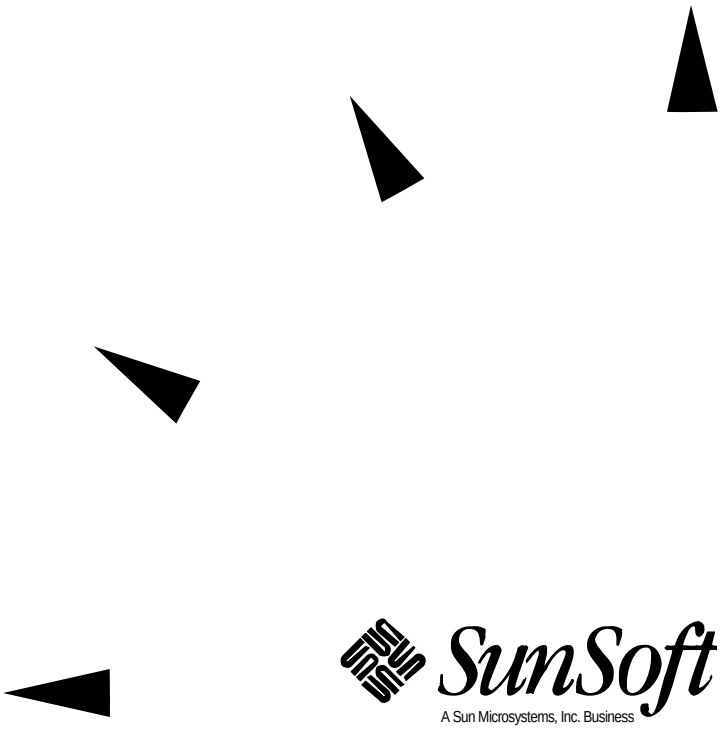
OpenBoot™ 3.x Command Reference Manual



2550 Garcia Avenue
Mountain View, CA 94043
U.S.A.

SunSoft
A Sun Microsystems, Inc. Business

Contents

Tables

Preface

OpenBoot® 3.x *Command Reference* describes how to use Sun™ systems that implement *firmware* that responds as described by *IEEE Standard 1275-1994*.

Who Should Use This Book

This manual is written for all users, from systems designers to systems administrators and end users, who wish to use OpenBoot to configure and debug their systems.

Contents

This manual contains information on using OpenBoot to perform tasks such as:

- Booting the operating system
- Running diagnostics
- Modifying system start-up configuration parameters
- Loading and executing programs
- Troubleshooting

If you want to write Forth programs or if you want to use the more advanced features of this firmware (such as its debugging capabilities), this manual also describes the commands of the OpenBoot Forth Interpreter.

Assumptions

This manual assumes that you are working on a system that uses Version 3.x OpenBoot. Other OpenBoot implementations may use different prompts and/or formatting, and may not support all of the tools and capabilities described in this manual.

How This Book Is Organized

- **Chapter 1, "Overview"**, describes the user interface and other main features of OpenBoot.
- **Chapter 2, "Booting and Testing Your System"**, explains the most common tasks for which OpenBoot is used.
- **Chapter 3, "Setting Configuration Variables"**, details how to perform system administration tasks with NVRAM parameters.
- **Chapter 4, "Using Forth Tools"**, describes both basic and advanced functions of the OpenBoot Forth language.
- **Chapter 5, "Loading and Executing Programs"**, describes how to load and execute programs from various sources (such as Ethernet, disk, or a serial port).
- **Chapter 6, "Debugging"**, describes OpenBoot's debugging capabilities, including the decompiler, the Forth source-level debugger, and breakpoints.
- **Appendix A, "Setting Up a TIP Connection,"**, describes how to connect your system to another system using serial ports.
- **Appendix B, "Building A Bootable Floppy Disk"**, tells you how to create a bootable floppy diskette from which you can load programs or files.
- **Appendix C, "Troubleshooting Guide"**, discusses solutions for typical situations where you cannot boot the operating system.
- **Appendix D, "Forth Word Reference"**, contains all currently-supported OpenBoot Forth commands.

Related Books

A companion document to this manual is:

- *OpenBoot Quick Reference Guide*, p/n 802-3240-10.

For information on OpenBoot FCode, refer to:

- *Writing FCode 2.x Programs*, p/n 801-5123-10

- *Writing FCode 3.x Programs*, p / n 802-3239-10

For information about Open Firmware, see the following manual:

- *IEEE Standard 1275-1994* Standard for Boot (Initialization, Configuration) Firmware, Core Requirements and Practices (IEEE Order Number SH17327. 1-800-678-4333)

For more information about Forth and Forth programming, refer to:

- *Programming Languages - Forth*, American National Standards Institute, Inc.
- *Forth: A Text and Reference*, Mahlon G. Kelly and Nicholas Spies. Prentice Hall, 1986.
- *Starting FORTH*, Leo Brody. FORTH, Inc., second edition, 1987.
- *Forth: The New Model*, Jack Woehr. M & T Books, 1992.
- Forth Interest Group (1-510-89-FORTH)

What Typographic Changes and Symbols Mean

The following table describes the typeface changes and symbols used in this book.

Typeface or Symbol	**Meaning**	**Example**
`AaBbCc123`	The names of commands, files, and directories; on-screen computer output	Edit your `.login` file. Use `ls -a` to list all files. `machine_name% You have mail.`
`AaBbCc123`	What you type, contrasted with on-screen computer output	`machine_name% su` `Password:`
AaBbCc123	Command-line placeholder: replace with a real name or value	To delete a file, type `rm` *filename*.
AaBbCc123	Book titles, new words or terms, or words to be emphasized	Read Chapter 6 in *User's Guide*. These are called *class* options. You *must* be root to do this.
Code samples are included in boxes and may display the following:		
ok	OpenBoot command prompt	ok
%	UNIX C shell prompt	system%
$	UNIX Bourne and Korn shell prompt	system$
#	Superuser prompt, all shells	system#

This manual follows a number of typographic conventions:

- Keys are indicated by their name. For example:

  Press the Return key.

- When you see two key names separated by a dash, press and hold the first key down, then press the second key. For example:

  To enter Control-C, press and hold Control, then press C, then release both keys.

  Although the keyname (i.e. C in the preceding example) is shown in uppercase, the actual keystroke may be lowercase.

- When you see two key names separated by a space, press and release the first key and then press and release the second key. For example:

  To enter Escape B, press and release Escape, then press and release B.

  Although the keyname (i.e. B in the preceding example) is shown in uppercase, the actual keystroke may be lowercase.

- In a command line, square brackets indicate an optional entry and italics indicate an argument that you must replace with the appropriate text. For example:

  `help` [*word*]

- The title line of the portion of the table on the second and succeeding pages contain the notation *(Continued)* to alert you to the fact that the table continues from the preceding page.

  For example, the first portion of such a split table would look like:

Table P-1 Diagnostic Test Command

Command	**Description**
`probe-scsi`	Identify devices attached to a SCSI bus.

while the second portion of the same table would look like:

Table P-2 Diagnostic Test Command *(Continued)*

Command	Description
`test` *device-specifier*	Execute the specified device's self-test method. For example: `test floppy` - test the floppy drive, if installed `test net` - test the network connection

Were this table contained in a single page, it would look like:

Table P-3 Diagnostic Test Commands

Command	Description
`probe-scsi`	Identify devices attached to a SCSI bus.
`test` *device-specifier*	Execute the specified device's self-test method. For example: `test floppy` - test the floppy drive, if installed `test net` - test the network connection

Ordering Sun Documents

The SunDocs Order Desk is a distribution center for Sun Microsystems technical documentation. You can use major credit cards and company purchase orders. You can order documentation in the following ways:

In the U.S.A.	Outside the U.S.A.
Call 1-800-247-0250	Call 1-801-342-3450
Fax 1-801-373-6798	Fax 1-801-373-6798
World Wide Web: `http://www.sun.com/sundocs/catalog.html`	

Sun Welcomes Your Comments

Please use the *Reader Comment Card* that accompanies this document if it is hard-copy. We are interested in improving our documentation and welcome your comments and suggestions.

Even if there is no card (on-line documentation),you can email or fax your comments to us. Please include the part number of your document in the subject line of your email or fax message.

- Email: smcc-docs@sun.com
- Fax: SMCC Document Feedback
  1-415-786-6443

Overview 1

This chapter introduces OpenBoot as defined by *IEEE Standard 1275-1994*. OpenBoot firmware is executed immediately after you turn on your system. The primary tasks of OpenBoot firmware are:

- Test and initialize the system hardware.
- Determine the hardware configuration.
- Boot the operating system from either a mass storage device or from a network.
- Provide interactive debugging facilities for testing hardware and software.

Features of OpenBoot

The OpenBoot architecture provides a significant increase in functionality and portability when compared to proprietary systems of the past. Although this architecture was first implemented by Sun Microsystems as OpenBoot on SPARC® systems, its design is processor-independent. Some notable features of OpenBoot firmware include:

- Plug-in device drivers.

  A plug-in device driver is usually loaded from a plug-in device such as an SBus card. The plug-in device driver can be used to boot the operating system from that device or to display text on the device before the operating

system has activated its own drivers. This feature allows the input and output devices supported by a particular system to evolve without changing the system PROM.

- FCode interpreter.

  Plug-in drivers are written in a *machine-independent* interpreted language called *FCode*. Each OpenBoot system PROM contains an FCode interpreter. Thus, the same device and driver can be used on machines with different CPU instruction sets.

- Device tree.

  The device tree is a data structure describing the devices (permanently installed and plug-in) attached to a system. Both the user and the operating system can determine the hardware configuration of the system by inspecting the device tree.

- Programmable User Interface.

  The OpenBoot *User Interface* is based on the interactive programming language *Forth*. Sequences of user commands can be combined to form complete programs, and this provides a powerful capability for debugging hardware and software.

The User Interface

The User Interface is based on an interactive command interpreter that gives you access to an extensive set of functions for hardware and software development, fault isolation, and debugging. A variety of system users, ranging from end-users to system administrators to system developers, can use these functions.

The User Interface prompt is implementation dependent.

You can enter the OpenBoot environment in the following ways:

- By halting the operating system.
- By executing the Stop-A keystroke sequence.
- By power-cycling the system.

  If your system is not configured to boot automatically, the system will stop at the User Interface.

If automatic booting is configured, you can cause the system to stop at the User Interface by entering the Stop-A key sequence from the keyboard after the display console banner appears but before the system starts booting the operating system.

- When the system hardware detects an error from which it cannot recover. (This is known as a Watchdog Reset.)

The Device Tree

Devices are attached to a host computer through a hierarchy of interconnected buses. OpenBoot represents the interconnected buses and their attached devices as a tree of nodes. Such a tree is called the *device tree*. A node representing the host computer's main physical address bus forms the tree's root node.

Each device node can have:

- **Properties**, which are data structures describing the node and its associated device
- **Methods**, which are the software procedures used to access the device
- **Data**, which are the initial values of the private data used by the methods
- **Children**, which are other device nodes "attached" to a given node and that lie directly below it in the device tree
- A **parent**, which is the node that lies directly above a given node in the device tree.

Nodes with children usually represent buses and their associated controllers, if any. Each such node defines a physical address space that distinguishes the devices connected to the node from one another. Each child of that node is assigned a physical address in the parent's address space.

The physical address generally represents a physical characteristic unique to the device (such as the bus address or the slot number where the device is installed). The use of physical addresses to identify devices prevents device addresses from changing when other devices are installed or removed.

Nodes without children are called leaf nodes and generally represent devices. However, some such nodes represent system-supplied firmware services.

1

Device Path Names, Addresses, and Arguments

OpenBoot deals directly with hardware devices in the system. Each device has a unique name representing the type of device and where that device is located in the system addressing structure. The following example shows a full device path name:

```
/sbus@1f,0/SUNW,fas@e,8800000
```

A full device path name is a series of node names separated by slashes (/). The root of the tree is the machine node, which is not named explicitly but is indicated by a leading slash (/). Each node name has the form:

driver-name@*unit-address*:*device-arguments*

Table 1 describes each of these parameters.

Table 1 Device Path Name Parameters

Path Name Parameter	Description
driver-name	A human-readable string consisting of one to 31 letters, digits and punctuation characters from the set “, . _ + - ” that, ideally, has some mnemonic value. Upper-case and lower-case characters are distinct. In some cases, this name includes the name of the device’s manufacturer and the device’s model name, separated by a comma. Typically, the manufacturer’s upper-case, publicly-listed stock symbol is used as the manufacturer’s name (e.g. SUNW,sd). For built-in devices, the manufacturer’s name is usually omitted (e.g. sbus).
@	Must precede the *address* parameter.
unit-address	A text string representing the physical address of the device in its parent’s address space. The format of the text is bus dependent.
:	Must precede the *arguments* parameter.
device-arguments	A text string, whose format depends on the particular device. It can be used to pass additional information to the device’s software.

The full device path name mimics the hardware addressing used by the system to distinguish between different devices. Thus, you can specify a particular device without ambiguity.

In general, the *unit-address* part of a node name represents an address in the physical address space of its parent. The exact meaning of a particular address depends on the bus to which the device is attached. Consider this example:

```
/sbus@1f,0/esp@0,40000/sd@3,0:a
```

- `1f,0` represents an address on the main system bus, because the SBus is directly attached to the main system bus in this example.
- `0,40000` is an SBus slot number (in other words, `0`) and an offset (in other words, `40000`), because the `esp` device is at offset 40000 on the card in SBus slot 0.
- `3,0` is a SCSI target and logical unit number, because the disk device is attached to a SCSI bus at target 3, logical unit 0.

When specifying a path name, either the *@unit-address* or *driver-name* part of a node name is optional, in which case the firmware tries to pick the device that best matches the given name. If there are several matching nodes, the firmware chooses one (but it may not be the one you want).

For example, using `/sbus/esp@0,40000/sd@3,0` assumes that the system in question has exactly one SBus on the main system bus, making `sbus` as unambiguous an address as `sbus@1f,0`. On the same system, however, `/sbus/esp/sd@3,0` might or might not be ambiguous. Since SBus accepts plug-in cards, there could be more than one `esp` device on the same SBus bus. If there were more than one on the system, using `esp` alone would not specify which one, and the firmware might not choose the one you intended.

As another example, `/sbus/@2,1/sd@3,0` would normally be unambiguous, while `/sbus/scsi@2,1/@3,0` usually would not, since both a SCSI disk device driver and a SCSI tape device driver can use the SCSI target, logical unit address `3,0`.

The `:`*device-arguments* part of the node name is also optional. Once again, in the example:

```
/sbus@1f,0/scsi@2,1/sd@3,0:a
```

the argument for the disk device is `a`. The software driver for this device interprets its argument as a disk partition, so the device path name refers to partition `a` on that disk.

Some implementations also allow you to omit pathname components. So long as the omission does not create any ambiguity, those implementations will select the device that you intended. For example, if our example system had only one `sd` device,

```
/sd:a
```

would identify the same device as the much longer preceding expression.

Device Aliases

A device alias, or simply, alias, is a shorthand representation of a *device path.*

For example, the alias `disk` may represent the complete device path name:

```
/sbus@1f,0/esp@0,40000/sd@3,0:a
```

Systems usually have predefined device aliases for the most commonly-used devices, so you rarely need to type a full device path name.

Table 2 describes the `devalias` command, which is used to examine, create, and change aliases.

Table 2 Examining and Creating Device Aliases

Command	**Description**
`devalias`	Display all current device aliases.
`devalias` *alias*	Display the device path name corresponding to *alias.*
`devalias` *alias device-path*	Define an alias representing *device-path.* If an alias with the same name already exists, the new value supersedes the old.

User-defined aliases are lost after a system reset or power cycle. If you want to create permanent aliases, you can either manually store the `devalias` command in a portion of non-volatile RAM (NVRAM) called *nvramrc*, or use the `nvalias` and `nvunalias` commands. (See Chapter 3, “Setting Configuration Variables” for more details.)

Displaying the Device Tree

You can browse the device tree to examine and modify individual device tree nodes. The device tree browsing commands are similar to the Solaris commands for changing, displaying and listing the current directory in the Solaris directory tree. Selecting a device node makes it the current node.

The User Interface commands for browsing the device tree are shown in Table 3.

