

# DELTA/XDELTA Debugger Manual

**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 x86-64 Version 9.2-2 or higher

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# 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. VSI Encourages Your Comments

You may send comments or suggestions regarding this manual or any VSI document by sending electronic mail to the following Internet address: <docinfo@vmssoftware.com>. Users who have VSI OpenVMS support contracts through VSI can contact <support@vmssoftware.com> for help with this product.

## 4. OpenVMS Documentation

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

## 5. Typographical Conventions

The following conventions are used in this manual:

| Convention             | Meaning                                                                                                                                                                                                                                                                                                                                                  |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Ctrl</b> / <i>x</i> | A sequence such as <b>Ctrl</b> / <i>x</i> indicates that you must hold down the key labeled <b>Ctrl</b> while you press another key or a pointing device button.                                                                                                                                                                                         |
| <b>PF1</b> <i>x</i>    | A sequence such as <b>PF1</b> <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"><li>• Additional optional arguments in a statement have been omitted.</li><li>• The preceding item or items can be repeated one or more times.</li><li>• Additional parameters, values, or other information can be entered.</li></ul> |
| .                      | 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.                                                                                                                                                                            |

| Convention         | Meaning                                                                                                                                                                                                                                                                                                                                |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ( )                | 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.                                                                                                                                                                        |
| <b>bold type</b>   | 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 radixes—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 IA-64 Systems

The following Intel Itanium® hardware registers are not supported by XDELTA on OpenVMS IA-64 systems:

- CUID
- 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 and a separator – an exclamation point (!).

On IA-64, the name and starting address are displayed as follows:

```
VSI 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 x86-64, you will see the following:

```
VSI VMS X86 DELTA Debugger
YMM0-15: Present, ZMM0-15: Present, X/Y/ZMM16-31: Present
```

```
Brk 0 at address
```

```
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

On x86-64, there are two types of XDELTA:

- XDELTA is compiled into the primary bootstrap program `SYSBOOT.EXE` for use during the early boot stages where the system is transitioning from physical to virtual addressing. To invoke this early XDELTA, issue the following commands prior to booting:

```
BOOTMGR> XDELTA
BOOTMGR> BREAK
```

This will enable the debugger and take the first available breakpoint inside `SYSBOOT.EXE`.

- XDELTA (`SYSDBG`) also exists as a loadable executive image. This allows it to be used on programs that run in virtual address space including drivers. To invoke the loadable XDELTA, issue the following commands prior to booting:

```
BOOTMGR> SYSDBG
BOOTMGR> BREAK
```

This will load the debugger and take the first available breakpoint inside `EXECINIT.EXE`. If you prefer to take breakpoints inside program modules, insert `ini$brk()` calls in your sources.

To proceed from the initial breakpoint, use the following command:

```
;P
```

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, "Boot Command Qualifier Values"*.

---

## 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.

---

On Alpha, use the boot command as follows:

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

On IA-64, use the boot command as follows:

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

On IA-64 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 IA-64 and `APB.EXE` on Alpha. For a description of the valid values for this flag, see *Table 1.1, "Boot Command Qualifier Values"*.

**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

On IA-64 and Alpha, 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, "Accessing the Initial Breakpoint"*.

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 IA-64 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.

For boot flag setting on x86-64, please refer to the [VSI OpenVMS x86-64 Boot Manager User Guide](https://docs.vmssoftware.com/vsi-openvms-x86-64-boot-manager-user-guide/) [https://docs.vmssoftware.com/vsi-openvms-x86-64-boot-manager-user-guide/].

To enable XDELTA at the Boot Manager on x86-64, use the following command:

```
BOOTMGR> SYSDBG
```

```
ENABLED: Loading of late XDELTA {SYSTEM_DEBUG} Execlet
```

```
BOOTMGR> BREAK
```

```
ENABLED: XDELTA Initial Breakpoint.
```

```
BOOTMGR>
```

## 1.8.1. 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 14<sub>10</sub> 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.

## 1.8.2. Requesting Interrupts on IA-64 and x86-64

To request an interrupt on IA-64 or x86-64, 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 21. 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.

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 IA-64, 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();
}
```

On x86-64, the **BREAK** command takes the first available breakpoint inside either `SYSBOOT.EXE` (if you are using `XDELTA` during early boot stages) or `EXECINIT.EXE` (if you are using `XDELTA` on programs that run in virtual address space). If you prefer to take breakpoints inside program modules, insert `ini$brk()` calls in your sources.

## 1.10. Proceeding from Initial XDELTA Breakpoints

On x86-64, when `XDELTA` reaches one of its breakpoints, it displays the following message:

```
Brk 0 at FFFF8300.06802620
FFFF8300.06802620!retq
```

On IA-64 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, "DELTA/XDELTA Symbols for OpenVMS x86-64 Systems"* shows the symbols that pertain to the OpenVMS x86-64 systems.
- *Table 2.2, "DELTA/XDELTA Symbols for OpenVMS IA-64 Systems"* shows the symbols that pertain to the OpenVMS IA-64 systems.
- *Table 2.3, "DELTA/XDELTA Symbols for OpenVMS Alpha Systems"* shows symbols that pertain to the OpenVMS Alpha systems.

**Table 2.1. DELTA/XDELTA Symbols for OpenVMS x86-64 Systems**

| Symbol                | Description                                                                                                                                                             |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AR $nn$               | Displays the XMACRO Alpha register set. <sup>1</sup>                                                                                                                    |
| Raa                   | Mnemonic access access to quadword register set (RAX, RBX, RCX, etc.)                                                                                                   |
| R $nn$                | Legacy syntax used to access x86-64 quadword register set using register number. (R0 = RAX, R1 = RBX, R2 = RCX, R3 = RDX, R4 = RSI, R5 = RDI, R6 = RBP, R7 = RSP, etc.) |
| %CR $nn$ <sup>b</sup> | The %CR $nn$ registers are not currently implemented on x86-64 and will display the value of 0xDEADDEAD.DEADDEAD.                                                       |
| %TSC <sup>b</sup>     | The Time Stamp Counter register that is constantly changing. Each access to the register will yield an updated value.                                                   |

<sup>1</sup>Note that your current PC must be in code generate by the XMACRO compiler for the register set to be valid.

<sup>b</sup>Caution should be exercised with deposits to either %CR $nn$  or %TSC, since these registers are used by SWIS and could cause XDELTA to fault or hang.

For a full list of registers supported on x86-64, refer to *Section 2.3, "Registers Supported on x86-64"*.

**Table 2.2. DELTA/XDELTA Symbols for OpenVMS IA-64 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. |
| AR $n$ | Application register $n$ where $n$ can range from 0 to 127 (decimal). Also see the P(ip $r$ ) symbol description. The AR $nn$ / command is used to displays the Application registers set.                                |
| BR $n$ | Branch register $n$ where $n$ can range from 0 to 7.                                                                                                                                                                      |

| Symbol       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CR $n$       | Control register $n$ where $n$ can range from 0 to 127 (decimal). See also the P( $i$ pr) symbol description.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| FP $n$       | Floating point register $n$ , where $n$ can range from 0 to 127 (decimal).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| FPSR         | The floating point status register.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| G            | $\wedge$ XFFFFFFF80000000, the prefix for system space addresses.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| H            | $\wedge$ X7FFE0000, the prefix for addresses in the control region (P1 space). H2E, for example, is equivalent to $\wedge$ X7FFE002E.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| P( $i$ pr)   | <p>The OpenVMS IA-64 software implementation of an Alpha internal processor register whose name is <code>i</code>pr. 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 IA-64.</p> <p>This syntax is also used to refer to Intel Itanium application and control registers using meaningful names, where <math>i</math>pr 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)<br/>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 IA-64 software implementation of a program counter register, formed by the union of the IP (instruction bundle pointer) and the slot offset (PSR.ri).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| $pid$ :R $n$ | General register $n$ in the process specified by process ID $pid$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| PS           | The processor status register.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| P $n$        | Predicate register $n$ where $n$ can range from 0 to 63 (decimal).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| R $n$        | General register $n$ where $n$ can range from 0 to 127 (decimal).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| X $n$        | <p>Base register <math>n</math>, where <math>n</math> 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 (; <b>E</b>) 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 2.3. 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 Q 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 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> |

## 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 IA-64, 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 IA-64, floating-point registers are always available to DELTA.

Table Table 2.4, "Floating Point Register Support by Platform" shows these relationships:

**Table 2.4. Floating Point Register Support by Platform**

|        | Alpha                       | IA-64            |
|--------|-----------------------------|------------------|
| 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. Registers Supported on x86-64

x86-64 supports various named registers which can be accessed via *%register-name*. The quadword integer registers and a few other registers can be accessed with the older syntax.

- **Quadword**

R0, R1, R2, R3, R4, R5, R6, R7 R8, R9, R10, R11, R12, R13, R14, R15

RAX, RBX, RCX, RDX, RSI, RDI, RBP, RSP, R8, R9, R10, R11, R12, R13, R14, R15

%RAX, %RBX, %RCX, %RDX, %RSI, %RDI, %RBP, %RSP, %R8, %R9, %R10, %R11, %R12, %R13, %R14, %R15

---

### Note

Quadword register can be access via older syntax of *Rregister-number* or newer *%REGISTER-NAME*. For example, R0 and %RAX access the same register.

---

- **Longword Integer registers**

%EAX, %EBX, %ECX, %EDX, %ESI, %EDI, %EBP, %ESP, %R8D, %R9D, %R10D, %R11D, %R12D, %R13D, %R14D, %R15D

- **Word**

%AX, %BX, %CX, %DX, %SI, %DI, %BP, %SP, %R8W, %R9W, %R10W, %R11W, %R12W, %R13W, %R14W, %R15W

- **Byte**

%AL, %BL, %CL, %DL, %SIL, %DIL, %BPL, %SPL, %R8B, %R9B, %R10B, %R11B, %R12B, %R13B, %R14B, %R15B

- **High Byte**

%AH, %BH, %CH %DH

R0/FFFFFFFF.FFFFFFFF ❶

RAX/FFFFFFFF.FFFFFFFF

