2.3. DELTA Debugging Session Example on VAX - Part 3

In the third part of the example session, the first breakpoint is cleared, then all breakpoints are listed. The program continues until the next breakpoint is encountered, and the user sets a new breakpoint.

The callout list following the example provides details for this example segment.

Example C.5. DELTA Debugging Session Example on VAX - Part 3

```

0,1;B                                ❶
;B                                    ❷
2 00000699                            ❸
;P                                    ❹
2 BRK AT 00000699
X1+0499/BSBB      X1+04A2  O
      PID= 0004      LOGINTIME= 12:50:20.40
X1+049B/BRB      X1+047A      ;P                                ❺
2 BRK AT 00000699
X1+0499/BSBB      X1+04A2 ;P
      PID= 0005      LOGINTIME= 12:50:25.61                    ❻
2 BRK AT 00000699
X1+0499/BSBB      X1+04A2 X1 4B9! CLRQ      -(SP)              ❼
Linefeed
X1+04BB/CLRQ      -(SP) Linefeed
X1+04BD/PUSHL      X1+002E Linefeed
X1+04C1/PUSHAL      X1+003A Linefeed
X1+04C5/CLRQ      -(SP) Linefeed
X1+04C7/PUSHL      #00 Linefeed
X1+04C9/MOVZWL      #0030;-(SP) Linefeed
X1+04CE/MOVZWL      X1+0012,-(SP) Linefeed
X1+04D3/PUSHL      #00 Linefeed
X1+04D5/CALLS      #0C,@#7FFEDE00 .;B                            ❾
;B                                    ❿
1 000006D5
2 00000699

```

- ❶ Breakpoint 1 is cleared using 0,[breakpoint #];B. (Never clear breakpoint 1 in XDELTA.)
- ❷ All breakpoints are listed again with ;B command.
- ❸ DELTA displays breakpoint 2 (breakpoint 1 cleared).
- ❹ Program execution continues using the ;P command.
- ❺ Breakpoint 2 is encountered; DELTA displays the breakpoint message and the instruction. The subroutine is executed with the O command and the subroutine output is displayed. The next instruction where the subroutine returns control is displayed. Program execution continues with the ;P command.
- ❻ Breakpoint 2 is encountered; DELTA displays the breakpoint message and the instruction. Program execution continues to the next breakpoint with the ;P command. The subroutine is executed, and the subroutine output is displayed.
- ❼ Breakpoint 2 is encountered again; the instruction at offset 4B9 (in the subroutine) is displayed using !. This instruction is part of the setup for the call to the system service \$QIOW.
- ❽ Successive address locations are displayed by pressing the **Linefeed** key nine times. These instructions are the remainder of the setup and the call to the system service \$QIOW.
- ❾ A breakpoint at X1+04D5 (the current address) is set using the ;B command. This breakpoint is in the subroutine. The . symbol represents the current address.
- ❿ The current breakpoints in the program are listed. The new breakpoint is assigned breakpoint 1.

C.2.4. DELTA Debugging Session Example on VAX - Part 4

In the final part of the example session, program execution continues and stops at the new breakpoint set in the previous example segment. DELTA executes the subroutine where the breakpoint was encountered and displays the output. The next breakpoint is reached and the user enters the `;O` command to step over the subroutine. When there are no more breakpoints, the program completes and final exit status is displayed.

The callout list following the example provides details for this example segment.

Example C.6. DELTA Debugging Session Example on VAX - Part 4

```

;P                                ❶
1 BRK AT 000006D5
X1+04D5/CALLS    #0C,@#7FFEDE00 ;P  ❷
      PID= 0006      LOGINTIME= 12:50:29.45
2 BRK AT 00000699
X1+0499/BSBB     X1+04A2 ;P        ❸
1 BRK AT 000006D5
X1+04D5/CALLS    #0C,@#7FFEDE00 ;P  ❹
      PID= 0007      LOGINTIME= 12:50:37.08
2 BRK AT 00000699
X1+0499/BSBB     X1+04A2 O        ❺
1 BRK AT 000006D5
X1+04D5/CALLS    #0C,@#7FFEDE00 ;P  ❻
      PID= 0008      LOGINTIME= 12:50:45.64
STEPOVER BRK AT 0000069B
X1+049B/BRB      X1+047A ;B       ❼
1 000006D5
2 00000699
0,2;B            ❽
0,1;B            ❾
;B               ❿
;P               ⓫
      PID= 0009      LOGINTIME= 12:51:22.51
      PID= 000A      LOGINTIME= 12:51:30.26
      PID= 000B      LOGINTIME= 12:51:36.21
      PID= 000C      LOGINTIME= 12:51:58.86  ⓬
EXIT 00000001    ⓭
80187E7E/POPR    #03 EXIT        ⓮

```

- ❶ Program execution continues with the `;P` command.
- ❷ Program execution stops at the new breakpoint 1, which is in the subroutine GOT_IT. DELTA displays the breakpoint message and the instruction at the new breakpoint. Program execution continues with the `;P` command.
- ❸ The subroutine completes and displays the output, and program execution continues until breakpoint 2. DELTA displays the breakpoint message and the breakpoint 2 instruction. Program execution continues with the `;P` command.
- ❹ Program execution stops at breakpoint 1 in the subroutine. Program execution continues with the `;P` command. The subroutine is executed, and the output is displayed.
- ❺ Program execution stops at breakpoint 2. The `O` command is entered to execute and step over the subroutine.
- ❻ Program execution stops at breakpoint 1 in the subroutine. Program execution continues with the `;P` command.

- ⑦ The subroutine completes execution and displays output. DELTA displays a STEPOVER break message to state that the **O** command has been completed, returning control at address 69B (an instruction in the main routine).
- ⑧ The instruction where the subroutine returns is displayed, and program execution is halted. The **;B** command is entered to display all current breakpoints.
- ⑨ The two current breakpoints are listed.
- ⑩ The command **0,2;B** clears breakpoint 2.
- ⑪ The command **0,1;B** clears breakpoint 1.
- ⑫ The **;B** command is entered to display all current breakpoints. Because all breakpoints have been cleared, DELTA does not display any.
- ⑬ Program execution continues with the **;P** command. Because there are no longer any breakpoints, the program executes to the end.
- ⑭ All current process login times are displayed.
- ⑮ Final exit status is displayed.
- ⑯ The DELTA EXIT command is entered to terminate the debugging session and leave DELTA.