Table 3 Commands for Browsing the Device Tree

Command	**Description**
`.properties`	Display the names and values of the current node's properties.
`dev` *device-path*	Choose the indicated device node, making it the current node.
`dev` *node-name*	Search for a node with the given name in the subtree below the current node, and choose the first such node found.
`dev ..`	Choose the device node that is the parent of the current node.
`dev /`	Choose the root machine node.
`device-end`	Leave the device tree.
`"` *device-path*`" find-device`	Choose device node, similar to `dev`.
`ls`	Display the names of the current node's children.
`pwd`	Display the device path name that names the current node.
`see` *wordname*	Decompile the specified word.
`show-devs [`*device-path*`]`	Display all the devices directly beneath the specified device in the device tree. `show-devs` used by itself shows the entire device tree.
`words`	Display the names of the current node's methods.
`"` *device-path*`" select-dev`	Select the specified device and make it the active node.

`.properties` displays the names and values of all the properties in the current node:

```
ok dev /zs@1,f0000000
ok .properties
address                 ffee9000
port-b-ignore-cd
port-a-ignore-cd
keyboard
device_type             serial
slave                   00000001
intr                    0000000c  00000000
interrupts              0000000c
reg                     00000001  f0000000  00000008
name                    zs
ok
```

`dev` sets the current node to the named node so its contents can be viewed. For example, to make the ACME company's SBus device named "ACME,widget" the current node:

```
ok dev /sbus/ACME,widget
```

`find-device` is essentially identical to `dev` differing only in the way the input pathname is passed.

```
ok " /sbus/ACME,widget" find-device
```

Note – After choosing a device node with `dev` or `find-device`, it is *not* in general possible to execute that node's methods because `dev` does not establish the current instance. For a detailed explanation of this issue, refer to *Writing FCode 3.x Programs*.

`show-devs` lists all the devices in the OpenBoot device tree, as shown in the following example:

```
ok show-devs
/SUNW,UltraSPARC@0,0
/sbus@1f,0
/counter-timer@1f,3c00
/virtual-memory
/memory@0,0
/aliases
/options
/openprom
/chosen
/packages
/sbus@1f,0/cgsix@1,0
/sbus@1f,0/lebuffer@0,40000
/sbus@1f,0/dma@0,81000
/sbus@1f,0/SUNW,bpp@e,c800000
/sbus@1f,0/SUNW,hme@e,8c00000
/sbus@1f,0/SUNW,fas@e,8800000
/sbus@1f,0/sc@f,1300000
/sbus@1f,0/zs@f,1000000
/sbus@1f,0/zs@f,1100000
/sbus@1f,0/eeprom@f,1200000
/sbus@1f,0/SUNW,fdtwo@f,1400000
/sbus@1f,0/flashprom@f,0
/sbus@1f,0/auxio@f,1900000
/sbus@1f,0/SUNW,CS4231@d,c000000
/sbus@1f,0/lebuffer@0,40000/le@0,60000
/sbus@1f,0/dma@0,81000/esp@0,80000
/sbus@1f,0/dma@0,81000/esp@0,80000/st
/sbus@1f,0/dma@0,81000/esp@0,80000/sd
/sbus@1f,0/SUNW,fas@e,8800000/st
/sbus@1f,0/SUNW,fas@e,8800000/sd
/openprom/client-services
/packages/disk-label
/packages/obp-tftp
/packages/deblocker
/packages/terminal-emulator
ok
```

Here is an example of the use of `words`:

```
ok dev /zs
ok words
ring-bell      read           remove-abort? install-abort
close          open           abort?        restore
clear           reset          initkbdmouse keyboard-addr mouse
1200baud        setbaud        initport     port-addr
ok
```

Getting Help

Whenever you see the `ok` prompt on the display, you can ask the system for help by typing one of the help commands shown in Table 4.

Table 4 Help Commands

Command	Description
`help`	List main help categories.
`help` *category*	Show help for all commands in the category. Use only the first word of the category description.
`help` *command*	Show help for individual command (where available).

`help`, without any specifier, displays instructions on how to use the help system and lists the available help categories. Because of the large number of commands, help is available only for commands that are used frequently.

If you want to see the help messages for all the commands in a selected category, or, possibly, a list of subcategories, type:

```
ok help category
```

If you want help for a specific command, type:

```
ok help command
```

For example, when you ask for information on the `dump` command, you might see the following message:

```
ok help dump
Category: Memory access
dump ( addr length -- ) display memory at addr for length bytes
ok
```

The above help message first shows that `dump` is a command from the `Memory access` category. The message also shows the format of the command.

Note – In some newer systems, descriptions of additional machine-specific commands are available with the `help` command. Help as described may not be available on all systems.

A Caution About Using Some OpenBoot Commands

If you boot the operating system, exit from the operating system into OpenBoot without resetting the system, then use some OpenBoot commands, the commands might not work as expected. In this case, you may have to power cycle the system to restore normal operation.

For example, suppose you boot the operating system, exit to OpenBoot, then execute the `probe-scsi` command (described in , “Booting and Testing Your System”). You may find that `probe-scsi` fails, and you may not be able to resume the operating system.

To re-execute an OpenBoot command which fails because the operating system has halted, reset the system first, then invoke the command, as shown:

```
ok reset-all
ok probe-scsi
ok
```

1

Booting and Testing Your System 2

This chapter describes the most common tasks that you perform using OpenBoot. These tasks let you:

- Boot your system.
- Run diagnostics.
- Display system information.
- Reset the system.

Booting Your System

The most important function of OpenBoot firmware is to boot the system. Booting is the process of loading and executing a stand-alone program such as an operating system. Booting can either be initiated automatically or by entering a command at the User Interface.

The boot process is controlled by a number of *configuration variables*. (Configuration variables are discussed in detail in Chapter 3, “Setting Configuration Variables”.) The configuration variables that affect the boot process are:

- `auto-boot?`

  This variable controls whether or not the system automatically boots after a system reset or when the power is turned on. This variable is typically `true`.

- `boot-command`

  This variable specifies the command to be executed when `auto-boot?` is `true`. The default value of `boot-command` is `boot` with no command line arguments.

- `diag-switch?`

  This value of this variable affects the value returned by `diagnostic-mode?`. This variable is `false` by default.

- `boot-device`

  This variable contains the name of the default boot device that is used when OpenBoot is not in diagnostic mode.

- `boot-file`

  This variable contains the default boot arguments that are used when OpenBoot is not in diagnostic mode.

- `diag-device`

  This variable contains the name of the default diagnostic mode boot device.

- `diag-file`

  This variable contains the default diagnostic mode boot arguments.

Based on the values of the above configuration variables, the boot process can proceed in a number of different ways. For instance:

- If `auto-boot?` is `true`, the machine will boot from either the default boot device or from the diagnostic boot device depending on whether OpenBoot is in diagnostic mode.
- If `auto-boot?` is `false`, the machine will stop at the OpenBoot User Interface without booting the system. To boot the system, you can do one of the following:
  - Enter the `boot` command without any arguments. The machine will boot from the default boot device using the default boot arguments.
  - Enter the `boot` command with an explicit boot device. The machine will boot from the specified boot device using the default boot arguments.
  - Enter the `boot` command with explicit boot arguments. The machine will use the specified arguments to boot from the default boot device.

- Enter the `boot` command with an explicit boot device and with explicit arguments. The machine will boot from the specified device with the specified arguments.

Booting for the Casual User

Typically, `auto-boot?` will be `true`, `boot-command` will be `boot`, and OpenBoot will not be in diagnostic mode. Consequently, the system will automatically load and execute the program and arguments described by `boot-file` from the device described by `boot-device` when the system is first turned on or following a system reset.

If you want to boot the default program when `auto-boot?` is `false`, simply type:

```
ok boot
```

at the `ok` prompt.

Booting for the Expert User

Booting is the process of loading and executing a client program. The client program is normally an operating system or an operating system's loader program, but `boot` can also be used to load and execute other kinds of programs, such as diagnostics. (For more details about loading programs other than the operating system, see Chapter 5, "Loading and Executing Programs").

Booting usually happens automatically based on the values contained in the configuration variables described above. However, the user can also initiate booting from the User Interface.

OpenBoot performs the following steps during the boot process:

- The firmware may reset the machine if a client program has been executed since the last reset. (The execution of a reset is implementation dependent.)
- A device is selected by parsing the `boot` command line to determine the boot device and the boot arguments to use. Depending on the form of the `boot` command, the boot device and/or argument values may be taken from configuration variables.

- The `bootpath` and `bootargs` properties in the `/chosen` node of the device tree are set with the selected values.
- The selected program is loaded into memory using a protocol that depends on the type of the selected device. For example, a disk boot might read a fixed number of blocks from the beginning of the disk, while a tape boot might read a particular tape file.
- The loaded program is executed. The behavior of the program may be further controlled by the argument string (if any) that was either contained in the selected configuration variable or was passed to the `boot` command on the command line.

Often, the program loaded and executed by the boot process is a *secondary boot program* whose purpose is to load yet another program. This secondary boot program may use a protocol different from that used by OpenBoot to load the secondary boot program. For example, OpenBoot might use the Trivial File Transfer Protocol (TFTP) to load the secondary boot program while the secondary boot program might then use the Network File System (NFS) protocol to load the operating system.

Typical secondary boot programs accept arguments of the form:

filename **`-flags`**

where *filename* is the name of the file containing the operating system and where *-flags* is a list of options controlling the details of the start-up phase of either the secondary boot program, the operating system or both. Please note that, as shown in the `boot` command template immediately below, OpenBoot treats all such text as a single, opaque *arguments* string that has no special meaning to OpenBoot itself; the arguments string is passed unaltered to the specified program.

The `boot` command has the following format:

```
ok boot [device-specifier] [arguments]
```

The optional parameters for the boot command are described in Table 5.

Table 5 Optional boot Command Parameters

Parameter	Description
[*device-specifier*]	The name (full path name or devalias) of the boot device. Typical values include: cdrom (CD-ROM drive) disk (hard disk) floppy (3-1/2" diskette drive) net (Ethernet) tape (SCSI tape) If *device-specifier* is not specified and if diagnostic-mode? returns false, boot uses the device specified by the boot-device configuration variable. If *device-specifier* is not specified and if diagnostic-mode? returns true, boot uses the device specified by the diag-device configuration variable.
[*arguments*]	The name of the program to be booted (e.g. *stand/diag*) and any program arguments. If *arguments* is not specified and if diagnostic-mode? returns false, boot uses the file specified by the boot-file configuration variable. If *arguments* is not specified and if diagnostic-mode? returns true, boot uses the file specified by the diag-file configuration variable.

Note – Most commands (such as boot and test) that require a device name accept either a full device path name or a device alias. In this manual, the term *device-specifier* indicates that either an appropriate device path name or a device alias is acceptable for such commands.

Since a device alias cannot be syntactically distinguished from the *arguments*, OpenBoot resolves this ambiguity as follows:

- If the space-delimited word following boot on the command line begins with /, the word is a device-path and, thus, a *device-specifier*. Any text to the right of this *device-specifier* is included in *arguments*.
- Otherwise, if the space-delimited word matches an existing device alias, the word is a *device-specifier*. Any text to the right of this *device-specifier* is included in *arguments*.
- Otherwise, the appropriate default boot device is used, and any text to the right of boot is included in *arguments*.

Consequently, `boot` command lines have the following possible forms.

```
ok boot
```

With this form, `boot` loads and executes the program specified by the default boot arguments from the default boot device.

```
ok boot device-specifier
```

If `boot` has a single argument that either begins with the character `/` or is the name of a defined `devalias`, `boot` uses the argument as a device specifier. `boot` loads and executes the program specified by the default boot arguments from the specified device.

For example, to explicitly boot from the primary disk, type:

```
ok boot disk
```

To explicitly boot from the primary network device, type:

```
ok boot net
```

If `boot` has a single argument that neither begins with the character `/` nor is the name of a defined `devalias`, `boot` uses all of the remaining text as its arguments.

```
ok boot arguments
```

`boot` loads and executes the program specified by the arguments from the default boot device.

```
ok boot device-specifier arguments
```

If there are at least two space-delimited arguments, and if the first such argument begins with the character / or if it is the name of a defined `devalias`, `boot` uses the first argument as a device specifier and uses all of the remaining text as its arguments. `boot` loads and executes the program specified by the arguments from the specified device.

For all of the above cases, `boot` records the device that it uses in the `bootpath` property of the `/chosen` node. `boot` also records the arguments that it uses in the `bootargs` property of the `/chosen` node.

Device alias definitions vary from system to system. Use the `devalias` command, described in Chapter 1, “Overview”, to obtain the definitions of your system’s aliases.

Running Diagnostics

Several diagnostic routines are available from the User Interface. These on-board tests let you check devices such as the network controller, the floppy disk system, memory, installed SBus cards and SCSI devices, and the system clock.

The value returned by `diagnostic-mode?` controls:

- The selection of the device and file that are used by the `boot` and `load` commands (if the device and file are not explicitly specified as arguments to those commands).
- The extent of the diagnostics performed during power-on self-test, and the (implementation dependent) number of diagnostic messages produced.

OpenBoot will be in diagnostic mode and the `diagnostic-mode?` command will return `true` if at least one of the following conditions is met:

- The configuration variable `diag-switch?` is set to `true`.
- The machine’s diagnostic switch (if any) is “on”.
- Another system-dependent indicator requests extensive diagnostics.

When OpenBoot is in `diagnostic-mode`, the value of `diag-device` is used as the *default boot device* and the value of `diag-file` is used as the *default boot arguments* for the `boot` command.

When OpenBoot is not in `diagnostic-mode`, the value of `boot-device` is used as the *default boot device* and the value of `boot-file` is used as the *default boot arguments* for the `boot` command.

Table 6 lists diagnostic test commands. Not all of these tests are available in all OpenBoot implementations.

Table 6 Diagnostic Test Commands

Command	Description
`probe-scsi`	Identify devices attached to a SCSI bus.
`test` *device-specifier*	Execute the specified device's `selftest` method. For example: `test floppy` - test the floppy drive `test /memory` - test number of megabytes specified in the `selftest-#megs` NVRAM parameter; or test all of memory in diagnostic mode `test net` - test the network connection
`watch-clock`	Test a clock function.
`watch-net`	Monitor a network connection.

Testing the SCSI Bus

To check a SCSI bus for connected devices, type:

```
ok probe-scsi
Target 1
  Unit 0 Disk SEAGATE ST1480 SUN04246266 Copyright (C) 1991 Seagate All rights reserved
Target 3
  Unit 0 Disk SEAGATE ST1480 SUN04245826 Copyright (C) 1991 Seagate All rights reserved

ok
```

The actual response depends on the devices on the SCSI bus.

Testing Installed Devices

To test a single installed device, type:

```
ok test device-specifier
```

In general, if no message is displayed, the test succeeded.

Note – Many devices require the system's `diag-switch?` parameter to be true in order to run this test.

Testing the Diskette Drive

The diskette drive test determines whether or not the diskette drive is functioning properly. For some implementations, a formatted, high-density (HD) disk must be in the diskette drive for this test to succeed.

To test the diskette drive, type:

```
ok test floppy
Testing floppy disk system. A formatted
disk should be in the drive.
Test succeeded.
ok
```

Note – Not all OpenBoot systems include this test word.

To eject the diskette from the diskette drive of a system capable of software-controlled ejection, type:

```
ok eject-floppy
ok
```

Testing Memory

To test memory, type:

```
ok test /memory
Testing 16 megs of memory at addr 4000000 11
ok
```

Note – Not all OpenBoot systems include this test word.

In the preceding example, the first number (4000000) is the base address of the testing, and the following number (11) is the number of megabytes to go.

Testing the Clock

To test the clock function, type:

```
ok watch-clock
Watching the 'seconds' register of the real time clock chip.
It should be ticking once a second.
Type any key to stop.
1
ok
```

The system responds by incrementing a number once a second. Press any key to stop the test.

Note – Not all OpenBoot systems include this test word.

Testing the Network Controller

To test the primary network controller, type:

```
ok test net
Internal Loopback test - (result)
External Loopback test - (result)
ok
```

The system responds with a message indicating the result of the test.