```
%RAX/FFFFFFFF.FFFFFFFF ❷  
  
%RAX/FFFFFFFF.FFFFFFFF 4444444433332211  
%RAX/44444444.33332211  
  
%AL/11 55  
%RAX/44444444.33332255  
  
%AH/22 66  
%RAX/44444444.33336655  
  
%AX/6655 7777  
%RAX/44444444.33337777  
  
%EAX/33337777 88888888  
%RAX/00000000.88888888  
  
%RAX/00000000.88888888 FFFFFFFF.FFFFFFFF  
%RAX/FFFFFFFF.FFFFFFFF
```

❶ Legacy access to x86-64 register set by name or number (quadword only).

❷ The "%" prefix to access the complete x86 register set.

---

## Note

On x86-64, a deposit into any longword register always clears the upper longword.

---

- **Instruction Pointer (Program Counter) registers**

**Quadword:** %RIP (Register can also be accessed with the older PC command)

**Longword:** %EIP

**Word:** %IP

- **Flags registers**

**Quadword:** %RFLAGS (Register can also be accessed with the older PS command)

**Longword:** %EFLAGS

**Word:** %FLAGS

- **Control registers (quadword)**

%CR0 - %CR15

- **Floating Point registers (octoword/128-bit)**

%ST0 - %ST8

- **AVX register set (VSI OpenVMS x86-64 V9.2-3 or higher)**

**XMM registers** (octoword/128-bit): %XMM0 - %XMM15

**High XMM registers** (if implemented) (octoword/128-bit): %XMM16 - %XMM31

**YMM registers** (if implemented) (256-bit): %YMM0 - %YMM15

**High YMM registers** (if implemented) (256-bit): %YMM16 - %YMM31

**ZMM registers** (if implemented) (512-bit): %ZMM0 - %ZMM15

**High ZMM registers** (if implemented) (512-bit): %ZMM16 - %ZMM31

DELTA will display the "Eh?" error message if an attempt is made to access a non-implemented AVX registers. See Intel Processor documentation for information on which processors support the optional AVX registers. DELTA will display which optional AVX register are accessible:

```
VSI VMS X86 DELTA Debugger
```

```
YMM0-15: Present, ZMM0-15: Present, X/Y/ZMM16-31: Present
```

Floating Point and AVX registers are normally accessed only in user mode code. These registers cannot be used in kernel mode code.

## 2.4. 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, "Arithmetic Operators"*.

**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 (IA-64 and Alpha only)

For examples of DELTA debugging sessions on various OpenVMS platforms, see *Appendix A, "Sample DELTA Debug Session on IA-64"* for IA-64 and *Appendix B, "Sample DELTA Debug Session on Alpha"* for Alpha.

## 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.

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, "DELTA/XDELTA Commands"*).

### 3.1.1. Referencing Addresses

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
```

## 3.2. 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 (IA-64 Only)

On IA-64, 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, "Intel Itanium Registers and their Associated Symbols"* 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 1<sub>10</sub> is R1<sub>10</sub> and register 10<sub>10</sub> is R10<sub>10</sub>.
- 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 1<sub>10</sub> is FP1<sub>10</sub> and floating point register 10<sub>10</sub> is FP10<sub>10</sub>.
- 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.

## 3.3. 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 IA-64, 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 0. 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 (IA-64 and Alpha Only)

On IA-64 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. 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 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 IA-64 systems, the implementation is different, but the outcome is the same: XDELTA avoids causing errors that could lead to unintended effects to other processors.

The processor's physical identification number is similarly displayed but the number is decimal instead of hexadecimal with no leading zeros. For example:

Brk 0 at FFFF8300.06802620 on CPU 1

## 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 (IA-64 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 IA-64, 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, "DELTA/XDELTA Command Summary (All platforms)"* provides a summary of the DELTA/XDELTA commands that are common to OpenVMS IA-64 and Alpha, and x86-64 systems.
- *Table 4.2, "DELTA/XDELTA Command Summary (IA-64 and Alpha Only)"* provides a summary of the DELTA/XDELTA commands that are available only on OpenVMS IA-64 and Alpha.
- *Table 4.3, "DELTA/XDELTA Command Summary (IA-64 Only)"* provides a summary of the DELTA/XDELTA commands that are available only on OpenVMS IA-64.
- *Table 4.4, "DELTA/XDELTA Command Summary (x86-64 Only)"* provides a summary of the DELTA/XDELTA commands that are available only on OpenVMS x86-64.

Many commands in this chapter include an example.