Note – Depending on the particular network controller and the type of network to which your system is attached, various levels of testing are possible. Some such tests may require that the network interface be connected to the network.

Monitoring the Network

To monitor a network connection, type:

```
ok watch-net
Internal Loopback test - succeeded
External Loopback test - succeeded
Looking for Ethernet packets.
'.' is a good packet. 'X' is a bad packet.
Type any key to stop
.....................X.....X..............
ok
```

The system monitors network traffic, displaying "." each time it receives an error-free packet and "X" each time it receives a packet with an error that can be detected by the network hardware interface.

Note – Not all OpenBoot systems include this test word.

Displaying System Information

The User Interface provides one or more commands to display system information. `banner` is provided by all OpenBoot implementations; the remaining commands represent extensions provided by some implementations. These commands, listed in Table 7, let you display the system banner, the Ethernet address for the Ethernet controller, the contents of the ID PROM, and the version number of OpenBoot. (The ID PROM contains information specific to each individual machine, including the serial number, date of manufacture, and Ethernet address assigned to the machine.)

Table 7 System Information Commands

Command	Description
`banner`	Display power-on banner.
`show-sbus`	Display list of installed and probed SBus devices.
`.enet-addr`	Display current Ethernet address.
`.idprom`	Display ID PROM contents, formatted.

Table 7 System Information Commands *(Continued)*

Command	Description
`.traps`	Display a list of processor-dependent trap types.
`.version`	Display version and date of the boot PROM.
.speed	Display processor and bus speeds.

Also see the device tree browsing commands in Table 3 on page 7.

Resetting the System

Occasionally, you may need to reset your system. The `reset-all` command resets the entire system and is similar to performing a power cycle.

To reset the system, type:

```
ok reset-all
```

If your system is set up to run the power-on self-test (POST) and initialization procedures on reset, these procedures begin executing once you initiate this command. (On some systems, POST is only executed after power-on.) Once POST completes, the system either boots automatically or enters the User Interface, just as it would have done after a power cycle.

Setting Configuration Variables 3

This chapter describes how to access and modify nonvolatile RAM (NVRAM) configuration variables.

System configuration variables are stored in the system NVRAM. These variables determine the start-up machine configuration and related communication characteristics. You can modify the values of the configuration variables, and any changes you make remain in effect even after a power cycle. Configuration variables should be adjusted cautiously.

The procedures described in this chapter assume that the User Interface is active. See Chapter 1, “Overview” for information about entering the User Interface.

Table 8 lists a typical set of NVRAM configuration variables defined by *IEEE Standard 1275-1994*.

Table 8 Standard Configuration Variables

Variable	Typical Default	Description
`auto-boot?`	true	If true, boot automatically after power on or reset.
`boot-command`	boot	Command that is executed if `auto-boot?` is true.
`boot-device`	disk net	Device from which to boot.
`boot-file`	empty string	Arguments passed to booted program.
`diag-device`	net	Diagnostic boot source device.
`diag-file`	empty string	Arguments passed to booted program in diagnostic mode.
`diag-switch?`	false	If true, run in diagnostic mode.

Table 8 Standard Configuration Variables *(Continued)*

Variable	Typical Default	Description
fcode-debug?	false	If true, include name fields for plug-in device FCodes.
input-device	keyboard	Console input device (usually keyboard, ttya, or ttyb).
nvramrc	empty	Contents of NVRAMRC.
oem-banner	empty string	Custom OEM banner (enabled by oem-banner? true).
oem-banner?	false	If true, use custom OEM banner.
oem-logo	no default	Byte array custom OEM logo (enabled by oem-logo? true). Displayed in hexadecimal.
oem-logo?	false	If true, use custom OEM logo (else, use Sun logo).
output-device	screen	Console output device (usually screen, ttya, or ttyb).
screen-#columns	80	Number of on-screen columns (characters/line).
screen-#rows	34	Number of on-screen rows (lines).
security-#badlogins	no default	Number of incorrect security password attempts.
security-mode	none	Firmware security level (options: none, command, or full).
security-password	no default	Firmware security password (never displayed).
use-nvramrc?	false	If true, execute commands in NVRAMRC during system start-up.

Additional configuration variables are defined by the SBus binding to *IEEE Standard 1275-1994*. These variables are shown in Table 9.

Table 9 SBus Configuration Variables

Variable	Typical Default	Description
sbus-probe-list	0123	Which SBus slots to probe and in what order.

Note – Different OpenBoot implementations may use different defaults and/or different configuration variables.

Displaying and Changing Variable Settings

NVRAM configuration variables can be viewed and changed using the commands listed in Table 10.

Table 10 Viewing / Changing Configuration Variables

Command	**Description**
`printenv`	Display current variables and current default values. `printenv` *variable* shows the current value of the named variable.
`setenv` *variable value*	Set *variable* to the given decimal or text *value*. (Changes are permanent, but often take effect only after a reset.)
`set-default` *variable*	Reset the value of *variable* to the factory default.
`set-defaults`	Reset variable values to the factory defaults.
`password`	Set `security-password`

The following pages show how these commands can be used.

Note – Solaris provides the `eeprom` utility for modifying OpenBoot configuration variables.

To display a list of the current variable settings on your system, type:

```
ok printenv
Variable Name       Value                          Default Value

oem-logo            2c 31 2c 2d 00 00 00 00 …
oem-logo?           false                          false
oem-banner
oem-banner?         false                          false
output-device       ttya                           screen
input-device        ttya                           keyboard
sbus-probe-list     03                             0123
diag-file
diag-device         net                            net
boot-file
boot-device         disk                           disk net
auto-boot?          false                          true
fcode-debug?        true                           false
use-nvramrc?        false                          false
nvramrc
screen-#columns     80                             80
screen-#rows        34                             34
security-mode       none                           none
security-password
security-#badlogins 0
diag-switch?        true                           false
ok
```

In the displayed, formatted list of the current settings, numeric variables are often shown in decimal.

To change a variable setting, type:

```
ok setenv variable-name value
```

variable-name is the name of the variable. *value* is a numeric value or text string appropriate to the named variable. A numeric value is interpreted as a decimal number, unless preceded by `0x`, which is the qualifier for a hexadecimal number.

For example, to set the `auto-boot?` variable to `false`, type:

```
ok setenv auto-boot? false
ok
```

Note – *Many variable changes do not affect the operation of the firmware until the next power cycle or system reset* at which time the firmware uses the variable's new value.

You can reset one or most of the variables to the original defaults using the `set-default` *variable* and `set-defaults` commands.

For example, to reset the `auto-boot?` variable to its default setting (true), type:

```
ok set-default auto-boot?
ok
```

To reset most variables to their default settings, type:

```
ok set-defaults
ok
```

On SPARC systems, it is possible to reset the NVRAM variables to their default settings by holding down `Stop-N` while the machine is powering up. When issuing this command, hold down `Stop-N` immediately after turning on the power to the SPARC system, and keep it pressed for a few seconds. This is a good technique to force a SPARC compatible machine's NVRAM variables to a known condition.

Setting Security Variables

The NVRAM system security variables are:

- `security-mode`
- `security-password`

- `security-#badlogins`

`security-mode` can restrict the set of operations that users are allowed to perform from the User Interface. The three security modes, and their available commands, are listed in the following table in order of most to least secure.

Table 11 Commands Available For security-mode Settings

Mode	Commands
`full`	All commands except for `go` require the password.
`command`	All commands except for `boot` and `go` require the password.
`none`	No password required (default).

Command Security

With `security-mode` set to `command`:

- A password is not required if you type the `boot` command by itself. However, if you use the `boot` command *with an argument*, a password is required.
- The `go` command never asks for a password.
- A password is required to execute any other command.

Examples are shown in the following screen.

```
ok boot              (no password required)
ok go                (no password required)
ok boot filename     (password required)
Password:            (password is not echoed as it is typed)
ok reset-all         (password required)
Password:            (password is not echoed as it is typed)
```

Warning – Set the security password *before* setting the security mode.

Caution – It is important to remember your security password. If you forget this password, you cannot use your system; you must call your vendor's customer support service to make your machine bootable again.

To set the security password and `command` security mode, type the following at the `ok` prompt:

```
ok password
ok New password (only first 8 chars are used):
ok Retype new password:
ok setenv security-mode command
ok
```

The security password you assign must be between zero and eight characters. Any characters after the eighth are ignored. You do not have to reset the system; the security feature takes effect as soon as you type the command.

If you enter an incorrect security password, there will be a delay of about 10 seconds before the next boot prompt appears. The number of times that an incorrect security password is typed is stored in the `security-#badlogins` variable.

Full Security

The `full` security mode is the most restrictive. With `security-mode` set to `full`:

- A password is required any time you execute the `boot` command.
- The `go` command never asks for a password.
- A password is required to execute any other command.

Here are some examples.

```
ok go                (no password required)
ok boot              (password required)
Password:            (password is not echoed as it is typed)
ok boot filename     (password required)
Password:            (password is not echoed as it is typed)
ok reset-all         (password required)
Password:            (password is not echoed as it is typed)
```

Warning – Set the security password *before* setting the security mode.

Caution – It is important to remember your security password. If you forget this password, you cannot use your system; you must call your vendor's customer support service to make your machine bootable again.

To set the security password and `full` security, type the following at the `ok` prompt:

```
ok password
ok New password (only first 8 chars are used):
ok Retype new password:
ok setenv security-mode full
ok
```

Changing the Power-on Banner

The banner configuration variables are:

- `oem-banner`
- `oem-banner?`
- `oem-logo`
- `oem-logo?`

To view the power-on banner, type:

```
ok banner

        Sun Ultra 1 SBus (UltraSPARC 167 MHz),Keyboard Present
        PROM Rev. 3.0, 64MB memory installed, Serial # 289
        Ethernet address 8:0:20:d:e2:7b, Host ID: 80000121


ok
```

The banner for your system may be different.

The banner consists of two parts: the text field and the logo (over serial ports, only the text field is displayed). You can replace the existing text field with a custom text message using the `oem-banner` and `oem-banner?` configuration variables.

To insert a custom text field in the power-on banner, type:

```
ok setenv oem-banner Hello Mom and Dad
ok setenv oem-banner? true
ok banner

          Hello Mom and Dad
```

```


ok
```

The system displays the banner with your new message, as shown in the preceding screen.

The graphic logo is handled differently. `oem-logo` is a 512-byte array, containing a total of 4096 bits arranged in a 64 x 64 array. Each bit controls one pixel. The most significant bit (MSB) of the first byte controls the upper-left corner pixel. The next bit controls the pixel to the right of it, and so on.

To create a new logo, first create a Forth array containing the correct data; then copy this array into `oem-logo`. The array is then installed in `oem-logo` with `$setenv`. The example below fills the top half of `oem-logo` with an ascending pattern.

```
ok create logoarray d# 512 allot
ok logoarray d# 256 0 do i over i + c! loop drop
ok logoarray d# 256 " oem-logo" $setenv
ok setenv oem-logo? true
ok banner
```

To restore the system's original power-on banner, set the `oem-logo?` and `oem-banner?` variables to `false`.

```
ok setenv oem-logo? false
ok setenv oem-banner? false
ok
```

Because the `oem-logo` array is so large, `printenv` displays approximately the first 8 bytes (in hexadecimal). To display the entire array, use the phrase `oem-logo dump`. The `oem-logo` array is not erased by `set-defaults`, since it might be difficult to restore the data. However, `oem-logo?` is set to false when `set-defaults` executes, so the custom logo is no longer displayed.

Note – Some systems do not support the `oem-logo` feature.

Input and Output Control

The console is used as the primary means of communication between OpenBoot and the user. The console consists of an input device, used for receiving information supplied by the user, and an output device, used for sending information to the user. Typically, the console is either the combination of a text / graphics display device and a keyboard or an ASCII terminal connected to a serial port.

The configuration variables related to the control of the console are:

- `input-device`
- `output-device`
- `screen-#columns`
- `screen-#rows`

You can use these variables to assign the power-on defaults for the console. These values do not take effect until after the next power cycle or system reset.

Selecting Input and Output Device Options

The `input-device` and `output-device` variables control the firmware's selection of input and output devices after a power-on reset. The default `input-device` value is `keyboard` and the default `output-device` value is `screen`. The values of `input-device` and `output-device` must be device specifiers. The aliases `keyboard` and `screen` are often used as the values of these variables.

When the system is reset, the named device becomes the initial firmware console input or output device. (If you want to temporarily change the input or output device, use the `input` or `output` commands described in Chapter 4, "Using Forth Tools".)

To set `ttya` as the initial console input device, type:

```
ok setenv input-device ttya
ok
```

If you select `keyboard` for `input-device`, and the device is not plugged in, input is accepted from a fallback device (typically `ttya`) after the next power cycle or system reset. If you select `screen` for `output-device`, but no frame buffer is available, output is sent to the fall-back device after the next power cycle or system reset.

To specify an SBus frame buffer as the default output device (especially if there are multiple frame buffers in the system), type:

```
ok setenv output-device /sbus/SUNW,leo
ok
```

Setting Serial Port Characteristics

The following values represent the typical range of communications characteristics for serial ports:

- *baud* = 110, 300, 1200, 2400, 4800, 9600, 19200, or 38400 bits/second
- *#bits* = 5, 6, 7, or 8 (data bits)
- *parity* = n (none), e (even), or o (odd), parity bit

- *#stop* = 1 (1), . (1.5), or 2 (2) stop bits

Note – rts/cts and xon/xoff handshaking are not implemented on some systems. When a selected protocol is not implemented, the handshake variable is accepted but ignored; no messages are displayed.

Selecting Boot Options

You can use the following configuration variables to determine whether or not the system will boot automatically after a power cycle or system reset.

- `auto-boot?`
- `boot-device`
- `boot-file`

If `auto-boot?` is `true` and if OpenBoot is not in diagnostic mode, the system boots automatically after a power-cycle or system reset using the `boot-device` and `boot-file` values.

These variables can also be used during manual booting to select the boot device and the program to be booted. For example, to specify default booting from the network server, type:

```
ok setenv boot-device net
ok
```

Changes to `boot-file` and `boot-device` take effect the next time that `boot` is executed.

Controlling Power-on Self-test

The power-on testing variables are:

- `diag-switch?`
- `diag-device`
- `diag-file`
- `diag-level`

Setting `diag-switch?` to `true` causes the function `diagnostic-mode?` to return `true`. When `diagnostic-mode?` returns `true`, the system:

- Performs more thorough selftests during any subsequent power-on or system reset process.
- May display additional status messages (the details are implementation dependent).
- Uses different configuration variables for booting. (For more details on the effects on the boot process, see Chapter 2, “Booting and Testing Your System”.)

Most systems have a factory default of `false` for the `diag-switch?` variable. To set `diag-switch?` to `true`, type:

```
ok setenv diag-switch? true
ok
```

Note – Some systems have a hardware diagnostic switch that also cause `diagnostic-mode?` to return `true`. Such systems run the full tests at power-on and system reset if either the hardware switch is set or `diag-switch?` is `true`.

Note – Some implementations enable you to force `diag-switch?` to `true` by using an implementation-dependent key sequence during power-on. Check your system’s documentation for details, or see Appendix C, “Troubleshooting Guide”.

To set `diag-switch?` to `false`, type:

```
ok setenv diag-switch? false
ok
```

When not in diagnostic mode, the system does not announce the diagnostic tests as they are performed (unless a test fails) and may perform fewer tests.

3

Using nvramrc

The `nvramrc` configuration variable whose contents are called the *script*, can be used to store user-defined commands executed during start-up.

Typically, `nvramrc` is used by a device driver to save start-up configuration variables, to patch device driver code, or to define installation-specific device configuration and device aliases. It can also be used for bug patches or for user-installed extensions. Commands are stored in ASCII, just as the user would type them at the console.

If the `use-nvramrc?` configuration variable is `true`, the script is evaluated during the OpenBoot start-up sequence as shown:

- Perform Power On Self Test (POST)
- Perform system initialization
- Evaluate the script (if `use-nvramrc?` is true)
- Execute `probe-all` (i.e. evaluate FCode)
- Execute `install-console`
- Execute banner
- Execute secondary diagnostics
- Perform default boot (if `auto-boot?` is true)

It is sometimes desirable to modify the sequence `probe-all install-console banner`. For example, commands that modify the characteristics of plug-in display devices may need to be executed after the plug-in devices have been probed, but before the console device has been selected. Such commands would need to be executed between `probe-all` and `install-console`. Commands that display output on the console would need to be placed after `install-console` or `banner`.