## 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, "DELTA and XDELTA Symbols and Expressions"*).
- On IA-64 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                                     |

| Command            | Description                                                                                                    |
|--------------------|----------------------------------------------------------------------------------------------------------------|
| <b>;G</b>          | Go                                                                                                             |
| <b>S</b>           | Step Instruction                                                                                               |
| <b>O</b>           | Step Instruction over Subroutine                                                                               |
| <b>;D 'string'</b> | Deposit ASCII String                                                                                           |
| <b>;E</b>          | Execute Command String                                                                                         |
| <b>;X</b>          | Load Base Register                                                                                             |
| <b>=</b>           | Display Value of Expression                                                                                    |
| <b>;M</b>          | Set All Processes Writable; also, set selected registers of other processes writable (available only on DELTA) |
| <b>;L</b>          | Lists Names and Locations of Loaded Executive Images                                                           |
| <b>EXIT</b>        | Exit from DELTA debugging session                                                                              |
| <b>Ctrl/J</b>      | Display next location                                                                                          |

**Table 4.2. DELTA/XDELTA Command Summary (IA-64 and Alpha Only)**

| Command         | Description                                                                                                                                                                                                        |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>;D</b>       | Dumps a region of memory                                                                                                                                                                                           |
| <b>;Q</b>       | Validate queue                                                                                                                                                                                                     |
| <b>;C</b>       | Force system to bug check and crash                                                                                                                                                                                |
| <b>;W</b>       | Locate and display the executive image that contains the specified address                                                                                                                                         |
| <b>;I</b>       | 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) |
| <b>;H</b>       | Display on video terminal or at hard copy terminal                                                                                                                                                                 |
| <b>\string\</b> | Display the ASCII text string enclosed in backslashes                                                                                                                                                              |

**Table 4.3. DELTA/XDELTA Command Summary (IA-64 Only)**

| Command   | Description                                       |
|-----------|---------------------------------------------------|
| <b>;T</b> | Display the address of the interrupt stack frame. |

**Table 4.4. DELTA/XDELTA Command Summary (x86-64 Only)**

| Command  | Description                                                                                                                |
|----------|----------------------------------------------------------------------------------------------------------------------------|
| <b>%</b> | If used as the first character, it gives access the entire x86-64 general register set. Otherwise, it is the MOD operator. |

## [ (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.                                 |
| 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 IA-64 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 quadword on IA-64 and x86-64. The display mode remains in effect until you enter another Set Display Mode command.

## Example

```
R0/    00000001    ❶
[B      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*.

[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 **;M** 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 (the "." 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 IA-64 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.

IA-64 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 00000030 ;;
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 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.

## " (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, "Symbols Supplied by DELTA and XDELTA"* 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 FF<sub>16</sub> and 1<sub>16</sub> are added together. DELTA/XDELTA displays the sum in hexadecimal.

❷ 1<sub>16</sub> is subtracted from A<sub>16</sub>. DELTA/XDELTA displays the result in hexadecimal.

## \string\ – Immediate mode text display command (IA-64 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.

## Ctrl/J – Display Next Location

**Ctrl/J** — Display next location.

### Synopsis

**Ctrl/J** key

### Description

The **Ctrl/J** can be used to display the next location.

The next location will be displayed with the current register format:

- If you examine R0, then **Ctrl/J** will display R1 and its contents.
- If you examine RAX, then **Ctrl/J** will display RBX and its contents.
- If you examine %RAX, then **Ctrl/J** will display %RBX and its contents.
- %EAX, %AX and %AL can be examined and their contents will be displayed in the correct size.

You can also use **Ctrl/J** to move forward in instruction decode mode.

### Example

VSI VMS X86 XDELTA Debugger [SYSBOOT], XF29, Mar 27 2019 06:44:56

Brk 0 at 00000000.004AEF7D

00000000.004AEF7D!movq \$00000042,%rax

```
%RAX/00000000.00000000 <^J>
%RBX/00000000.00000002 <^J>
%RCX/00000000.004225F0 <^J>
%RDX/00000000.DFF14918 <^J>
%RSI/00000000.00000000 <^J>
%RDI/00000000.00000048 <^J>
%RBP/00000000.7FFF6E10 <^J>
%RSP/00000000.7FFF6B48 <^J>
%R8/00000000.00000000 <^J>
%R9/00000000.00462D10 <^J>
%R10/00000000.00000000 <^J>
%R11/00000000.FFFF03FC <^J>
%R12/00000000.00422658 <^J>
%R13/00000000.00DAA520 <^J>
%R14/00000000.007CFC00 <^J>
%R15/00000000.005189D0 <^J>
```

## ESC (Escape key) – Open Location and Display Previous Location

**ESC (Escape 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 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 keyboards) generates different characters and cannot be used for the **ESC** command. You must use **Ctrl/3**.

On x86-64, the **ESC** key can be used to display the previous location after pressing **Ctrl/J**. This feature is similar to capabilities in Alpha and IA-64 version of XDELTA, but the x86-64 version has been updated to display the correct register names.

---

### Note

On x86-64, the **ESC** command will not work in instruction mode. x86-64 systems have variable length instruction so it is difficult to calculate the address of the previous instruction. Alpha and IA-64 have fixed length instruction, and it is easy to find the address of the previous instruction.

---

## 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**.

## Example

```
R0/FFFFFFFF.80094308 <^J>
R1/FFFFFFFF.87318E00 <^J>
R2/FFFFFFFF.80094000
```

```
R0/FFFFFFFF.80094308 <^J>
R1/FFFFFFFF.87318E00 <ESC>
R0/FFFFFFFF.80094308
```

```
RAX/FFFFFFFF.80094308 <^J>
RBX/FFFFFFFF.87318E00 <ESC>
RAX/FFFFFFFF.80094308
```

```
%RAX/FFFFFFFF.80094308 <^J>
```

```
%RBX/FFFFFFFF.87318E00 <ESC>
%RAX/FFFFFFFF.80094308
```

```
%EAX/80094308 <^J>
%EBX/87318E00 <ESC>
%EAX/80094308
```

```
%AX/4308 <^J>
%BX/8E00 <ESC>
%AX/4308
```

```
%AL/08 <^J>
%BL/00 <ESC>
%AL/08
```

```
FFFF8300.108B3DC2!movq    %rax, (%rbx) <^J>
FFFF8300.108B3DC5!movq    %rdx, 08(%rbx) <^J>
FFFF8300.108B3DC9!btl     $00, 000000F0(%rbx) <^J>
FFFF8300.108B3DD1!jnb     00006011 <^J>
FFFF8300.108B3DD7!movq    0003494A(%rip), %r10 <^J>
FFFF8300.108B3DDE!leaq    20(%r10), %r10 <^J>
FFFF8300.108B3DE2!movzwb  (%r10), %r11 <^J>
FFFF8300.108B3DE6!movq    00034923(%rip), %r10 <^J>
FFFF8300.108B3DED!leaq    00000708(%r10), %r10 <^J>
FFFF8300.108B3DF4!movw    %r11w, (%r10) <^J>
FFFF8300.108B3DF8!movq    00034929(%rip), %r10 <^J>
FFFF8300.108B3DFF!leaq    00000108(%r10), %r10 <^J>
FFFF8300.108B3E06!movslq  (%r10), %r11 <ESC>  ! Not supported in instruction
mode
FFFF8300.108B3E06!movslq  (%r10), %r11 <ESC>
FFFF8300.108B3E06!movslq  (%r10), %r11 <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.

On x86-64, you can also use **Ctrl/J** to move forward in instruction decode mode, but **ESC** cannot be used to look at the previous instruction due to the complexity of the variable length instruction set on x86-64. This restriction is similar to the VAX restriction.

## Examples

The following examples illustrate the command on each OpenVMS platform.

IA-64 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.

## 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 IA-64 and Alpha, the same is true for the commands that are specific to this implementation, as follow:

- **;Q**
- **;C**

- `;D`
- `;H`
- `;I`
- `;T` (IA-64 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.

IA-64 and Alpha example:

```
10000/00083089      ❶  
00010004/00000000    ❷  
00010008/00030000    ❸  
00030000/23DEFFE0
```

- 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.

## ;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?.

For both XDELTA and 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 IA-64, Alpha, and x86-64, the format of the display is shown in the following example:

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

- On IA-64 and Alpha systems, if the interrupt priority level (IPL) has changed, the new IPL is printed (XDELTA only). Also on IA-64 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 CUID of the processor where the break was taken is also displayed.

On IA-64, Alpha, and x86-64, 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
```

## 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 (IA-64 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

**;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 IA-64 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 00000200 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
```

❶  
❷  
❸

```

00000000 00000000 00000000 00000000 ..... : 800000D0
00000000 00000000 00000000 00000000 ..... : 800000E0
00000000 00000000 00000000 00000000 ..... : 800000F0
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.

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 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 (IA-64 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 (IA-64 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 IA-64 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.

Using **nn;L** will display an image identified by the sequence number. This is useful if the full list scrolls off the screen.

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.

On x86-64, **1;L** will display a 1-line version of **;L**.

## Examples

The following examples illustrate the command on each platform.

The following IA-64 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 0 selects `SYS$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 | SYS\$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
```

The next example is taken from an x86-64 processor system:

;**L**

| Seq# | LDRISD            | Image Name               | Base               | End                | Link              |
|------|-------------------|--------------------------|--------------------|--------------------|-------------------|
|      |                   | End                      |                    |                    |                   |
| 0040 | FFFFFFFF.8167E200 | SYS\$DMDRIVER            |                    |                    |                   |
| 0    | FFFFFFFF.8167E338 | Read Write               | FFFFFFFF.8011FC00  | FFFFFFFF.8011FC10  | 00000000.00002000 |
|      | 00000000.00002010 |                          |                    |                    |                   |
| 1    | FFFFFFFF.8167E388 | Read                     | FFFFF8300.111EF400 | FFFFF8300.111EFC20 | 00000000.80000000 |
|      | 00000000.80000820 |                          |                    |                    |                   |
| 2    | FFFFFFFF.8167E3D8 | Read Execute             | FFFFF8300.111EFD00 | FFFFF8300.111F1C10 | 00000000.80002000 |
|      | 00000000.80003F10 |                          |                    |                    |                   |
| 3    | FFFFFFFF.8167E428 | Read Fixed               | FFFFF8300.111F3D00 | FFFFF8300.111F3EA0 | 00000000.80006000 |
|      | 00000000.800061A0 |                          |                    |                    |                   |
| 4    | FFFFFFFF.8167E478 | Read Write               | FFFFFFFF.8011FE00  | FFFFFFFF.80120316  | 00000000.00004000 |
|      | 00000000.00004516 |                          |                    |                    |                   |
| 7    | FFFFFFFF.8167E568 | Read Execute             | FFFFFFFF.862BE800  | FFFFFFFF.862BE8C0  | 00000000.00006000 |
|      | 00000000.000060C0 |                          |                    |                    |                   |
| 003E | FFFFFFFF.81662EC0 | SYS\$TTDRIVER            |                    |                    |                   |
| 0    | FFFFFFFF.81662FF8 | Read                     | FFFFF8300.111C4000 | FFFFF8300.111C4B28 | 00000000.80000000 |
|      | 00000000.80000B28 |                          |                    |                    |                   |
| 1    | FFFFFFFF.81663048 | Read Execute             | FFFFF8300.111C4C00 | FFFFF8300.111EBB78 | 00000000.80002000 |
|      | 00000000.80028F78 |                          |                    |                    |                   |
| 2    | FFFFFFFF.81663098 | Read Fixed               | FFFFF8300.111EEC00 | FFFFF8300.111EF318 | 00000000.8002C000 |
|      | 00000000.8002C718 |                          |                    |                    |                   |
| 3    | FFFFFFFF.816630E8 | Read Write               | FFFFFFFF.8011EE00  | FFFFFFFF.8011FAF8  | 00000000.00002000 |
|      | 00000000.00002CF8 |                          |                    |                    |                   |
| 6    | FFFFFFFF.816631D8 | Read Execute             | FFFFFFFF.862BE400  | FFFFFFFF.862BE750  | 00000000.00004000 |
|      | 00000000.00004350 |                          |                    |                    |                   |
| 003C | FFFFFFFF.816770C0 | SYS\$ISA_SUPPORT         |                    |                    |                   |
| 0    | FFFFFFFF.816771F8 | Read Write               | FFFFFFFF.8011E400  | FFFFFFFF.8011E404  | 00000000.00002000 |
|      | 00000000.00002004 |                          |                    |                    |                   |
| 1    | FFFFFFFF.81677248 | Read                     | FFFFF8300.111BF900 | FFFFF8300.111BFD20 | 00000000.80000000 |
|      | 00000000.80000420 |                          |                    |                    |                   |
| 2    | FFFFFFFF.81677298 | Read Execute             | FFFFF8300.111BFE00 | FFFFF8300.111C26E8 | 00000000.80002000 |
|      | 00000000.800048E8 |                          |                    |                    |                   |
| 3    | FFFFFFFF.816772E8 | Read Fixed               | FFFFF8300.111C3E00 | FFFFF8300.111C3FD0 | 00000000.80006000 |
|      | 00000000.800061D0 |                          |                    |                    |                   |
| 4    | FFFFFFFF.81677338 | Read Write               | FFFFFFFF.8011E600  | FFFFFFFF.8011ECAD  | 00000000.00004000 |
|      | 00000000.000046AD |                          |                    |                    |                   |
| 7    | FFFFFFFF.81677428 | Read Execute             | FFFFFFFF.862BE200  | FFFFFFFF.862BE290  | 00000000.00006000 |
|      | 00000000.00006090 |                          |                    |                    |                   |
| 003A | FFFFFFFF.81625900 | SYS\$PCI_SUPPORT         |                    |                    |                   |
| 0    | FFFFFFFF.81625A38 | Read                     | FFFFF8300.111AA400 | FFFFF8300.111AB040 | 00000000.80000000 |
|      | 00000000.80000C40 |                          |                    |                    |                   |
| 1    | FFFFFFFF.81625A88 | Read Execute             | FFFFF8300.111AB100 | FFFFF8300.111BBC48 | 00000000.80002000 |
|      | 00000000.80012B48 |                          |                    |                    |                   |
| 2    | FFFFFFFF.81625AD8 | Read Fixed               | FFFFF8300.111BF100 | FFFFF8300.111BF830 | 00000000.80016000 |
|      | 00000000.80016730 |                          |                    |                    |                   |
| 3    | FFFFFFFF.81625B28 | Read Write               | FFFFFFFF.8011CA00  | FFFFFFFF.8011E3DB  | 00000000.00002000 |
|      | 00000000.000039DB |                          |                    |                    |                   |
| 6    | FFFFFFFF.81625C18 | Read Execute             | FFFFFFFF.862BDE00  | FFFFFFFF.862BE020  | 00000000.00004000 |
|      | 00000000.00004220 |                          |                    |                    |                   |
| 0038 | FFFFFFFF.816243C0 | VMS_EXTENSION            |                    |                    |                   |
| 0    | FFFFFFFF.81624500 | Read                     | FFFFF8300.11077A00 | FFFFF8300.11077B40 | 00000000.80000000 |
|      | 00000000.80000140 |                          |                    |                    |                   |
| 1    | FFFFFFFF.81624550 | Read Execute             | FFFFF8300.111A6300 | FFFFF8300.111A9970 | 00000000.80002000 |
|      | 00000000.80005670 |                          |                    |                    |                   |
| 2    | FFFFFFFF.816245A0 | Read Fixed               | FFFFF8300.111AA300 | FFFFF8300.111AA370 | 00000000.80006000 |
|      | 00000000.80006070 |                          |                    |                    |                   |
| 3    | FFFFFFFF.816245F0 | Read Write               | FFFFFFFF.8011C800  | FFFFFFFF.8011C810  | 00000000.00002000 |
|      | 00000000.00002010 |                          |                    |                    |                   |
| 7    | FFFFFFFF.81624730 | Read Execute             | FFFFFFFF.862BDC00  | FFFFFFFF.862BDCA0  | 00000000.00006000 |
|      | 00000000.000060A0 |                          |                    |                    |                   |
| 0036 | FFFFFFFF.81623D00 | SYSINITX                 |                    |                    |                   |
| 0    | FFFFFFFF.81623E40 | Read Write               | FFFFFFFF.800FDE00  | FFFFFFFF.800FDE40  | 00000000.00002000 |
|      | 00000000.00002040 |                          |                    |                    |                   |
| 1    | FFFFFFFF.81623E90 | Read Write               | FFFFFFFF.80108A00  | FFFFFFFF.80108A27  | 00000000.00004000 |
|      | 00000000.00004027 |                          |                    |                    |                   |
| 2    | FFFFFFFF.81623EE0 | Read                     | FFFFFFFF.862BD400  | FFFFFFFF.862BD420  | 00000000.00006000 |
|      | 00000000.00006020 |                          |                    |                    |                   |
| 3    | FFFFFFFF.81623F30 | Read Execute             | FFFFF8300.11141500 | FFFFF8300.111417C8 | 00000000.80000000 |
|      | 00000000.800002C8 |                          |                    |                    |                   |
| 4    | FFFFFFFF.81623F80 | Read Write Execute Fixed | FFFFF8300.11143500 | FFFFF8300.11143530 | 00000000.80002000 |
|      | 00000000.80002030 |                          |                    |                    |                   |
| 5    | FFFFFFFF.81623FD0 | Read Fixed               | FFFFF8300.11145500 | FFFFF8300.11145538 | 00000000.80004000 |
|      | 00000000.80004038 |                          |                    |                    |                   |
| 6    | FFFFFFFF.81624020 | Read                     | FFFFF8300.11145600 | FFFFF8300.11147BE0 | 00000000.80006000 |
|      | 00000000.800085E0 |                          |                    |                    |                   |