This is accomplished by creating a custom script which contains either `banner` or `suppress-banner` since the sequence `probe-all install-console banner` is not executed if either `banner` or `suppress-banner` is executed from the script. This allows the use of `probe-all`, `install-console` and `banner` inside the script, possibly interspersed with other commands, without having those commands re-executed after the script finishes.

Most User Interface commands can be used in the script. *The following cannot:*

- `boot`
- `go`
- `nvedit`
- `password`
- `reset-all`
- `setenv security-mode`

Editing the Contents of the Script

The script editor, `nvedit`, lets you create and modify the script using the commands listed in Table 12.

Table 12 Script Editor Commands

Command	Description
`nvalias` *alias device-path*	Stores the command "devalias *alias device-path*" in the script. The alias persists until either `nvunalias` or `set-defaults` is executed.
`$nvalias`	Performs the same function as `nvalias` except that it takes its arguments, *name-string device-string*, from the stack
`nvedit`	Enters the script editor. If data remains in the temporary buffer from a previous `nvedit` session, resumes editing those previous contents. If not, reads the contents of `nvramrc` into the temporary buffer and begins editing it.
`nvquit`	Discards the contents of the temporary buffer, without writing it to `nvramrc`. Prompts for confirmation.
`nvrecover`	Recovers the contents of `nvramrc` if they have been lost as a result of the execution of `set-defaults`; then enters the editor as with `nvedit`. `nvrecover` fails if `nvedit` is executed between the time that the `nvramrc` contents were lost and the time that `nvrecover` is executed.
`nvrun`	Executes the contents of the temporary buffer.
`nvstore`	Copies the contents of the temporary buffer to `nvramrc`; discards the contents of the temporary buffer.
`nvunalias` *alias*	Deletes the specified alias from `nvramrc`.
`$nvunalias`	Performs the same function as `nvunalias` except that it takes its argument, *name-string*, from the stack

The editing commands shown in Table 13 are used in the script editor.

Table 13 Script Editor Keystroke Commands

Keystroke	Description
`Control-B`	Moves backward one character.
`Escape B`	Moves backward one word.
`Control-F`	Moves forward one character.
`Escape F`	Moves forward one word.
`Control-A`	Moves backward to beginning of the line.
`Control-E`	Moves forward to end of the line.
`Control-N`	Moves to the next line of the script editing buffer.
`Control-P`	Moves to the previous line of the script editing buffer.
`Return` `(Enter)`	Inserts a newline at the cursor position and advances to the next line.
`Control-O`	Inserts a newline at the cursor position and stays on the current line.
`Control-K`	Erases from the cursor position to the end of the line, storing the erased characters in a save buffer. If at the end of a line, joins the next line to the current line (i.e. deletes the newline).
`Delete`	Erases the previous character.
`Backspace`	Erases the previous character.
`Control-H`	Erases the previous character.
`Escape H`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-W`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-D`	Erases the next character.
`Escape D`	Erases from the cursor to the end of the word, storing the erased characters in a save buffer.
`Control-U`	Erases the entire line, storing the erased characters in a save buffer.
`Control-Y`	Inserts the contents of the save buffer before the cursor.
`Control-Q`	Quotes the next character (i.e. allows you to insert control characters).
`Control-R`	Retypes the line.
`Control-L`	Displays the entire contents of the editing buffer.
`Control-C`	Exits the script editor, returning to the OpenBoot command interpreter. The temporary buffer is preserved, but is not written back to the script. (Use `nvstore` afterwards to write it back.)

Activating the Script

Use the following steps to create and activate the script:

1. At the ok prompt, type nvedit

Edit the script using editor commands.

2. Type Control-C to get out of the editor and back to the ok prompt.

If you have not yet typed nvstore to save your changes, you may type nvrun to execute the contents of the temporary edit buffer.

3. Type nvstore to save your changes.

4. Enable the interpretation of the script by typing:

setenv use-nvramrc? true

5. Type reset-all to reset the system and execute the script, or type:

nvramrc evaluate

to execute the contents directly.

The following example shows you how to create a simple colon definition in the script.

```
ok nvedit
0: : hello ( -- )
1: ." Hello, world. " cr
2: ;
3: ^C
ok nvstore
ok setenv use-nvramrc? true
ok reset-all
…
ok hello
Hello, world.
ok
```

Notice the nvedit line number prompts (0:, 1:, 2:, 3:) in the above example. These prompts are system-dependent.

3

Using Forth Tools 4

This chapter introduces the Forth programming language as it is implemented in OpenBoot. Even if you are familiar with Forth, work through the examples shown in this chapter; they provide specific, OpenBoot-related information.

The version of Forth contained in OpenBoot is based on ANS Forth. Appendix D, “Forth Word Reference”, lists the complete set of available commands.

Note – This chapter assumes that you know how to enter and leave the User Interface. At the ok prompt, if you type commands that hang the system and you cannot recover using a key sequence, you may need to perform a power cycle to return the system to normal operation.

4

Forth Commands

Forth has a very simple command structure. Forth commands, also called Forth *words*, consist of any combination of characters that can be printed—for example, letters, digits, or punctuation marks. Examples of legitimate words are shown below:

```
@
dump
.
0<
+
probe-scsi
```

Forth words must be separated from one another by one or more spaces (blanks). Characters that are normally treated as "punctuation" in some other programming languages do *not* separate Forth words. In fact, many of those "punctuation" characters *are* Forth words!

Pressing Return at the end of any command line executes the typed commands. (In all the examples shown, a Return at the end of the line is assumed.)

A command line can have more than one word. Multiple words on a line are executed one at a time, from left to right, in the order in which they were typed. For example:

```
ok testa testb testc
ok
```

is equivalent to:

```
ok testa
ok testb
ok testc
ok
```

In OpenBoot, uppercase and lowercase letters are equivalent in Forth word names. Therefore, `testa`, `TESTA`, and `TesTa` all invoke the same command. However, words are conventionally written in lowercase.

Some commands generate large amounts of output (for example, `dump` or `words`). You can interrupt such a command by pressing any key except `q`. (If you press `q`, the output is aborted, not suspended.) Once a command is interrupted, output is suspended and the following message appears:

```
More [<space>,<cr>,q] ?
```

Press the space bar (`<space>`) to continue, press Return (`<cr>`) to output one more line and pause again, or type `q` to abort the command. When a command generates more than one page of output, the system automatically displays this prompt at the end of each page.

Data Types

The terms shown in Table 14 describe the data types used by Forth.

Table 14 Forth Data Type Definitions

Notation	**Description**
byte	An 8-bit value.
cell	The implementation-defined fixed size of a cell is specified in address units and the corresponding number of bits. Data-stack elements, return-stack elements, addresses, execution tokens, flags and integers are one cell wide. On OpenBoot systems, a cell consists of at least 32-bits, and is sufficiently large to contain a virtual address. The cell size may vary between implementations. A 32-bit implementation has a cell size of 4. A 64-bit implementation has a cell size of 8. OpenBoot 3.x is a 64-bit implementation.
doublet	A 16-bit value.
octlet	A 64-bit value; only defined on 64-bit implementations,
quadlet	A 32-bit value.

4

Using Numbers

Enter a number by typing its value, for example, 55 or -123. Forth accepts only integers (whole numbers); it does not understand fractional values (e.g. 2/3). A period at the end of a number signifies a double number. Periods or commas embedded in a number are ignored, so 5.77 is understood as 577. By convention, such punctuation usually appears every four digits. Use one or more spaces to separate a number from a word or from another number.

Unless otherwise specified, OpenBoot performs integer arithmetic on data items that are one cell in size, and creates results that are one cell in size.

Although OpenBoot implementations are encouraged to use base 16 (hexadecimal) by default, they are not required to do so. Consequently, you must establish a specific number base if your code depends on a given base for proper operation. You can change the number base with the commands `decimal` and `hex` which cause all subsequent numeric input and output to be performed in base 10 or 16, respectively.

For example, to operate in decimal, type:

```
ok decimal
ok
```

To change to hexadecimal type:

```
ok hex
ok
```

To identify the current number base, you can use:

```
ok 10 .d
16
ok
```

The `16` on the display shows that you are operating in hexadecimal. If `10` showed on the display, it would mean that you are in decimal base. The `.d` command displays a number in base 10, regardless of the current number base.

The Stack

The Forth *stack* is a last-in, first-out buffer used for temporarily holding numeric information. Think of it as a stack of books: the last one you put on the top of the stack is the first one you take off. *Understanding the stack is essential to using Forth.*

To put a number on the stack, simply type its value.

```
ok 44   (The value 44 is now on top of the stack)
ok 7    (The value 7 is now on top, with 44 just underneath)
ok
```

Displaying Stack Contents

The contents of the stack are normally invisible. However, properly visualizing the current stack contents is important for achieving the desired result. To show the stack contents with every `ok` prompt, type:

```
ok showstack
44 7 ok 8
47 7 8 ok noshowstack
ok
```

The topmost stack item is always shown as the last item in the list, immediately before the `ok` prompt. In the above example, the topmost stack item is `8`.

If `showstack` has been previously executed, `noshowstack` will remove the stack display prior to each prompt.

Note – In some of the examples in this chapter, `showstack` is enabled. In those examples, each `ok` prompt is immediately preceded by a display of the current contents of the stack. The examples work the same if `showstack` is not enabled, except that the stack contents are not displayed.

Nearly all words that require numeric parameters fetch those parameters from the top of the stack. Any values returned are generally left on top of the stack, where they can be viewed or consumed by another command. For example,

the Forth word + removes two numbers from the stack, adds them together, and leaves the result on the stack. In the example below, all arithmetic is in hexadecimal.

```
44 7 8 ok +
44 f ok +
53 ok
```

Once the two values are added together, the result is put onto the top of the stack. The Forth word . removes the top stack item and displays that value on the screen. For example:

```
53 ok 12
53 12 ok .
12
53 ok .
53
ok  (The stack is now empty)
ok 3 5 + .
8
ok  (The stack is now empty)
ok .
Stack Underflow
ok
```

The Stack Diagram

To aid understanding, conventional coding style requires that a *stack diagram* of the form (--) appear on the first line of every definition of a Forth word. The stack diagram specifies what the execution of the word does to the stack.

Entries to the left of -- represent those stack items that the word removes from the stack and uses during its operation. The right-most of these items is on top of the stack, with any preceding items beneath it. In other words, arguments are pushed onto the stack in left to right order, leaving the most recent one (the right-most one in the diagram) on the top.

Entries to the right of -- represent those stack items that the word leaves on the stack after it finishes execution. Again, the right-most item is on top of the stack, with any preceding items beneath it.

For example, a stack diagram for the word + is:

(nu1 nu2 -- sum)

Therefore, + removes two numbers (nu1 and nu2) from the stack and leaves their sum (sum) on the stack. As a second example, a stack diagram for the word . is:

(nu --)

The word . removes the number on the top of the stack (nu) and displays it.

Words that have no effect on the contents of the stack (such as showstack or decimal), have a (--) stack diagram.

Occasionally, a word will require another word or other text immediately following it on the command line. The word see, used in the form:

see *thisword*

is such an example.

Stack items are generally written using descriptive names to help clarify correct usage. See Table 15 for stack item abbreviations used in this manual.

Table 15 Stack Item Notation

Notation	Description
|	Alternate stack results shown with space, e.g. (input -- addr len false | result true).
???	Unknown stack item(s).
…	Unknown stack item(s). If used on both sides of a stack comment, means the same stack items are present on both sides.
< > <space>	Space delimiter. Leading spaces are ignored.
a-addr	Variable-aligned address.
addr	Memory address (generally a virtual address).
addr len	Address and length for memory region
byte b*xxx*	8-bit value (low order byte in a cell).
char	7-bit value (low order byte in a cell, high bit of low order byte unspecified).
cnt	Count.
len	Length
size	Count or length.
d*xxx*	Double (extended-precision) numbers. 2 cells, hi quadlet on top of stack.

Table 15 Stack Item Notation *(Continued)*

Notation	Description
`<eol>`	End-of-line delimiter.
`false`	0 (false flag).
`n n1 n2 n3`	Normal signed, one-cell values
`nu nu1`	Signed or unsigned one-cell values
`<nothing>`	Zero stack items.
`o o1 o2 oct1 oct2`	Octlet (64 bit signed value)
`oaddr`	Octlet (64-bit) aligned address
`octlet`	An eight-byte quantity.
`phys`	Physical address (actual hardware address).
`phys.lo phys.hi`	Lower / upper cell of physical address
`pstr`	Packed string.
`quad q`*xxx*	Quadlet (32-bit value, low order four bytes in a cell).
`qaddr`	Quadlet (32-bit) aligned address
`true`	-1 (true flag).
u*xxx*	Unsigned positive, one-cell values
`virt`	Virtual address (address used by software).
`waddr`	Doublet (16-bit) aligned address
`word w`*xxx*	Doublet (16-bit value, low order two bytes in a cell).
`x x1`	Arbitrary, one cell stack item
`x.lo x.hi`	Low / high significant bits of a data item
`xt`	Execution token.
`xxx?`	Flag. Name indicates usage (e.g. `done? ok? error?`).
`xyz-str xyz-len`	Address and length for unpacked string.
`xyz-sys`	Control-flow stack items, implementation-dependent.
`( C: -- )`	Compilation stack diagram
`( -- )` `( E: -- )`	Execution stack diagram
`( R: -- )`	Return stack diagram

Manipulating the Stack

Stack manipulation commands (described in Table 16) allow you to add, delete, and reorder items on the stack.

Table 16 Stack Manipulation Commands

Command	Stack Diagram	Description
`clear`	(??? --)	Empty the stack.
`depth`	(... -- ... u)	Return the number of items on the stack.
`drop`	(x --)	Remove top item from the stack.
`2drop`	(x1 x2 --)	Remove 2 items from the stack.
`3drop`	(x1 x2 x3 --)	Remove 3 items from the stack.
`dup`	(x -- x x)	Duplicate the top stack item.
`2dup`	(x1 x2 -- x1 x2 x1 x2)	Duplicate 2 stack items.
`3dup`	(x1 x2 x3 -- x1 x2 x3 x1 x2 x3)	Duplicate 3 stack items.
`?dup`	(x -- x x | 0)	Duplicate the top stack item if it is non-zero.
`nip`	(x1 x2 -- x2)	Discard the second stack item.
`over`	(x1 x2 -- x1 x2 x1)	Copy second stack item to top of stack.
`2over`	(x1 x2 x3 x4 -- x1 x2 x3 x4 x1 x2)	Copy second 2 stack items.
`pick`	(xu … x1 x0 u -- xu … x1 x0 xu)	Copy *u*-th stack item (`1 pick` = `over`).
`>r`	(x --) (R: -- x)	Move a stack item to the return stack.
`r>`	(-- x) (R: x --)	Move a return stack item to the stack.
`r@`	(-- x) (R: x -- x)	Copy the top of the return stack to the stack.
`roll`	(xu … x1 x0 u -- xu-1 … x1 x0 xu)	Rotate `u` stack items (`2 roll` = `rot`).
`rot`	(x1 x2 x3 -- x2 x3 x1)	Rotate 3 stack items.
`-rot`	(x1 x2 x3 -- x3 x1 x2)	Inversely rotate 3 stack items.
`2rot`	(x1 x2 x3 x4 x5 x6 -- x3 x4 x5 x6 x1 x2)	Rotate 3 pairs of stack items.
`swap`	(x1 x2 -- x2 x1)	Exchange the top 2 stack items.
`2swap`	(x1 x2 x3 x4 -- x3 x4 x1 x2)	Exchange 2 pairs of stack items.
`tuck`	(x1 x2 -- x2 x1 x2)	Copy top stack item below second item.

A typical use of stack manipulation might be to display the top stack item while preserving all stack items, as shown in this example:

```
5 77 ok dup          (Duplicates the top item on the stack)
5 77 77 ok .         (Removes and displays the top stack item)
77
5 77 ok
```

Creating Custom Definitions

Forth provides an easy way to create new command words from sequences of existing words. Table 17 shows the Forth words used to create such new words.

Table 17 Colon Definition Words

Command	Stack Diagram	Description
: *new-name*	(--)	Start a new colon definition of the word *new-name*.
;	(--)	End a colon definition.

This kind of word is called a *colon definition*, named after the word : that is used to create them. For example, suppose you want to create a new word, add4, that will add any four numbers together and display the result. You could create the definition as follows:

```
ok : add4  + + + .  ;
ok
```

The ; (semicolon) marks the end of the definition that defines add4 to have the behavior (+ + + .). The three addition operators (+) reduce the four stack items to a single sum on the stack; then . removes and displays that result. An example follows.

```
ok 1 2 3 3 + + + .
9
ok 1 2 3 3 add4
9
ok
```

Definitions are forgotten if a machine reset takes place. To keep useful definitions, put them into the script or save them in a text file on a host system. This text file can then be loaded as needed. (See Chapter 5, “Loading and Executing Programs” for more information on loading files.)

When you type a definition from the User Interface, the ok prompt becomes a] (right square bracket) prompt after you type the : (colon) and before you type the ; (semicolon). For example, you could type the definition for add4 like this:

```
ok : add4
]  + + +
]  .
]  ;
ok
```

The above use of] while inside a multi-line definition is a characteristic of Sun’s implementation.

- The stack diagram shows proper use of a word, so include a stack diagram with every definition you create, even if the stack effect is nil (--) . Use generous stack comments in complex definitions to trace the flow of execution. For example, when creating add4, you could define it as:

```
: add4  ( n1 n2 n3 n4 -- )  + + + .  ;
```

Or you could define it as follows:

```
: add4  ( n1 n2 n3 n4 -- )
   + + +   ( sum )
   .       (     )
;
```

Note – The ”(“ is a Forth word meaning ignore the text up to the “)”. Like any other Forth word, the “(“ must have one or more spaces after it.

Using Arithmetic Functions

Single-Precision Integer Arithmetic

The commands listed in Table 18 perform single-precision arithmetic.

Table 18 Single-Precision Arithmetic Functions

Command	**Stack Diagram**	**Description**
+	(nu1 nu2 -- sum)	Adds *nu1* + *nu2*.
-	(nu1 nu2 -- diff)	Subtracts *nu1* - *nu2*.
*	(nu1 nu2 -- prod)	Multiplies *nu1* times *nu2*.
*/	(n1 n2 n3 -- quot)	Calculates *nu1* * *nu2* / *n3*. Inputs, outputs and intermediate products are all one cell.
/	(n1 n2 -- quot)	Divides *n1* by *n2*; remainder is discarded.
1+	(nu1 -- nu2)	Adds one.
1-	(nu1 -- nu2)	Subtracts one.
2+	(nu1 -- nu2)	Adds two.
2-	(nu1 -- nu2)	Subtracts two.
abs	(n -- u)	Absolute value.
bounds	(start len -- len+start start)	Converts *start*,*len* to *end*,*start* for do or ?do loop.
even	(n -- n | n+1)	Round to nearest even integer >= *n*.
max	(n1 n2 -- n3)	n3 is maximum of *n1* and *n2*
min	(n1 n2 -- n3)	n3 is minimum of *n1* and *n2*

Table 18 Single-Precision Arithmetic Functions *(Continued)*

Command	Stack Diagram	Description
mod	(n1 n2 -- rem)	Remainder of *n1* / *n2*.
*/mod	(n1 n2 n3 -- rem quot)	Remainder, quotient of *n1* * *n2* / *n3*.
/mod	(n1 n2 -- rem quot)	Remainder, quotient of *n1* / *n2*.
negate	(n1 -- n2)	Change the sign of *n1*.
u*	(u1 u2 -- uprod)	Multiply 2 unsigned numbers yielding an unsigned product.
u/mod	(u1 u2 -- urem uquot)	Divide unsigned one-cell number by an unsigned one-cell number; yield one-cell remainder and quotient.
<<	(x1 u -- x2)	Synonym for lshift.
>>	(x1 u -- x2)	Synonym for rshift.
2*	(x1 -- x2)	Multiply by 2.
2/	(x1 -- x2)	Divide by 2.
>>a	(x1 u -- x2)	Arithmetic right-shift *x1* by *u* bits.
and	(x1 x2 -- x3)	Bitwise logical AND.
invert	(x1 -- x2)	Invert all bits of *x1*.
lshift	(x1 u -- x2)	Left-shift *x1* by *u* bits. Zero-fill low bits.
not	(x1 -- x2)	Synonym for invert.
or	(x1 x2 -- x3)	Bitwise logical OR.
rshift	(x1 u -- x2)	Right-shift *x1* by *u* bits. Zero-fill high bits.
u2/	(x1 -- x2)	Logical right shift 1 bit; zero shifted into high bit.
xor	(x1 x2 -- x3)	Bitwise exclusive OR.

Double Number Arithmetic

The commands listed in Table 19 perform double number arithmetic.

Table 19 Double Number Arithmetic Functions

Command	Stack Diagram	Description
d+	(d1 d2 -- d.sum)	Add *d1* to *d2* yielding double number *d.sum*.
d-	(d1 d2 --d.diff)	Subtract *d2* from *d1* yielding double number *d.diff*.
fm/mod	(d n -- rem quot)	Divide *d* by *n*.
m*	(n1 n2 -- d)	Signed multiply with double-number product.

Table 19 Double Number Arithmetic Functions *(Continued)*

Command	Stack Diagram	Description
s>d	(n1 -- d1)	Convert a number to a double number.
sm/rem	(d n -- rem quot)	Divide *d* by *n*, symmetric division.
um*	(u1 u2 -- ud)	Unsigned multiply yielding unsigned double number product.
um/mod	(ud u -- urem uprod)	Divide *ud* by *u*.

Data Type Conversion

The commands listed in Table 20 perform data type conversion.

Table 20 32-Bit Data Type Conversion Functions

Command	Stack Diagram	Description
bljoin	(b.low b2 b3 b.hi -- quad)	Join four bytes to form a quadlet
bwjoin	(b.low b.hi -- word)	Join two bytes to form a doublet.
lbflip	(quad1 -- quad2)	Reverse the bytes in a quadlet
lbsplit	(quad -- b.low b2 b3 b.hi)	Split a quadlet into four bytes.
lwflip	(quad1 -- quad2)	Swap the doublets in a quadlet.
lwsplit	(quad -- w.low w.hi)	Split a quadlet into two doublets.
wbflip	(word1 -- word2)	Swap the bytes in a doublet.
wbsplit	(word -- b.low b.hi)	Split a doublet into two bytes.
wljoin	(w.low w.hi -- quad)	Join two doublets to form a quadlet.

The data type conversion commands listed in Table 21 are available only on 64-bit OpenBoot implementations.

Table 21 64-Bit Data Type Conversion Functions

Command	Stack Diagram	Description
bxjoin	(b.lo b.2 b.3 b.4 b.5 b.6 b.7 b.hi -- o)	Join eight bytes to form an octlet.
lxjoin	(quad.lo quad.hi -- o)	Join two quadlets to form an octlet.
wxjoin	(w.lo w.2 w.3 w.hi -- o)	Join four doublets to form an octlet.
xbflip	(oct1 -- oct2)	Reverse the bytes in an octlet.

Table 21 64-Bit Data Type Conversion Functions *(Continued)*

Command	Stack Diagram	Description
xbsplit	(o -- b.lo b.2 b.3 b.4 b.5 b.6 b.7 b.hi)	Split an octlet into eight bytes.
xlflip	(oct1 -- oct2)	Reverse the quadlets in an octlet. The bytes in each quadlet are not reversed.
xlsplit	(o -- quad.lo quad.hi)	Split on octlet into two quadlets.
xwflip	(oct1 -- oct2)	Reverse the doublets in an octlet. The bytes in each doublet are not reversed.
xwsplit	(o -- w.lo w.2 w.3 w.hi)	Split an octlet into four doublets.

Address Arithmetic

The commands listed in Table 22 perform address arithmetic.

Table 22 Address Arithmetic Functions

Command	Stack Diagram	Description
aligned	(n1 -- n1 | a-addr)	Increase *n1* if necessary to yield a variable aligned address.
/c	(-- n)	The number of address units to a byte: 1.
/c*	(nu1 -- nu2)	Synonym for chars.
ca+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /c.
ca1+	(addr1 -- addr2)	Synonym for char+.
cell+	(addr1 -- addr2)	Increment *addr1* by the value of /n.
cells	(nu1 -- nu2)	Multiply *nu1* by the value of /n.
char+	(addr1 -- addr2)	Increment *addr1* by the value of /c.
chars	(nu1 -- nu2)	Multiply *nu1* by the value of /c.
/l	(-- n)	Number of address units to a quadlet; typically 4.
/l*	(nu1 -- nu2)	Multiply *nu1* by the value of /l.
la+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /l.
la1+	(addr1 -- addr2)	Increment *addr1* by the value of /l.
/n	(-- n)	Number of address units in a cell.
/n*	(nu1 -- nu2)	Synonym for cells.
na+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /n.
na1+	(addr1 -- addr2)	Synonym for cell+.

Table 22 Address Arithmetic Functions

Command	Stack Diagram	Description
/w	(-- n)	Number of address units to a doublet; typically 2.
/w*	(nu1 -- nu2)	Multiply *nu1* by the value of /w.
wa+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /w.
wa1+	(addr1 -- addr2)	Increment *addr1* by the value of /w.

The address arithmetic commands listed in Table 23 are available only on 64-bit OpenBoot implementations.

Table 23 64-Bit Address Arithmetic Functions

Command	Stack Diagram	Description
/x	(-- n)	Number of address units in an octlet, typically eight.
/x*	(nu1 -- nu2)	Multiply *nu1* by the value of /x.
xa+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /x.
xa1+	(addr1 -- addr2)	Increment *addr1* by the value of /x.

Accessing Memory

Virtual Memory

The User Interface provides interactive commands for examining and setting memory. With it, you can:

- Read and write to any virtual address.
- Map virtual addresses to physical addresses.

Memory operators let you read from and write to any memory location. All memory addresses shown in the examples that follow are virtual addresses.

A variety of 8-bit, 16-bit, and 32-bit (and in some systems, 64-bit) operations are provided. In general, a c (character) prefix indicates an 8-bit (one byte) operation; a w (word) prefix indicates a 16-bit (doublet) operation; an l (longword) prefix indicates a 32-bit (quadlet) operation; and an x prefix indicates a 64-bit (octlet) operation.

waddr, qaddr, and oaddr indicate addresses with alignment restrictions. For example, qaddr indicates 32-bit (4 byte) alignment; on many systems such an address must be a multiple of 4, as shown in the following example:

```
ok 4028 l@
ok 4029 l@
Memory address not aligned
ok
```

Forth, as implemented in OpenBoot, adheres closely to the ANS Forth Standard. If you explicitly want a 16-bit fetch, a 32-bit fetch or (on some systems) a 64-bit fetch, use w@, l@ or x@ instead of @. Other memory and device register access commands also follow this convention.

Table 24 lists commands used to access memory.

Table 24 Memory Access Commands

Command	Stack Diagram	Description
!	(x a-addr --)	Store a number at *a-addr*.
+!	(nu a-addr --)	Add *nu* to the number stored at *a-addr*.
@	(a-addr -- x)	Fetch a number from *a-addr*.
2!	(x1 x2 a-addr --)	Store 2 numbers at *a-addr*, *x2* at lower address.
2@	(a-addr -- x1 x2)	Fetch 2 numbers from *a-addr*, *x2* from lower address.
blank	(addr len --)	Set *len* bytes of memory beginning at *addr* to the space character (decimal 32).
c!	(byte addr --)	Store *byte* at *addr*.
c@	(addr -- byte)	Fetch a *byte* from *addr*.
cpeek	(addr -- false | byte true)	Attempt to fetch the byte at *addr*. Return the data and true if the access was successful. Return false if a read access error occurred.
cpoke	(byte addr -- okay?)	Attempt to store the *byte* to *addr*. Return true if the access was successful. Return false if a write access error occurred.
comp	(addr1 addr2 len -- diff?)	Compare two byte arrays. *diff?* is 0 if the arrays are identical, *diff?* is -1 if the first byte that is different is lesser in the string at *addr1*, *diff?* is 1 otherwise.
dump	(addr len --)	Display *len* bytes of memory starting at *addr*.
erase	(addr len --)	Set *len* bytes of memory beginning at *addr* to 0.

Table 24 Memory Access Commands *(Continued)*

Command	Stack Diagram	Description
`fill`	(addr len byte --)	Set *len* bytes of memory beginning at *addr* to the value *byte*.
`l!`	(q qaddr --)	Store a quadlet *q* at *qaddr*.
`l@`	(qaddr -- q)	Fetch a quadlet *q* from *qaddr*.
`lbflips`	(qaddr len --)	Reverse the bytes in each quadlet in the specified region.
`lwflips`	(qaddr len --)	Swap the doublets in each quadlet in specified region.
`lpeek`	(qaddr -- false | quad true)	Attempt to fetch the quadlet at *qaddr*. Return the data and `true` if the access was successful. Return `false` if a read access error occurred.
`lpoke`	(q qaddr -- okay?)	Attempt to store the quadlet 8 at *qaddr*. Return `true` if the access was successful. Return `false` if a a write access error occurred.
`move`	(src-addr dest-addr len --)	Copy *len* bytes from *src-addr* to *dest-addr*.
`off`	(a-addr --)	Store `false` at *a-addr*.
`on`	(a-addr --)	Store `true` at *a-addr*.
`unaligned-l!`	(q addr --)	Store a quadlet *q*, any alignment
`unaligned-l@`	(addr -- q)	Fetch a quadlet *q*, any alignment.
`unaligned-w!`	(w addr --)	Store a doublet *w*, any alignment.
`unaligned-w@`	(addr -- w)	Fetch a doublet *w*, any alignment.
`w!`	(w waddr --)	Store a doublet *w* at *waddr*.
`w@`	(waddr -- w)	Fetch a doublet *w* from *waddr*.
`<w@`	(waddr -- n)	Fetch doublet *n* from *waddr*, sign-extended.
`wbflips`	(waddr len --)	Swap the bytes in each doublet in the specified region.
`wpeek`	(waddr -- false | w true)	Attempt to fetch the doublet w at *waddr*. Return the data and `true` if the access was successful. Return `false` if a read access error occurred.
`wpoke`	(w waddr -- okay?)	Attempt to store the doublet w to *waddr*. Return `true` if the access was successful. Return `false` if a write access error occurred.

The memory access commands listed in Table 25 are available only on 64-bit

OpenBoot implementations.

Table 25 64-Bit Memory Access Functions

Command	Stack Diagram	Description
`<l@`	(qaddr -- n)	Fetch quadlet from qaddr, sign-extended.
`x@`	(oaddr -- o)	Fetch octlet from an octlet aligned address.
`x!`	(o oaddr --)	Store octlet to an octlet aligned address.
`xbflips`	(oaddr len --)	Reverse the bytes in each octlet in the given region.The behavior is undefined if *len* is not a multiple of `/x`.
`xlflips`	(oaddr len --)	Reverse the quadlets in each octlet in the given region. The bytes in each quadlet are not reversed. The behavior is undefined if *len* is not a multiple of `/x`.
`xwflips`	(oaddr len --)	Reverse the doublets in each octlet in the given region. The bytes in each doublet are not reversed. The behavior is undefined if *len* is not a multiple of `/x`.

The `dump` command is particularly useful. It displays a region of memory as both bytes and ASCII values. The example below displays the contents of 20 bytes of memory starting at virtual address 10000.

```
ok 10000 20 dump        (Display 20 bytes of memory starting at virtual address 10000)
       \/ 1  2  3  4  5  6  7   8  9  a  b  c  d  e  f  v123456789abcdef
 10000 05 75 6e 74 69 6c 00 40  4e d4 00 00 da 18 00 00 .until.@NT..Z...
 10010 ce da 00 00 f4 f4 00 00  fe dc 00 00 d3 0c 00 00 NZ..tt..~\..S...
ok
```

Some implementations support variants of `dump` that display memory as 16-, 32- and 64-bit values. You can use `sifting dump` (see “Searching the Dictionary” on page 66) to find out if your system has such variants.