|      |                   |                |         |                    |                    |                    |                   |
|------|-------------------|----------------|---------|--------------------|--------------------|--------------------|-------------------|
| 7    | FFFFFFFF.81624070 | Read           | Execute | FFFFF8300.11147C00 | FFFFF8300.1119B5B0 | 00000000.8000A000  |                   |
|      | 00000000.8005D9B0 |                |         |                    |                    |                    |                   |
| 8    | FFFFFFFF.816240C0 | Read           | Fixed   | FFFFF8300.111A3C00 | FFFFF8300.111A62A8 | 00000000.80066000  |                   |
|      | 00000000.800686A8 |                |         |                    |                    |                    |                   |
| 9    | FFFFFFFF.81624110 | Read           | Write   | FFFFFFFF.80108C00  | FFFFFFFF.8011C47B  | 00000000.00008000  |                   |
|      | 00000000.0001B87B |                |         |                    |                    |                    |                   |
| A    | FFFFFFFF.81624160 | Read           | Write   | FFFFFFFF.873FA000  | FFFFFFFF.873FA0A4  | 00000000.0001C000  |                   |
|      | 00000000.0001C0A4 |                |         |                    |                    |                    |                   |
| B    | FFFFFFFF.816241B0 | Read           | Write   | Execute            | FFFFFFFF.7FF0E000  | FFFFFFFF.7FF0E3F8  | 00000000.8006A000 |
|      | 00000000.8006A3F8 |                |         |                    |                    |                    |                   |
| C    | FFFFFFFF.81624200 | Read           | Fixed   | FFFFFFFF.7FF10000  | FFFFFFFF.7FF10050  | 00000000.8006C000  |                   |
|      | 00000000.8006C050 |                |         |                    |                    |                    |                   |
| D    | FFFFFFFF.81624250 | Read           | Write   | FFFFFFFF.8011C600  | FFFFFFFF.8011C60C  | 00000000.0001E000  |                   |
|      | 00000000.0001E00C |                |         |                    |                    |                    |                   |
| E    | FFFFFFFF.816242A0 | Read           |         | FFFFF8300.11077400 | FFFFF8300.11077980 | 00000000.8006E000  |                   |
|      | 00000000.8006E580 |                |         |                    |                    |                    |                   |
| F    | FFFFFFFF.816242F0 | Read           | Execute | FFFFFFFF.862BD600  | FFFFFFFF.862BDA60  | 00000000.00020000  |                   |
|      | 00000000.00020460 |                |         |                    |                    |                    |                   |
| 0034 | FFFFFFFF.81623640 | SYS\$LOGINOUT  |         |                    |                    |                    |                   |
| 0    | FFFFFFFF.81623780 | Read           | Write   | FFFFFFFF.800FD400  | FFFFFFFF.800FD420  | 00000000.00002000  |                   |
|      | 00000000.00002020 |                |         |                    |                    |                    |                   |
| 1    | FFFFFFFF.816237D0 | Read           | Write   | FFFFFFFF.800FD600  | FFFFFFFF.800FD62A  | 00000000.00004000  |                   |
|      | 00000000.0000402A |                |         |                    |                    |                    |                   |
| 2    | FFFFFFFF.81623820 | Read           |         | FFFFF8300.11072600 | FFFFF8300.11074B38 | 00000000.80000000  |                   |
|      | 00000000.80002538 |                |         |                    |                    |                    |                   |
| 3    | FFFFFFFF.81623870 | Read           | Write   | FFFFFFFF.800FD800  | FFFFFFFF.800FD81C  | 00000000.00006000  |                   |
|      | 00000000.0000601C |                |         |                    |                    |                    |                   |
| 4    | FFFFFFFF.816238C0 | Read           | Write   | FFFFFFFF.800FDA00  | FFFFFFFF.800FDA18  | 00000000.00008000  |                   |
|      | 00000000.00008018 |                |         |                    |                    |                    |                   |
| 5    | FFFFFFFF.81623910 | Read           |         | FFFFF8300.11074C00 | FFFFF8300.11077128 | 00000000.80004000  |                   |
|      | 00000000.80006528 |                |         |                    |                    |                    |                   |
| 6    | FFFFFFFF.81623960 | Read           |         | FFFFFFFF.862BA400  | FFFFFFFF.862BC860  | 00000000.0000A000  |                   |
|      | 00000000.0000C460 |                |         |                    |                    |                    |                   |
| 7    | FFFFFFFF.816239B0 | Read           | Execute | FFFFF8300.11078000 | FFFFF8300.1112CFA9 | 00000000.80008000  |                   |
|      | 00000000.800BCFA9 |                |         |                    |                    |                    |                   |
| 8    | FFFFFFFF.81623A00 | Read           | Fixed   | FFFFF8300.1113E000 | FFFFF8300.11141428 | 00000000.800CE000  |                   |
|      | 00000000.800D1428 |                |         |                    |                    |                    |                   |
| 9    | FFFFFFFF.81623A50 | Read           | Write   | FFFFFFFF.800FE000  | FFFFFFFF.80108978  | 00000000.0000E000  |                   |
|      | 00000000.00018978 |                |         |                    |                    |                    |                   |
| A    | FFFFFFFF.81623AA0 | Read           | Write   | FFFFFFFF.873F8000  | FFFFFFFF.873F80A4  | 00000000.0001A000  |                   |
|      | 00000000.0001A0A4 |                |         |                    |                    |                    |                   |
| B    | FFFFFFFF.81623AF0 | Read           | Write   | Execute            | FFFFFFFF.7FF2C000  | FFFFFFFF.7FF2C3F8  | 00000000.800D2000 |
|      | 00000000.800D23F8 |                |         |                    |                    |                    |                   |
| C    | FFFFFFFF.81623B40 | Read           | Fixed   | FFFFFFFF.7FF2E000  | FFFFFFFF.7FF2E050  | 00000000.800D4000  |                   |
|      | 00000000.800D4050 |                |         |                    |                    |                    |                   |
| D    | FFFFFFFF.81623B90 | Read           | Write   | FFFFFFFF.800FDC00  | FFFFFFFF.800FDC40  | 00000000.0001C000  |                   |
|      | 00000000.0001C040 |                |         |                    |                    |                    |                   |
| E    | FFFFFFFF.81623BE0 | Read           |         | FFFFF8300.11077200 | FFFFF8300.11077388 | 00000000.800D6000  |                   |
|      | 00000000.800D6188 |                |         |                    |                    |                    |                   |
| F    | FFFFFFFF.81623C30 | Read           | Execute | FFFFFFFF.862BCA00  | FFFFFFFF.862BD340  | 00000000.0001E000  |                   |
|      | 00000000.0001E940 |                |         |                    |                    |                    |                   |
| 0032 | FFFFFFFF.816230C0 | SYS\$DIRECTORY |         |                    |                    |                    |                   |
| 0    | FFFFFFFF.81623200 | Read           |         | FFFFFFFF.862B9800  | FFFFFFFF.862B9AC0  | 00000000.00002000  |                   |
|      | 00000000.000022C0 |                |         |                    |                    |                    |                   |
| 1    | FFFFFFFF.81623250 | Read           | Execute | FFFFF8300.10F6EB00 | FFFFF8300.10F6F238 | 00000000.80000000  |                   |
|      | 00000000.80000738 |                |         |                    |                    |                    |                   |
| 2    | FFFFFFFF.816232A0 | Read           | Execute | Fixed              | FFFFF8300.10F70B00 | FFFFF8300.10FE22E1 | 00000000.80002000 |
|      | 00000000.800737E1 |                |         |                    |                    |                    |                   |
| 3    | FFFFFFFF.816232F0 | Read           | Fixed   | FFFFF8300.10FECB00 | FFFFF8300.10FEF2A8 | 00000000.8007E000  |                   |
|      | 00000000.800807A8 |                |         |                    |                    |                    |                   |
| 4    | FFFFFFFF.81623340 | Read           | Write   | FFFFFFFF.800F2000  | FFFFFFFF.800F624B  | 00000000.00004000  |                   |
|      | 00000000.0000824B |                |         |                    |                    |                    |                   |
| 5    | FFFFFFFF.81623390 | Read           | Write   | FFFFFFFF.800F6400  | FFFFFFFF.800FCECC  | 00000000.0000A000  |                   |
|      | 00000000.00010ACC |                |         |                    |                    |                    |                   |
| 6    | FFFFFFFF.816233E0 | Read           | Write   | FFFFFFFF.800FD000  | FFFFFFFF.800FD018  | 00000000.00012000  |                   |
|      | 00000000.00012018 |                |         |                    |                    |                    |                   |
| 7    | FFFFFFFF.81623430 | Read           | Write   | FFFFFFFF.800FD200  | FFFFFFFF.800FD26C  | 00000000.00014000  |                   |
|      | 00000000.0001406C |                |         |                    |                    |                    |                   |
| 8    | FFFFFFFF.81623480 | Read           | Execute | FFFFF8300.10FEF300 | FFFFF8300.110643A8 | 00000000.80082000  |                   |
|      | 00000000.800F70A8 |                |         |                    |                    |                    |                   |
| 9    | FFFFFFFF.816234D0 | Read           | Fixed   | FFFFF8300.1106D300 | FFFFF8300.1106DF58 | 00000000.80100000  |                   |
|      | 00000000.80100C58 |                |         |                    |                    |                    |                   |
| A    | FFFFFFFF.81623520 | Read           |         | FFFFF8300.1106E000 | FFFFF8300.11072538 | 00000000.80102000  |                   |
|      | 00000000.80106538 |                |         |                    |                    |                    |                   |
| B    | FFFFFFFF.81623570 | Read           | Execute | FFFFFFFF.862B9C00  | FFFFFFFF.862BA290  | 00000000.00016000  |                   |
|      | 00000000.00016690 |                |         |                    |                    |                    |                   |
| 0030 | FFFFFFFF.81622C40 | SYS\$LDLDR_DYN |         |                    |                    |                    |                   |
| 0    | FFFFFFFF.81622D78 | Read           | Write   | FFFFFFFF.800ED200  | FFFFFFFF.800ED23C  | 00000000.00002000  |                   |
|      | 00000000.0000203C |                |         |                    |                    |                    |                   |
| 1    | FFFFFFFF.81622DC8 | Read           |         | FFFFF8300.10F4BF00 | FFFFF8300.10F4DDF8 | 00000000.80000000  |                   |
|      | 00000000.80001EF8 |                |         |                    |                    |                    |                   |

## Chapter 4. DELTA/XDELTA Commands

```

2 FFFFFFFF.81622E18 Read      Execute      FFFF8300.10F4DE00  FFFF8300.10F6B2F8  00000000.80002000
00000000.8001F4F8
3 FFFFFFFF.81622E68 Read      Fixed FFFF8300.10F6DE00  FFFF8300.10F6EA98  00000000.80022000
00000000.80022C98
4 FFFFFFFF.81622EB8 Read Write      FFFFFFFF.800ED400  FFFFFFFF.800F1EB9  00000000.00004000
00000000.00008AB9
8 FFFFFFFF.81622FF8 Read      Execute      FFFFFFFF.862B9600  FFFFFFFF.862B96B0  00000000.0000C000
00000000.0000C0B0
002E FFFFFFFF.81622800 MESSAGE_ROUTINES
0 FFFFFFFF.81622940 Read      FFFF8300.10F22700  FFFF8300.10F23420  00000000.80000000
00000000.80000D20
1 FFFFFFFF.81622990 Read      Execute      FFFF8300.10F23500  FFFF8300.10F48A08  00000000.80002000
00000000.80027508
2 FFFFFFFF.816229E0 Read      Fixed FFFF8300.10F4B500  FFFF8300.10F4BE08  00000000.8002A000
00000000.8002A908
3 FFFFFFFF.81622A30 Read Write      FFFFFFFF.800EC600  FFFFFFFF.800ED200  00000000.00002000
00000000.00002C00
4 FFFFFFFF.81622A80 Read Write      FFFFFFFF.873F4000  FFFFFFFF.873F4124  00000000.00004000
00000000.00004124
5 FFFFFFFF.81622AD0 Read Write Execute      FFFFFFFF.7FF50000  FFFFFFFF.7FF50710  00000000.8002C000
00000000.8002C710
6 FFFFFFFF.81622B20 Read      Fixed FFFFFFFF.7FF52000  FFFFFFFF.7FF52098  00000000.8002E000
00000000.8002E098
7 FFFFFFFF.81622B70 Read      Execute      FFFFFFFF.862B9200  FFFFFFFF.862B94D0  00000000.00006000
00000000.000062D0

```

### 4;L

| Seq# | LDRISD            | Image Name            | Base               | End                | Link              |
|------|-------------------|-----------------------|--------------------|--------------------|-------------------|
| 0004 | FFFFFFF.81601D40  | SYS\$PLATFORM_SUPPORT |                    |                    |                   |
| 0    | FFFFFFF.81601E80  | Read Write            | FFFFFFF.8001B000   | FFFFFFF.8001B128   | 00000000.00002000 |
| 1    | FFFFFFF.81601ED0  | Read                  | FFFFF8300.1060D300 | FFFFF8300.106116B0 | 00000000.80000000 |
| 2    | FFFFFFF.81601F20  | Read                  | FFFFF8300.10611700 | FFFFF8300.10611850 | 00000000.80006000 |
| 3    | FFFFFFF.81601F70  | Read Execute          | FFFFF8300.10611900 | FFFFF8300.10654198 | 00000000.80008000 |
| 4    | FFFFFFF.81601FC0  | Read Fixed            | FFFFF8300.1065B900 | FFFFF8300.1065D3B0 | 00000000.80052000 |
| 5    | FFFFFFF.81602010  | Read Write            | FFFFFFF.8001B200   | FFFFFFF.800406E0   | 00000000.00004000 |
| 8    | FFFFFFF.81602100  | Read                  | FFFFF8300.1065D400 | FFFFF8300.1065D450 | 00000000.80058000 |
| 9    | FFFFFFF.81602150  | Read Execute          | FFFFFFF.86250A00   | FFFFFFF.86251240   | 00000000.0002A000 |
| A    | FFFFFFF.816021A0  | Read                  | FFFFF8300.168C8000 | FFFFF8300.168D33D8 | 00000000.8005A000 |
|      | 00000000.800653D8 | Symbol Vector         | FFFFFFF.86250A00   |                    |                   |