If you try to access an invalid memory location (with `@`, for example), the operation may abort and display an error message, such as `Data Access Exception` or `Bus Error`.

Table 26 lists memory mapping commands.

Table 26 Memory Mapping Commands

Command	Stack Diagram	Description
`alloc-mem`	(len -- a-addr)	Allocate *len* bytes of memory; return the virtual address.
`free-mem`	(a-addr len --)	Free memory allocated by `alloc-mem`.

The following screen is an example of the use of `alloc-mem` and `free-mem`.

- `alloc-mem` allocates 4000 bytes of memory, and the starting address (`ef7a48`) of the reserved area is displayed.
- `dump` displays the contents of 20 bytes of memory starting at `ef7a48`.
- This region of memory is then filled with the value `55`.
- Finally, `free-mem` returns the 4000 allocated bytes of memory starting at `ef7a48`.

```
ok
ok 4000 alloc-mem .
ef7a48
ok
ok ef7a48 constant temp
ok temp 20 dump
       0  1  2  3  4  5  6  7  \/  9  a  b  c  d  e  f   01234567v9abcdef
ef7a40  00 00 f5 5f 00 00 40 08  ff ef c4 40 ff ef 03 c8  ..u_..@..oD@.o.H
ef7a50  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  ................
ef7a60  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  ................
ok temp 20 55 fill
ok temp 20 dump
       0  1  2  3  4  5  6  7  \/  9  a  b  c  d  e  f   01234567v9abcdef
ef7a40  00 00 f5 5f 00 00 40 08  55 55 55 55 55 55 55 55  ..u_..@.UUUUUUUU
ef7a50  55 55 55 55 55 55 55 55  55 55 55 55 55 55 55 55  UUUUUUUUUUUUUUUU
ef7a60  55 55 55 55 55 55 55 55  00 00 00 00 00 00 00 00  UUUUUUUU........
ok
ok temp 4000 free-mem
ok
```

Device Registers

Device registers cannot be reliably accessed using the virtual memory access operators discussed in the last section. There are special operators for accessing device registers, and these operators require that the machine be properly set up prior to their use. For a detailed explanation of this topic, please see *Writing FCode 3.x Programs.*

Using Defining Words

The *dictionary* contains all the available Forth words. Forth *defining words* create new Forth words.

Defining words require two stack diagrams. The first diagram shows the stack effect when the new word is created. The second (or “Execution:”) diagram shows the stack effect when that word is later executed.

Table 27 lists the defining words that you can use to create new Forth words.

If a Forth command is created with the same name as an existing command, the new command will be created normally. Depending on the implementation, a warning message `"new-name isn't unique"` may be displayed. Previous uses of that command name will be unaffected. Subsequent uses of that command name will use the latest definition of that command name. (To correct the original definition such that *all* uses of the command name get the corrected behavior, make the correction with `patch`. (See “Using patch and (patch)” on page 107.)

Table 27 Defining Words

Command	Stack Diagram	Description
`:` *name*	(--) (E: … -- ???)	Begin creation of a colon definition.
`;`	(--)	End creation of a colon definition.
`alias` *new-name old-name*	(--) (E: … -- ???)	Create *new-name* with the same behavior as *old-name*.
`buffer:` *name*	(size --) (E: -- a-addr)	Create a named data buffer. *name* returns *a-addr*.
`constant` *name*	(x --) (E: -- x)	Create a constant (for example, `3 constant bar`).
`2constant` *name*	(x1 x2 --) (E: -- x1 x2)	Create a 2-number constant.
`create` *name*	(--) (E: -- a-addr)	Create a new command whose behavior will be set by further commands.
`$create`	(name-str name-len --)	Call `create` with the name specified by *name-string*.
`defer` *name*	(--) (E: … -- ???)	Create a command with alterable behavior. Alter with `to`.
`does>`	(… -- … a-addr) (E: … -- ???)	Specify the run-time behavior of a `created` word.

Table 27 Defining Words *(Continued)*

Command	Stack Diagram	Description
`field` *name*	(offset size -- offset+size) (E: addr -- addr+offset)	Create a field offset pointer named *name*.
`struct`	(-- 0)	Start a `struct`…`field` definition.
`value` *name*	(x --) (E: -- x)	Create a named variable. Change with `to`.
`variable` *name*	(--) (E: -- a-addr)	Create a named variable. *name* returns *a-addr*.

`value` lets you create a name for a numerical value that can be changed. Later execution of that name leaves the assigned value on the stack. The following example creates a word named `foo` with an initial value of 22, and then calls `foo` to use its value in an arithmetic operation.

```
ok 22 value foo
ok foo 3 + .
25
ok
```

The value can be changed with the word `to`. For example:

```
ok 43 value thisval
ok thisval .
43
ok 10 to thisval
ok thisval .
10
ok
```

Words created with `value` are convenient, because you do not have to use `@` to retrieve their values.

The defining word `variable` creates a name with an associated one-cell memory location. Later execution of that name leaves the address of the memory on the stack. `@` and `!` are used to read or write to that address. For example:

```
ok variable bar
ok 33 bar !
ok bar @ 2 + .
35
ok
```

The defining word `defer` creates a word whose behavior can be changed later, by creating a slot which can be loaded with different behaviors at different times. For example:

```
ok hex
ok defer printit
ok ['] .d  to  printit
ok ff printit
255
ok : myprint ( n -- ) ." It is " .h
] ." in hex " ;
ok ['] myprint to printit
ok ff printit
It is ff in hex
ok
```

4

Searching the Dictionary

The *dictionary* contains all the available Forth words. Table 28 lists some useful tools you can use to search the dictionary. Please note that some of these tools work only with methods or commands while others work with all types of words (including, for example, variables and values).

Table 28 Dictionary Searching Commands

Command	Stack Diagram	Description
`'` *name*	(-- xt)	Find the named word in the dictionary. Returns the execution token. Use outside definitions.
`[']` *name*	(-- xt)	Similar to `'` but is used either inside or outside definitions.
`.calls`	(xt --)	Display a list of all commands which use the execution token *xt*.
`$find`	(str len -- xt true | str len false)	Search for word named by *str,len*. If found, leave *xt* and *true* on stack. If not found, leave name string and *false* on stack.
`find`	(pstr -- xt n | pstr false)	Search for word named by *pstr*. If found, leave *xt* and *true* on stack. If not found, leave name string and *false* on stack. (We recommend using `$find` to avoid using packed strings.)
`see` *thisword*	(--)	Decompile the specified word
`(see)`	(xt --)	Decompile the word whose execution token is *xt*.
`$sift`	(text-addr text-len --)	Display all command names containing *text-string*.
`sifting` *text*	(--)	Display all command names containing *text*. *text* contains no spaces.
`words`	(--)	Display the names of words in the dictionary as described below.

Before you can understand the operation of the dictionary searching tools, you need to understand how words become *visible*. If there is an *active package* at the time a word is defined, the new word becomes a method of the active package, and is visible only when that package is the active package. The commands `dev` and `find-device` can be used to select or change the active package. The command `device-end` deselects the currently active package leaving no active package.

If there is no active package at the time a word is defined, the word is *globally visible* (i.e. not specific to a particular package and always available).

The dictionary searching commands first search through the words of the active package, if there is one, and then through the globally visible words.

Note – The Forth commands `only` and `also` will affect which words are visible.

`.calls` can be used to locate all of the Forth commands that use a specified word in their definition. `.calls` takes an execution token from the stack and searches the entire dictionary to produce a listing of the names and addresses of every Forth command which uses that execution token. For example:

```
ok ' input .calls
    Called from input at 1e248d8
    Called from io at 1e24ac0
    Called from install-console at 1e33598
    Called from install-console at 1e33678
ok
```

`see`, used in the form:

`see` *thisword*

displays a “pretty-printed” listing of the source for *thisword* (without the comments, of course). For example:

```
ok see see
: see
    ' ['] (see) catch if
        drop
    then
;
ok
```

For more details on the use of `see`, refer to “Using the Forth Language Decompiler” on page 99.

`sifting` takes a string from the input stream and searches vocabularies in the dictionary search order to find every command name that contains the specified string as shown in the following screen.

```
ok sifting input

       In vocabulary options
(1e333f8) input-device
       In vocabulary forth
(1e2476c) input           (1e0a9b4) set-input       (1e0a978) restore-
input
(1e0a940) save-input      (1e0a7f0) more-input?     (1e086cc) input-
file
ok
```

`words` displays all the visible word names in the dictionary, starting with the most recent definition. If a node is currently selected (as with `dev`), the list produced by `words` is limited to the words in that selected node.

Compiling Data into the Dictionary

The commands listed in Table 29 control the compilation of data into the dictionary.

Table 29 Dictionary Compilation Commands

Command	Stack Diagram	Description
`,`	(n --)	Place a number in the dictionary.
`c,`	(byte --)	Place a byte in the dictionary.
`w,`	(word --)	Place a 16-bit number in the dictionary.
`l,`	(quad --)	Place a 32-bit number in the dictionary.
`[`	(--)	Begin interpreting.
`]`	(--)	End interpreting, resume compilation.
`allot`	(n --)	Allocate *n* bytes in the dictionary.
`>body`	(xt -- a-addr)	Find the data field address from the execution token.
`body>`	(a-addr -- xt)	Find the execution token from the data field address.

Table 29 Dictionary Compilation Commands *(Continued)*

Command	Stack Diagram	Description
`compile`	(--)	Compile the next word at run time. (Recommend using `postpone` instead.)
`[compile]` *name*	(--)	Compile the next (immediate) word. (Recommend using `postpone` instead.)
`here`	(-- addr)	Address of top of dictionary.
`immediate`	(--)	Mark the last definition as immediate.
`to` *name*	(n --)	Install a new action in a `defer` word or `value`.
`literal`	(n --)	Compile a number.
`origin`	(-- addr)	Return the address of the start of the Forth system.
`patch` *new-word old-word word-to-patch*	(--)	Replace *old-word* with *new-word* in *word-to-patch*.
`(patch)`	(new-n old-n xt --)	Replace *old-n* with *new-n* in word indicated by *xt*.
`postpone` *name*	(--)	Delay the execution of the word *name*.
`recurse`	(... -- ???)	Compile a recursive call to the word being compiled.
`recursive`	(--)	Make the name of the colon definition being compiled visible in the dictionary, and thus allow the name of the word to be used recursively in its own definition.
`state`	(-- addr)	Variable that is non-zero in compile state.

The dictionary compilation commands listed in Table 30 are available only on 64-bit OpenBoot implementations.

Table 30 64-Bit Dictionary Compilation Commands

Command	Stack Diagram	Description
`x,`	(o --)	Compile an octlet, `o`, into the dictionary (doublet-aligned).

4

Displaying Numbers

Basic commands to display stack values are shown in Table 31.

Table 31 Basic Number Display

Command	Stack Diagram	Description
`.`	(n --)	Display a number in the current base.
`.r`	(n size --)	Display a number in a fixed width field.
`.s`	(--)	Display contents of data stack.
`showstack`	(??? -- ???)	Execute `.s` automatically before each `ok` prompt.
`noshowstack`	(??? -- ???)	Turn off automatic display of the stack before each `ok` prompt
`u.`	(u --)	Display an unsigned number.
`u.r`	(u size --)	Display an unsigned number in a fixed width field.

The `.s` command displays the entire stack contents without disturbing them. It can usually be used safely for debugging purposes. (This is the function that `showstack` performs automatically.)

Changing the Number Base

You can print numbers in a specific number base or change the operating number base using the commands in Table 32.

Table 32 Changing the Number Base

Command	Stack Diagram	Description
`.d`	(n --)	Display *n* in decimal without changing base.
`.h`	(n --)	Display *n* in hex without changing base.
`base`	(-- addr)	Variable containing number base.
`decimal`	(--)	Set the number base to 10.
`d#` *number*	(-- n)	Interpret *number* in decimal; base is unchanged.
`hex`	(--)	Set the number base to 16.
`h#` *number*	(-- n)	Interpret *number* in hex; base is unchanged.

The d#and h# commands are useful when you want to input a number in a specific base without explicitly changing the current base. For example:

```
ok decimal          (Changes base to decimal)
ok 4 h# ff 17 2
4 255 17 2 ok
```

The .d and .h commands act like "." but display the value in decimal or hexadecimal, respectively, regardless of the current base setting. For example:

```
ok hex
ok ff .  ff .d
ff 255
```

Controlling Text Input and Output

This section describes text and character input and output commands.

Table 33 lists commands to control text input.

Table 33 Controlling Text Input

Command	Stack Diagram	Description
(*ccc*)	(--)	Create a comment. Conventionally used for stack diagrams.
\ *rest-of-line*	(--)	Treat the rest of the line as a comment.
ascii *ccc*	(-- char)	Get numerical value of first ASCII character of next word.
accept	(addr len1 -- len2)	Get a line of edited input from the console input device; store at *addr*. *len1* is the maximum allowed length. *len2* is the actual length received.
expect	(addr len --)	Get and display a line of input from the console; store at *addr*. (Recommend using accept instead.)
key	(-- char)	Read a character from the console input device.
key?	(-- flag)	True if a key has been typed on the console input device.

Table 33 Controlling Text Input *(Continued)*

Command	Stack Diagram	Description
`parse`	(char -- str len)	Parse text from the input buffer delimited by *char*.
`parse-word`	(-- str len)	Skip leading spaces and parse text from the input buffer delimited by white space.
`word`	(char -- pstr)	Collect a string delimited by *char* from the input buffer and place it as a packed string in memory at *pstr*. (Recommend using `parse` instead.)

Comments are used with Forth source code (generally in a text file) to describe the function of the code. The `(` (open parenthesis) is the Forth word that begins a comment. Any character up to the closing parenthesis `)` is ignored by the Forth interpreter. Stack diagrams are one example of comments using `(`.

Note – Remember to follow the`(` with a space, so that it is recognized as a Forth word.

`\` (backslash) indicates a comment terminated by the end of the line of text.

`key` waits for a key to be pressed, then returns the ASCII value of that key on the stack.

`ascii`, used in the form `ascii` *x*, returns on the stack the numerical code of the character *x*.

`key?` looks at the keyboard to see whether the user has recently typed any key. It returns a flag on the stack: `true` if a key has been pressed and `false` otherwise. See “Conditional Flags” on page 79 for a discussion on the use of flags.

Table 34 lists general-purpose text display commands.

Table 34 Displaying Text Output

Command	Stack Diagram	Description
`."` *ccc*`"`	(--)	Compile a string for later display.
`(cr`	(--)	Move the output cursor back to the beginning of the current line.
`cr`	(--)	Terminate a line on the display and go to the next line.
`emit`	(char --)	Display the character.

Table 34 Displaying Text Output *(Continued)*

Command	Stack Diagram	Description
`exit?`	(-- flag)	Enable the scrolling control prompt: `More [<space>,<cr>,q] ?` The return flag is `true` if the user wants the output to be terminated.
`space`	(--)	Display a `space` character.
`spaces`	(+n --)	Display +*n* spaces.
`type`	(addr +n --)	Display the +*n* characters beginning at *addr*.

`cr` sends a carriage-return / linefeed sequence to the console output device. For example:

```
ok 3 . 44 . cr 5 .
3 44
5
ok
```

`emit` displays the letter whose ASCII value is on the stack.

```
ok ascii a
61 ok 42
61 42 ok emit emit
Ba
ok
```

Table 35 shows commands used to manipulate text strings.

Table 35 Manipulating Text Strings

Command	Stack Diagram	Description
`",`	(addr len --)	Compile an array of bytes from *addr* of length *len*, at the top of the dictionary as a packed string.
`" ccc"`	(-- addr len)	Collect an input stream string, either interpreted or compiled.
`." ccc"`		Display the string *ccc* .
`.( ccc)`	(--)	Display the string *ccc* immediately.
`-trailing`	(addr +n1 -- addr +n2)	Remove trailing spaces.

Table 35 Manipulating Text Strings *(Continued)*

Command	Stack Diagram	Description
`bl`	(-- char)	ASCII code for the space character; decimal 32.
`count`	(pstr -- addr +n)	Unpack a packed string.
`lcc`	(char -- lowercase-char)	Convert a character to lowercase.
`left-parse-string`	(addr len char -- addrR lenR addrL lenL)	Split a string at *char* (which is discarded).
`pack`	(addr len pstr -- pstr)	Store the string *addr,len* as a packed string at *pstr*.
`upc`	(char -- uppercase-char)	Convert a character to uppercase.

Some string commands specify an address (the location in memory where the characters reside) and a length (the number of characters in the string). Other commands use a packed string or `pstr`, which is a location in memory containing a byte for the length, immediately followed by the characters. The stack diagram for the command indicates which form is used. For example, `count` converts a packed string to an address-length string.

The command `."` is used in the form: `."` *string*`"`. It outputs text immediately when it is encountered by the interpreter. A " (double quotation mark) marks the end of the text string. For example:

```
ok  : testing 34 .  ." This is a test"  55 . ;
ok
ok testing
34 This is a test55
ok
```

When " is used outside a colon definition, only two interpreted strings of up to 80 characters each can be assembled concurrently. This limitation does not apply in colon definitions.

Redirecting Input and Output

Normally, OpenBoot uses a keyboard for command input, and a frame buffer with a connected display screen for display output. (Server systems may use an ASCII terminal connected to a serial port. For more information on how to

connect a terminal to your system, see your system's installation manual.) You can redirect the input, the output, or both, to a serial port. This may be useful, for example, when debugging a frame buffer.

Table 36 lists commands you can use to redirect input and output.

Table 36 I/O Redirection Commands

Command	Stack Diagram	Description
`input`	(device --)	Select device, for example `ttya`, `keyboard`, or *device-specifier*, for subsequent input.
`io`	(device --)	Select device for subsequent input and output.
`output`	(device --)	Select device, for example `ttya`, `keyboard`, or *device-specifier*, for subsequent output.

The commands `input` and `output` temporarily change the current devices for input and output. The change takes place as soon as you enter a command; you do not have to reset your system. A system reset or power cycle causes the input and output devices to revert to the default settings specified in the NVRAM configuration variables `input-device` and `output-device`. These variables can be modified, if needed (see Chapter 3, "Setting Configuration Variables").

`input` must be preceded by one of the following: `keyboard`, `ttya`, `ttyb`, or *device-specifier* text string. For example, if input is currently accepted from the keyboard, and you want to make a change so that input is accepted from a terminal connected to the serial port `ttya`, type:

```
ok ttya input
ok
```

At this point, the keyboard becomes nonfunctional (except perhaps for `Stop-A`), but any text entered from the terminal connected to `ttya` is processed as input. All commands are executed as usual.

To resume using the keyboard as the input device, *use the terminal keyboard* to type:

```
ok keyboard input
ok
```

Similarly, `output` must be preceded by one of the following: `screen`, `ttya`, or `ttyb` or *device-specifier*. For example, if you want to send output to a serial port instead of the normal display screen, type:

```
ok ttya output
ok
```

The screen does *not* show the answering `ok` prompt, but the terminal connected to the serial port shows the `ok` prompt and all further output as well.

`io` is used in the same way, except that it changes both the input and output to the specified place. For example:

```
ok ttya io
ok
```

Generally, the argument to `input`, `output`, and `io` is a *device-specifier*, which can be either a device path name or a device alias. *The device must be specified as a Forth string, using double quotation marks* ("), as shown in the two examples below:

```
ok " /sbus/cgsix" output
```

or:

```
ok " screen" output
```

In the preceding examples, `keyboard`, `screen`, `ttya`, and `ttyb` are predefined Forth words that put their corresponding device alias string on the stack.

Command Line Editor

OpenBoot implements a command line editor (similar to EMACS, a common text editor), some optional extensions and an optional history mechanism for the User Interface. You use these tools to re-execute previous commands without retyping them, to edit the current command line to fix typing errors, or to recall and change previous commands.

Table 37 lists line-editing commands available at the `ok` prompt.

Table 37 Required Command Line Editor Keystroke Commands

Keystroke	Description
Delete	Erases previous character.
Backspace	Erases previous character.
Control-U	Erases the entire line.
Return (Enter)	Finishes editing of the line and submits the entire visible line to the interpreter regardless of the current cursor position.
Control-B	Moves backward one character.
Escape B	Moves backward one word.
Control-F	Moves forward one character.
Escape F	Moves forward one word.
Control-A	Moves backward to beginning of line.
Control-E	Moves forward to end of line.
Delete	Erases previous character.
Backspace	Erases previous character.
Control-H	Erases previous character.
Escape H	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
Control-W	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
Control-D	Erases next character.
Escape D	Erases from cursor to end of the word, storing erased characters in a save buffer.
Control-K	Erases from cursor to end of line, storing erased characters in a save buffer.
Control-U	Erases entire line, storing erased characters in a save buffer.

Table 37 Required Command Line Editor Keystroke Commands *(Continued)*

Keystroke	Description
Control-R	Retypes the line.
Control-Q	Quotes next character (allows you to insert control characters).
Control-Y	Inserts the contents of the save buffer before the cursor.

The command line history extension saves previously-typed commands in an EMACS-like command history ring that contains at least 8 entries. Commands may be recalled by moving either forward or backward around the ring. Once recalled, a command may be edited and/or resubmitted (by typing the Return key). The command line history extension keys are:

Table 38 Command Line History Keystroke Commands

Keystroke	Description
Control-P	Selects and displays the previous command in the command history ring.
Control-N	Selects and displays the next command in the command history ring.
Control-L	Displays the entire command history ring.

The command completion extension enables the system to complete long Forth word names by searching the dictionary for one or more matches based on the already-typed portion of a word. When you type a portion of a word followed by the command completion keystroke, `Control-Space`, the system behaves as follows:

- If the system finds exactly one matching word, the remainder of the word is automatically displayed.
- If the system finds several possible matches, the system displays all of the characters that are common to all of the possibilities.
- If the system cannot find a match for the already-typed characters, the system deletes characters from the right until there is at least one match for the remaining characters.
- The system beeps if it cannot determine an unambiguous match.

The command completion extension keys are:

Table 39 Command Completion Keystroke Commands

Keystroke	Description
Control-Space	Complete the name of the current word.
Control-?	Display all possible matches for the current word.
Control-/	Display all possible matches for the current word.

Conditional Flags

Forth conditionals use flags to indicate true/false values. A flag can be generated in several ways, based on testing criteria. The flag can then be displayed from the stack with the word ".", or it can be used as input to a conditional control command. Control commands can cause one behavior if a flag is true and another behavior if the flag is false. Thus, execution can be altered based on the result of a test.

A `0` value indicates that the flag value is `false`. A `-1` or any other nonzero number indicates that the flag value is `true`.

Table 40 lists commands that perform relational tests, and leave a `true` or `false` flag result on the stack.

Table 40 Comparison Commands

Command	Stack Diagram	Description
`<`	(n1 n2 -- flag)	True if *n1* < *n2*.
`<=`	(n1 n2 -- flag)	True if *n1* <= *n2*.
`<>`	(n1 n2 -- flag)	True if *n1* is not equal to *n2*.
`=`	(n1 n2 -- flag)	True if *n1* = *n2*.
`>`	(n1 n2 -- flag)	True if *n1* > *n2*.
`>=`	(n1 n2 -- flag)	True if *n1* >= *n2*.
`0<`	(n -- flag)	True if *n* < 0.
`0<=`	(n -- flag)	True if *n* <= 0.
`0<>`	(n -- flag)	True if *n* <> 0.
`0=`	(n -- flag)	True if *n* = 0 (also inverts any flag).
`0>`	(n -- flag)	True if *n* > 0.
`0>=`	(n -- flag)	True if *n* >= 0.

Table 40 Comparison Commands *(Continued)*

Command	Stack Diagram	Description
`between`	(n min max -- flag)	True if *min* <= *n* <= *max*.
`false`	(-- 0)	The value `FALSE`, which is 0.
`true`	(-- -1)	The value `TRUE`, which is -1.
`u<`	(u1 u2 -- flag)	True if *u1* < *u2*, unsigned.
`u<=`	(u1 u2 -- flag)	True if *u1* <= *u2*, unsigned.
`u>`	(u1 u2 -- flag)	True if *u1* > *u2*, unsigned.
`u>=`	(u1 u2 -- flag)	True if *u1* >= *u2*, unsigned.
`within`	(n min max -- flag)	True if *min* <= *n* < *max*.

`>` takes two numbers from the stack, and returns `true` (`-1`) on the stack if the first number was greater than the second number, or returns `false` (`0`) otherwise. An example follows:

```
ok 3 6 > .
0                    (3 is not greater than 6)
ok
```

`0=` takes one item from the stack, and returns `true` if that item was 0 or returns `false` otherwise. This word inverts any flag to its opposite value.

Control Commands

The following sections describe words used in a Forth program to control the flow of execution.

The `if…else…then` Structure

The commands `if`, `else` and `then` provide a simple control structure.

The commands listed in Table 41 control the flow of conditional execution.

Table 41 `if…else…then` Commands

Command	Stack Diagram	Description
if	(flag --)	Execute the following code when *flag* is `true`.
else	(--)	Execute the following code when *flag* is `false`.
then	(--)	Terminate `if…else…then`.

The format for using these commands is:

```
flag  if
      (do this if true)
then
(continue normally)
```

or

```
flag  if
      (do this if true)
else
      (do this if false)
then
(continue normally)
```

The `if` command consumes a flag from the stack. If the flag is `true` (nonzero), the commands following the `if` are performed. Otherwise, the commands (if any) following the `else` are performed.

```
ok : testit  ( n -- )
] 5 >  if  ." good enough "
] else  ." too small "
] then
] ." Done. "  ;
ok
ok 8 testit
good enough Done.
ok 2 testit
too small Done.
ok
```

Note – The] prompt reminds you that you are part way through creating a new colon definition. It reverts to ok after you finish the definition with a semicolon.

The case *Statement*

A high-level case command is provided for selecting alternatives with multiple possibilities. This command is easier to read than deeply-nested if…then commands.

Table 42 lists the conditional case commands.

Table 42 case Statement Commands

Command	Stack Diagram	Description
case	(selector -- selector)	Begin a case…endcase conditional.
endcase	(selector --)	Terminate a case…endcase conditional.
endof	(--)	Terminate an of…endof clause in a case…endcase
of	(selector test-value -- selector | {empty})	Begin an of…endof clause in a case conditional.

Here is a simple example of a case command:

```
ok : testit  ( testvalue -- )
]   case
]       0  of  ." It was zero "              endof
]       1  of  ." It was one "               endof
]       ff of  ." Correct "                  endof
]       -2 of  ." It was minus-two "         endof
]       ( default )  ." It was this value: "  dup .
]   endcase   ." All done."  ;
ok
ok 1 testit
It was one All done.
ok ff testit
Correct All done.
ok 4 testit
It was this value: 4 All done.
ok
```

Note – The (optional) `default` clause can use the test value which is still on the stack, but should *not* remove it (use the phrase "`dup .`" instead of "`.`"). A successful `of` clause automatically removes the test value from the stack.

The `begin` Loop

A `begin` loop executes the same commands repeatedly until a certain condition is satisfied. Such a loop is also called a conditional loop.

Table 43 lists commands to control the execution of conditional loops.

Table 43 `begin` (Conditional) Loop Commands

Command	Stack Diagram	Description
`again`	(--)	End a `begin`…`again` infinite loop.
`begin`	(--)	Begin a `begin`…`while`…`repeat`, `begin`…`until`, or `begin`…`again` loop.
`repeat`	(--)	End a `begin`…`while`…`repeat` loop.
`until`	(flag --)	Continue executing a `begin`…`until` loop until *flag* is true.
`while`	(flag --)	Continue executing a `begin`…`while`…`repeat` loop while *flag* is true.

There are two general forms:

```
begin    any commands…    flag  until
```

and

```
begin    any commands…    flag    while
         more commands            repeat
```

In both cases, the commands in the loop are executed repeatedly until the proper flag value causes the loop to be terminated. Then execution continues normally with the command following the closing command word (`until` or `repeat`).

In the `begin`…`until` case, `until` removes a flag from the top of the stack and inspects it. If the flag is `false`, execution continues just after the `begin`, and the loop repeats. If the flag is `true`, the loop is exited.

In the `begin`…`while`…`repeat` case, `while` removes a flag from the top of the stack and inspects it. If the flag is `true`, the loop continues by executing the commands just after the `while`. The `repeat` command automatically sends control back to `begin` to continue the loop. If the flag is `false` when `while` is encountered, the loop is exited immediately; control goes to the first command after the closing `repeat`.

An easy mnemonic for either of these loops is: If true, fall through.

A simple example follows.

```
ok begin 4000 c@ .  key? until    (repeat until any key is pressed)
43 43 43 43 43 43 43 43 43 43 43 43 43 43 43 43 43
ok
```

The loop starts by fetching a byte from location 4000 and displaying the value. Then, the `key?` command is called, which leaves a `true` on the stack if the user has pressed any key, and `false` otherwise. This flag is consumed by `until` and, if the value is `false`, then the loop continues. Once a key is pressed, the next call to `key?` returns `true`, and the loop terminates.

Unlike many versions of Forth, the User Interface allows the interactive use of loops and conditionals — that is, without first creating a definition.

The `do` Loop

A `do` loop (also called a counted loop) is used when the number of iterations of the loop can be calculated in advance. A `do` loop normally exits just *before* the specified ending value is reached.

Table 44 lists commands to control the execution of counted loops.

Table 44 `do` (Counted) Loop Commands

Command	Stack Diagram	Description
`+loop`	(n --)	End a `do`…`+loop` construct; add `n` to loop index and return to `do` (if *n* < 0, index goes from *start* to *end* inclusive).
`?do`	(end start --)	Begin `?do`…`loop` to be executed 0 or more times. Index goes from *start* to *end*-1 inclusive. If *end* = *start*, loop is not executed.
`?leave`	(flag --)	Exit from a `do`…`loop` if *flag* is non-zero.
`do`	(end start --)	Begin a `do`…`loop`. Index goes from *start* to *end*-1 inclusive. Example: `10 0 do i . loop` (prints 0 1 2…d e f).
`i`	(-- n)	Leaves the loop index on the stack.
`j`	(-- n)	Leaves the loop index of the next outer enclosing loop on the stack.
`leave`	(--)	Exit from `do`…`loop.`
`loop`	(--)	End of `do`…`loop.`

The following screen shows several examples of how loops are used.

```
ok 10 5 do  i .  loop
5 6 7 8 9 a b c d e f
ok
ok 2000 1000 do i .  i c@ . cr   i c@ ff = if leave then  4 +loop
1000 23
1004 0
1008 fe
100c 0
1010 78
1014 ff
ok : scan ( byte -- )
]    6000 5000      ( Scan memory 5000 - 6000 for bytes not equal to the specified byte )
]    do dup i c@ <> ( byte error? )
]      if i . then  ( byte )
]    loop
]    drop ( the original byte was still on the stack, discard it )
]  ;
ok 55 scan
5005 5224 5f99
ok 6000 5000 do i i c! loop      ( Fill a region of memory with a stepped pattern )
ok
ok 500 value testloc
ok : test16 ( -- ) 1.0000 0 ( do 0-ffff )  ( Write different 16-bit values to a location )
]     do i testloc w! testloc w@ i <> ( error? )    ( Also check the location )
]       if ." Error - wrote " i . ." read " testloc w@ . cr
]        leave ( exit after first error found )    ( This line is optional )
]       then
]     loop
]  ;
ok test16
ok 6000 to testloc
ok test16
Error - wrote 200 read 300
ok
```

Additional Control Commands

Table 45 contains descriptions of additional program execution control commands.

Table 45 Program Execution Control Commands

Command	Stack Diagram	Description
`abort`	(--)	Abort current execution and interpret keyboard commands.
`abort"` *ccc*`"`	(abort? --)	If *abort?* is true, abort and display message.
`eval`	(addr len --)	Interpret Forth source from addr len.
`execute`	(xt --)	Execute the word whose execution token is on the stack.
`exit`	(--)	Return from the current word. (Cannot be used in counted loops.)
`quit`	(--)	Same as `abort`, but leave stack intact.