### 1;L

Loaded Image List:

| Seq | Image Name                | Base               | End                | Link              | Base |
|-----|---------------------------|--------------------|--------------------|-------------------|------|
| 50  | SYS\$SRDRIVER             | FFFFF8300.111D0C00 | FFFFF8300.111D88F8 | 00000000.80000000 |      |
| 4E  | SYS\$DMDRIVER             | FFFFF8300.111CA900 | FFFFF8300.111CDDA0 | 00000000.80000000 |      |
| 4C  | SYS\$TTDRIVER             | FFFFF8300.1119E100 | FFFFF8300.111C2688 | 00000000.80000000 |      |
| 4A  | SYS\$ISA_SUPPORT          | FFFFF8300.11197F00 | FFFFF8300.1119A9C8 | 00000000.80000000 |      |
| 48  | SYS\$PCI_SUPPORT          | FFFFF8300.11181700 | FFFFF8300.11192378 | 00000000.80000000 |      |
| 46  | <SYS\$LDR>TR\$DEBUG       | FFFFF8300.1117B500 | FFFFF8300.1117D7F0 | 00000000.80000000 |      |
| 44  | <SYS\$LDR>TQ\$DEBUG       | FFFFF8300.11177300 | FFFFF8300.111788F0 | 00000000.80000000 |      |
| 42  | <SYS\$LDR>IO\$DEBUG       | FFFFF8300.11173100 | FFFFF8300.11174420 | 00000000.80000000 |      |
| 40  | SWISS\$DEBUG              | FFFFF8300.1116CF00 | FFFFF8300.1116FD28 | 00000000.80000000 |      |
| 3E  | ACME                      | FFFFF8300.11154B00 | FFFFF8300.111682B0 | 00000000.80000000 |      |
| 3C  | SYS\$MME_SERVICES         | FFFFF8300.11150A00 | FFFFF8300.11152748 | 00000000.80000000 |      |
| 3A  | SYS\$LDR_DYN              | FFFFF8300.1112BD00 | FFFFF8300.11147F30 | 00000000.80000000 |      |
| 38  | SYS\$IPC_SERVICES         | FFFFF8300.1106E800 | FFFFF8300.11114461 | 00000000.80000000 |      |
| 36  | MULTIPATH                 | FFFFF8300.1105A200 | FFFFF8300.1106A930 | 00000000.80000000 |      |
| 34  | SYS\$UTC_SERVICES         | FFFFF8300.11054000 | FFFFF8300.11057658 | 00000000.80000000 |      |
| 32  | SYS\$TRANSACTION_SERVICES | FFFFF8300.11002C00 | FFFFF8300.110419E0 | 00000000.80018000 |      |
| 30  | SYSLICENSE                | FFFFF8300.10FD2700 | FFFFF8300.10FE5F78 | 00000000.80006000 |      |
| 2E  | MESSAGE_ROUTINES          | FFFFF8300.10FA3C00 | FFFFF8300.10FC93F8 | 00000000.80000000 |      |
| 2C  | SYS\$VM                   | FFFFF8300.10E97D00 | FFFFF8300.10F81139 | 00000000.80000000 |      |
| 2A  | SYSGETSYI                 | FFFFF8300.10E7D700 | FFFFF8300.10E90A30 | 00000000.80000000 |      |
| 28  | SECURITY_MON              | FFFFF8300.10E18800 | FFFFF8300.10E6F258 | 00000000.80000000 |      |
| 26  | IMAGE_MANAGEMENT          | FFFFF8300.10DD1200 | FFFFF8300.10E0E350 | 00000000.80000000 |      |
| 24  | RMS                       | FFFFF8300.10C34400 | FFFFF8300.10D9CAC0 | 00000000.80002000 |      |
| 22  | F11BXQP                   | FFFFF8300.10B76C00 | FFFFF8300.10C18058 | 00000000.80000000 |      |

|    |                            |                   |                   |                   |
|----|----------------------------|-------------------|-------------------|-------------------|
| 20 | LOGICAL_NAMES              | FFFF8300.10B5A700 | FFFF8300.10B728E8 | 00000000.80000000 |
| 1E | SHELL8K                    | FFFF8300.10B52400 | FFFF8300.10B57D38 | 00000000.80000000 |
| 1C | LOCKING                    | FFFF8300.10B15900 | FFFF8300.10B4A3E8 | 00000000.80000000 |
| 1A | PROCESS_MANAGEMENT_MON     | FFFF8300.10A43200 | FFFF8300.10AF5879 | 00000000.80000000 |
| 18 | SYSDEVICE                  | FFFF8300.10A32F00 | FFFF8300.10A3E4D0 | 00000000.80000000 |
| 16 | IO_ROUTINES_MON            | FFFF8300.1096E900 | FFFF8300.10A0FFD0 | 00000000.80000000 |
| 14 | EXCEPTION_MON              | FFFF8300.10911000 | FFFF8300.10965608 | 00000000.80000000 |
| 12 | EXEC_INIT                  | FFFF8300.108B2E00 | FFFF8300.10900A78 | 00000000.80000000 |
| 10 | SYS\$OPDRIVER              | FFFF8300.108A6B00 | FFFF8300.108AE5D0 | 00000000.80000000 |
| 0E | SYSTEM_DEBUG               | FFFF8300.1081D200 | FFFF8300.10891769 | 00000000.80000000 |
| 0C | SYSTEM_SYNCHRONIZATION_UNI | FFFF8300.107EC300 | FFFF8300.108112F0 | 00000000.80000000 |
| 0A | SYSTEM_PRIMITIVES_6        | FFFF8300.10725B00 | FFFF8300.107CBA40 | 00000000.80000000 |
| 08 | SYS\$ACPI                  | FFFF8300.10676300 | FFFF8300.106F83B0 | 00000000.80000000 |
| 06 | ERRORLOG                   | FFFF8300.1066E000 | FFFF8300.106734D0 | 00000000.80000000 |
| 04 | SYS\$PLATFORM_SUPPORT      | FFFF8300.10610200 | FFFF8300.1065D808 | 00000000.80000000 |
| 02 | SYS\$BASE_IMAGE            | FFFF8300.10602100 | FFFF8300.1060CF90 | 00000000.80000000 |
| 00 | SYS\$PUBLIC_VECTORS        | FFFF8300.10600000 | FFFF8300.10600028 | 00000000.80000000 |

## **;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.

IA-64 example:

```

G0BF5D60, 0;X                                ❶
G0BF5D60
X0+60;B                                       ❷
  1 00000060                                  ❸
;P                                           ❹
Brk 1 at X0+00000060 on CPU 0
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                                           ❶
  1 00030010                                  ❷
;P                                           ❸
Brk 1 at 00030010
00030010!          STQ          R26, #X0008 (SP)

```

- 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.

## **;Q – Validate Queue (IA-64 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 (IA-64 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 IA-64 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 (IA-64 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
```

In the following example the command is used with the current location pointer after following a jump instruction to a new address.

```
FFFF8300.108B998C!movq    %rax, (%rbx) .;W
Seq#  LDRISD      Image Name                               Base      End      Offset
0012  FFFFFFFF.81604480 EXEC_INIT
      2 FFFFFFFF.81604658 Read      Execute    FFFF8300.1088C700  FFFF8300.108DFA28  00000000.8003328C
```

## ;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 IA-64 and Alpha, a parameter for modifying the default offset of  $10000_{16}$ . The valid range is 1 to FFFFFFFF.

## Description

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 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 all platforms, the default offset is  $100000_{16}$ , which can be modified.

## Examples

The following examples illustrate the command on each platform.

Alpha example:

```
30000,0;X
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.

## 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 IA-64, the subroutine call instruction is `br.call`.

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

On x86-64, the subroutine call instructions is `CALLQ`.

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:

```
Step-over 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 IA-64 and Alpha, the CPU ID is displayed as a decimal number with no leading zeros.

## Examples

The following examples illustrate the command on each OpenVMS platform.

IA-64 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
```

- 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.

- ③ Program execution continues using ;**P**.
- ④ 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).
- ⑤ The next instruction is a subroutine call (BSR). The subroutine is stepped over using the **O** command.
- ⑥ 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.

## 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 IA-64, 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.

---

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

IA-64 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 0000061. 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 0000062. The instruction at this address is a Move Application Register. Step execution is then continued using the **S** command.
- ❸ The instruction at offset 0000070 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.



# Appendix A. Sample DELTA Debug Session on IA-64

This appendix gives an example of how you would use DELTA to debug a program executing on OpenVMS IA-64. 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, "Listing File for C Example Program"* shows the source and machine listing files for the example C program.
- *Section A.2, "Example DELTA Debugging Session on IA-64"* 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, "Source Listing for IA-64 Debugging Example"*—C source code
- *Section A.1.2, "Machine Code Listing for IA-64 Debugging Example"*—Machine code

See *Section A.2, "Example DELTA Debugging Session on IA-64"* for the corresponding sample debugging session using this program.

### A.1.1. Source Listing for IA-64 Debugging Example

*Example A.1, "Listing File for LOG: C Source Code"* 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 IA-64 Debugging Example

*Example A.2, "Listing File for LOG: Machine Code \_MAIN Procedure" through Example A.4, "Listing File for LOG: Machine Code PRINT\_LINE Procedure" 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, ".MAP File for the Sample Program"*. 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 IA-64

The DELTA debugging session on OpenVMS IA-64 for the sample program is shown in the three example segments that follow.

### DELTA Debugging Session Example on IA-64 - 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 IA-64 - Part 1**

```

$ DEFINE LIB$DEBUG SYS$SHARE:DELTA
$ RUN/DEBUG LOG
hp OpenVMS Industry Standard 64 DELTA Debugger
  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
X1 322!      br.call.sptk.many b0 = 0000070 ;; .;B
;P
Brk 1 at X1+00000280
X1+00000280!   cmp4.eq      p7, p6 = r32, r33 R32/000000000 000000001 ;P
Brk 2 at X1+00000322
X1+00000322!   br.call.sptk.many b0 = 0000070 ;; 0
          PID= 37E00401      PRCNAM= SWAPPER LOGINTIM= 00:00:00.00

```

- ❶ DELTA is enabled as the debugger.
- ❷ The example program LOG is invoked with DELTA.
- ❸ 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.
- ❹ 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.)
- ❺ 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.)
- ❻ 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.
- ❼ The function *print\_line* is executed and the output (PID, process name, and login time) is displayed.

## DELTA Debugging Session Example on IA-64 - Part 2

In the second part of the example session, program execution continues and DELTA stop sat 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 IA-64 - Part 2

```

X1+00000330!    br.many      1FFFE0 ;P                                ❶
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                    ❷
                PID= 37E00407   PRCNAM= CLUSTER_SERVER  LOGINTIM= 13:48:49.48
X1+00000330!    br.many      1FFFE0 ;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                                                ❸
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; O
                PID= 37E00408   PRCNAM= CONFIGURE      LOGINTIM= 13:48:52.06
X1+00000330!    br.many      1FFFE0 ;P
Brk 2 at X1+00000322                                                ❹
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; O
                PID= 37E00409   PRCNAM= USB$UCM_SERVER  LOGINTIM= 13:48:54.80
X1+00000330!    br.many      1FFFE0 ;P
Brk 2 at X1+00000322                                                ❺
X1+00000322!    br.call.sptk.many b0 = 0000070 ;; X1 491! ld8 r44 = [r44]
Linefeed                                                         ❻
X1+00000492!    mov          r25 = 000004 ;; Linefeed
X1+000004A0!    br.call.sptk.many b0 = 0000150 .;B                    ❼
;B
1 X1+000004A0
2 X1+00000322
;P                                                                    ❽
Brk 1 at X1+000004A0                                                ❾
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                                                ❿
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.

- ⑩ 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, "Listing File for C Example Program"* shows the source and machine listing files for the example C program
- *Section B.2, "Example DELTA Debugging Session on Alpha"* 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, "Source Listing for Alpha Debugging Example"*—C source code
- *Section B.1.2, "Machine Code Listing for Alpha Debugging Example"*—Machine code

See *Section B.2, "Example DELTA Debugging Session on Alpha"* for the corresponding sample debugging session using this program.

### B.1.1. Source Listing for Alpha Debugging Example

*Example B.1, "Listing File for LOG: C Source Code"* 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     }
```

```
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 **);
4446         int status;
4447         int argc;
4448         void *argv;
4449         void *envp;
4450
4451         decc$main(p1, p2, p3, p4, p5, p6, &argc, &argv, &envp);
4452
4453         status = main4453
4454
4455
4456
4457             );
4458
4459         decc$exit(status);
4460     }
```

## B.1.2. Machine Code Listing for Alpha Debugging Example

*Example B.2, "Listing File for LOG: Machine Code" 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, ".MAP File for the Sample Program"*. 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

| +-----+<br>! Program Section Synopsis !<br>+-----+ |             |          |          |   |       |        |          |          |                  |
|----------------------------------------------------|-------------|----------|----------|---|-------|--------|----------|----------|------------------|
| 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.

- ⑤ 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,#FFFFFF94 O
PID= 00000021 PRCNAM= SWAPPER LOGINTIM= 00:00:00.00
X1+000001B0! BR R31,#FFFFFFE1 ;P
Brk 1 at 00030164
X1+00000164! CMPEQ R0,#X14,R16 R0/ 00000001 ;P
Brk 2 at 000301AC
X1+000001AC! BSR R26,#FFFFFF94 O
PID= 00000024 PRCNAM= ERRFMT LOGINTIM= 16:24:01.03
X1+000001B0! BR R31,#FFFFFFE1 ;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,#FFFFFF94 O
PID= 00000025 PRCNAM= OPCOM LOGINTIM= 16:24:02.56
X1+000001B0! BR R31,#FFFFFFE1 ;P
Brk 2 at 000301AC
X1+000001AC! BSR R26,#FFFFFF94 O
PID= 00000026 PRCNAM= AUDIT_SERVER LOGINTIM=16:24:03.66
X1+000001B0! BR R31,#FFFFFFE1 ;P
Brk 2 at 000301AC
X1+000001AC! BSR R26,#FFFFFF94 X1 84! LDQ R16,#X0040(R2)

```

- ① The ;P command lets you proceed from the breakpoint.
- ② 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.

- ③ The function print\_line is executed, and the output (PID, process name, and login time) is displayed.
- ④ 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

|                   |     |                     |                       |
|-------------------|-----|---------------------|-----------------------|
| <b>Linefeed</b>   |     |                     | ①                     |
| X1+00000088!      | LDL | R18, #X0010 (FP)    | <b>Linefeed</b>       |
| 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,#FFFFFF94
;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 ❸
Exit 00000001
8002228C!      ADDL                R15,SP,SP EXIT ❹

```

- 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.