`abort` causes immediate termination and returns control to the keyboard. `abort"` is similar to `abort` but is different in two respects. `abort"` removes a flag from the stack and only aborts if the flag is `true`. Also, `abort"` prints any desired message when the abort takes place.

`eval` takes a string from the stack (specified as an address and a length). The characters in that string are then interpreted as if they were entered from the keyboard. If a Forth text file has been loaded into memory (see Chapter 5, “Loading and Executing Programs”), then `eval` can be used to compile the definitions contained in the file.

4

Loading and Executing Programs 5

The User Interface provides several methods for loading and executing a program on the machine. These methods load a file into memory from Ethernet, a hard disk, a floppy disk, or a serial port, and support the execution of Forth, FCode and binary executable programs.

Most of these methods require the file to have a Client program header; see *IEEE 1275.1-1994 Standard for Boot (Initialization Configuration) Firmware* for a description. This header is similar to the `a.out` header used by many UNIX systems. Sun's FCode tokenizer generates files with the Client program header.

5

OpenBoot commands for loading files from various sources are listed in Table 46.

Table 46 File Loading Commands and Extensions

Command	Stack Diagram	Description
`boot` [*device-specifier*] [*arguments*]	(--)	Depending on the values of various configuration variables and the optional arguments, determine the file and device to be used. Reset the machine, load the identified program from the identified device, and execute the program.
`byte-load`	(addr xt --)	Interpret FCode beginning at *addr*. If *xt* is 1 (the usual case), use `rb@` to read the FCode. Otherwise, use the access routine whose execution token is *xt*.
`dl`	(--)	Load a Forth source text file over a serial line until Control-D is detected and then interpret. Using `tip` as an example, type: **`~C cat`** *filename* **`Control-D`**
`dlbin`	(--)	Load a binary file over a serial line. Using `tip` as an example, type: **`~C cat`** *filename*
`dload` *filename*	(addr --)	Load the specified file over Ethernet at the given address.
`eval`	(... str len -- ???)	Synonym for `evaluate`.
`evaluate`	(... str len -- ???)	Interpret Forth source text from the specified string.
`go`	(--)	Begin executing a previously-loaded binary program, or resume executing an interrupted program.
`init-program`	(--)	Prepare machine to execute a binary file.
`load` [*device-specifier*] [*arguments*]	(--)	Depending on the values of various configuration variables and the optional arguments, determine the file and device to be used, and load the identified program from the identified device.
`load-base`	(-- addr)	Address at which `load` places the data it reads from a device.
`?go`	(--)	Execute Forth, FCode or binary programs.

Using boot

Although boot is normally used to boot the operating system, it can be used to load and execute any client program. Although booting usually happens automatically, the user can also initiate booting from the User Interface.

The boot process is as follows:

- The machine may be reset if a client program has been executed since the last reset. (The execution of a reset is implementation dependent.)
- A device is selected by parsing the boot command line to determine the boot device and the boot arguments to use. Depending on the form of the boot command, the boot device and/or argument values may be obtained from configuration variables.
- The bootpath and bootargs properties in the /chosen node of the device tree are set with the selected values.
- The selected program is loaded into memory using a protocol that depends on the type of the selected device. For example, a disk boot might read a fixed number of blocks from the beginning of the disk, while a tape boot might read a particular tape file.
- The loaded program is executed. The behavior of the program may be further controlled by the argument string (if any) that was either contained within the selected configuration variable or was passed to the boot command on the command line.

boot has the following general format:

```
boot [device-specifier] [arguments]
```

where *device-specifier* and *arguments* are optional. For a complete discussion of the use of the boot command, see “Booting for the Expert User” on page 15.

Using dl to Load Forth Text Files Over Serial Port A

Forth programs loaded with dl must be ASCII files.

To load a file over the serial line, connect the test system's serial port A to a machine that is able to transfer a file on request (in other words, a *server*). Start a terminal emulator on the server, and use that terminal emulator to download the file using dl.

The following example assumes the use of the Solaris terminal emulator `tip`. (See Appendix A, “Setting Up a TIP Connection”, for information on this procedure.)

1. At the `ok` prompt of the test system, type:

```
ok dl
```

2. In the `tip` window of the server, type:

`~C`

to obtain a command line with which to issue a Solaris command on the server.

Note – The `C` is case-sensitive and must be capitalized.

Note – `tip` will only recognize the `~` as a `tip` command if it is the first character on the command line. If `tip` fails to recognize the `~C`, type Enter in the `tip` window and repeat `~C`.

---

3. At the `local command` prompt, use `cat` to send the file.

```
~C (local command) cat filename
(Away two seconds)
Control-D
```

When `tip` displays a message of the form `(Away n seconds)`, type:

`Control-D`

in the `tip` window to signal `dl` that the end of the file has been reached.

`dl` then automatically interprets the file, and the `ok` prompt reappears on the screen of the test system.

Using `load`

The syntax and behavior of `load` are similar to `boot` except that the program is only loaded and not executed. `load` also does not do a machine reset prior to loading as `boot` may.

The general form of the `load` command is:

`load` [*device-specifier*] [*arguments*]

The parsing of the `load` command's parameters is affected by the same configuration variables as `boot`, and `load`'s *device-specifier* and *arguments* are identified by the same process. (See "Booting for the Expert User" on page 15 for the details.)

Once the *device-specifier* and *arguments* are identified, loading proceeds as follows:

1. The *device-specifier* and *arguments* are saved in the `bootpath` and `bootargs` properties, respectively, of the `/chosen` node.
2. If the *device-specifier* was obtained from a configuration variable, its value may be a list of devices. If the list contains only a single entry, that entry is used by `load` as the *device-specifier*.

   If the list contains more than one entry, an attempt is made to open each listed device, beginning with the first entry, and continuing until the next to last entry. If the system successfully opens a device, that device is closed and is used by `load` as the *device-specifier*. If none of these devices can be opened, the last device in the list is used by `load` as the *device-specifier*.
3. `load` attempts to open the device specified by *device-specifier*. If the device cannot be opened, loading is terminated.
4. If the device is successfully opened, the device's `load` method is invoked to load the specified program from the specified device at the system's default load address.
5. If `load` is successful, and if the beginning of the loaded image is a valid client program header for the system:
   a. Memory is allocated at the address and of the size specified in that header.
   b. The loaded image is moved from the default load address to the newly allocated memory.
   c. The system is initialized such that a subsequent `go` command will begin the execution of the loaded program.

5

Using `dlbin` *to Load FCode or Binary Executables Over Serial Port A*

FCode or binary programs loaded with `dlbin` must be Client program header files. `dlbin` loads the files at the entry point indicated in the Client program header. Link binary files for 4000 (hex). Recent versions of the FCode Tokenizer create a Client program header file with entry point 4000.

To load a file over the serial line, connect the test system's serial port A to a machine that is able to transfer a file on request (i.e. a *server*). Start a terminal emulator on the server, and use that terminal emulator to download the file using `dlbin`.

The following example assumes the use of the Solaris terminal emulator `tip`. (See Appendix A, “Setting Up a TIP Connection”, for information on this procedure.)

1. At the test system’s `ok` prompt, type:

```
ok dlbin
```

2. In the `tip` window of the server, type:

`~C`

to obtain a command line with which to issue a Solaris command on the server.

Note – The `C` is case-sensitive and must be capitalized.

Note – `tip` will only recognize the `~` as a `tip` command if it is the first character on the command line. If `tip` fails to recognize the `~C`, type Enter in the `tip` window and repeat `~C`.

---

3. At the “local command” prompt, use `cat` to send the file.

```
~C (local command) cat filename
(Away two seconds)
```

When `tip` completes the download, it displays a message of the form `(Away` *n* `seconds)`, and the `ok` prompt reappears on the screen of the test system.

To execute an FCode program, type:

```
ok 4000 1 byte-load
```

To execute the downloaded program, type:

```
ok go
```

Using `dload` to Load from Ethernet

`dload` loads files over Ethernet at a specified address, as shown below.

```
ok 4000 dload filename
```

In the above example, *filename* must be relative to the server's root. Use **`4000`** (hex) as the address for `dload` input. `dload` uses the trivial file transfer protocol (TFTP), so the server may need to have its permissions adjusted for this to work.

Forth Programs

Forth programs loaded with `dload` must be ASCII files beginning with the two characters "\ " (backslash and space). To execute the loaded Forth program, type:

```
ok 4000 file-size @ eval
```

In the above example, *file-size* contains the size of the loaded image.

FCode Programs

FCode programs loaded with `dload` must be Client program header files. To execute the loaded FCode program, type:

```
ok 4000 1 byte-load
```

`byte-load` is used by OpenBoot to interpret FCode programs on expansion boards such as SBus. The `1` in the example is a specific value of a parameter that specifies the separation between FCode bytes in the general case. Since `dload` loads into system memory, `1` is the correct spacing.

Binary Executables

`dload` requires binary programs to be in Client program header. Executable binary programs loaded must be either linked to `dload`'s input address (e.g., 4000) or be position independent. To execute the binary program, type:

```
ok go
```

To run the program again, type:

```
ok init-program go
```

`dload` does not use intermediate booters (unlike the boot command). Thus, any symbol information included in the Client program header file is available to the User Interface's symbolic debugging capability. (See Chapter 6, “Debugging” for more information on symbolic debugging.)

Using ?go

Once a program has been loaded into the system, `?go` can be used to execute that program regardless of the type of the program.

`?go` examines the start of the loaded image. If the image begins with the string “\ “ (backslash and space), the image is assumed to be Forth text. The Forth interpreter is invoked to interpret the image.

If the image does not start with “\ “, ?go checks the start of the image for the string “CODE”. If this string is found, the image is assumed to be FCode.

If the image does not start with “CODE”, ?go executes the image as a binary program.

5

Debugging 6

OpenBoot provides debugging tools that include a Forth language decompiler, a machine language disassembler, register display commands, a symbolic debugger, breakpoint commands, a Forth source level debugger, a high-level language patching facility and exception tracing. This chapter describes the capabilities specified by *IEEE Standard 1275-1994*.

Using the Forth Language Decompiler

The built-in Forth language decompiler can be used to recreate the source code for any previously-defined Forth word. The command:

```
ok see old-name
```

displays a listing of the source for `old-name` (without the source comments, of course).

A companion to `see` is `(see)` which is used to decompile the Forth word whose execution token is taken from the stack. For example:

```
ok ' old-name (see)
```

`(see)` produces a listing in a format identical to `see`.

```
ok see see
: see
   ' ['] (see) catch if
      drop
   then
;
ok see (see)
defer (see) is
: (f0018a44)
   40 rmargin ! dup dup (f00189c4) dup (f0018944) (f0018980) (f0018658)
   ??cr
;
ok f0018a44 (see)
: (f0018a44)
   40 rmargin ! dup dup (f00189c4) dup (f0018944) (f0018980) (f0018658)
   ??cr
;
```

The preceding listing shows that:

- `see` itself is composed only of Forth source words that were compiled as `external` or as `headers` with `fcode-debug?` set to true.
- `(see)` is a defer word. `(see)` also contains words that were compiled as `headerless` and are, consequently, displayed as hex addresses surrounded by parentheses.
- Decompiling a word with `(see)` produces a listing identical to that produced by `see`.

For words implemented in Forth assembler language, `see` displays a Forth assembler listing. For example, decompiling `dup` displays:

```
ok see dup
code dup
f0008c98     sub         %g7, 8, %g7
f0008c9c     stx         %g4, [%g0 + %g7]
f0008ca0     ld          [%g5], %l0
f0008ca4     jmp         %l0, %g2, %g0
f0008ca8     add         %g5, 4, %g5
```

Using the Disassembler

The built-in disassembler translates the contents of memory into equivalent assembly language.

Table 47 lists commands that disassemble memory into equivalent opcodes.

Table 47 Disassembler Commands

Command	Stack Diagram	Description
`+dis`	(--)	Continue disassembling where the last disassembly left off.
`dis`	(addr --)	Begin disassembling at the specified address.

`dis` begins to disassemble the data content of any desired location. The system pauses when:

- Any key is pressed while disassembly is taking place.
- The disassembler output fills the display screen.
- A `call` or `jump` opcode is encountered.

Disassembly can then be stopped or the `+dis` command can be used to continue disassembling at the location where the last disassembly stopped.

Memory addresses are normally shown in hexadecimal. However, if a symbol table is present, memory addresses are displayed symbolically whenever possible.

Displaying Registers

You can enter the User Interface from the middle of an executing program as a result of a program crash, a user abort, or an encountered breakpoint. (Breakpoints are discussed on page 104.) In all these cases, the User Interface automatically saves all the CPU data register values in a buffer area. These values can then be inspected or altered for debugging purposes.

6

SPARC Registers

Table 48 lists the SPARC register commands.

Table 48 SPARC Register Commands

Command	Stack Diagram	Description
`%g0 through %g7`	(-- value)	Return the value in the specified global register.
`%i0 through %i7`	(-- value)	Return the value in the specified input register.
`%l0 through %l7`	(-- value)	Return the value in the specified local register.
`%o0 through %o7`	(-- value)	Return the value in the specified output register.
`%pc %npc %y`	(-- value)	Return the value in the specified register.
`%f0 through %f31`	(-- value)	Return the value in the specified floating point register.
`.fregisters`	(--)	Display the values in `%f0` through `%f31`.
`.locals`	(--)	Display the values in the `i`, `l` and `o` registers.
`.registers`	(--)	Display values in processor registers.
`.window`	(window# --)	Same as `w .locals`; display the desired window.
`ctrace`	(--)	Display the return stack showing C subroutines.
`set-pc`	(new-value --)	Set `%pc` to *new-value*, and set `%npc` to (*new-value*+4).
`to` *regname*	(new-value --)	Change the value stored in any of the above registers. Use in the form: *new-value* `to` *regname*.
`w`	(window# --)	Set the current window for displaying `%i`*x*, `%l`*x*, or `%o`*x*.

Table 49 SPARC V9 Register Commands

Command	Stack Diagram	Description

`%fprs`
`%asi`
`%pstate`
`%tl-c`
`%pil`
`%tstate`
`%tt`
`%tba`
`%cwp`
`%cansave`
`%canrestore`
`%otherwin`
`%wstate`
`%cleanwin`
	(-- value)	Return the value in the specified register

`.pstate`	(--)	Formatted display of the processor state register
`.ver`	(--)	Formatted display of the version register
`.ccr`	(--)	Formatted display of the `%ccr` register
`.trap-registers`	(--)	Display trap-related registers

The values of all of these registers are saved and can be altered with `to`. After the values have been inspected and/or modified, program execution can be continued with the `go` command. The saved (and possibly modified) register values are copied back into the CPU, and execution resumes at the location specified by the saved program counter.

If you change `%pc` with `to`, you should also change `%npc`. (It is easier to use `set-pc`, which changes both registers automatically.)

For the `w` and `.window` commands, a window value of 0 usually specifies the current window—that is, the active window for the subroutine where the program was interrupted. A value of 1 specifies the window for the caller of this subroutine, 2 specifies the caller's caller, and so on, up to the number of active stack frames. The default starting value is 0.

6

Breakpoints

The User Interface provides a breakpoint capability to assist in the development and debugging of stand-alone programs. (Programs that run over the operating system generally do not use this OpenBoot feature, but use other debuggers designed to run with the operating system.) The breakpoint feature lets you stop the program under test at desired points. After program execution has stopped, registers or memory can be inspected or changed, and new breakpoints can be set or cleared. You can resume program execution with the `go` command.

Table 50 lists the breakpoint commands that control and monitor program execution.

Table 50 Breakpoint Commands

Command	Stack Diagram	Description
`+bp`	(addr --)	Add a breakpoint at the specified address.
`-bp`	(addr --)	Remove the breakpoint at the specified address.
`--bp`	(--)	Remove the most-recently-set breakpoint.
`.bp`	(--)	Display all currently set breakpoints.
`.breakpoint`	(--)	Perform a specified action when a breakpoint occurs. This word can be altered to perform any desired action. For example, to display registers at every breakpoint, type: `['] .registers to .breakpoint`. The default behavior is `.instruction`. To perform multiple behaviors, create a single definition which calls all desired behaviors, then load that word into `.breakpoint`.
`.instruction`	(--)	Display the address, opcode for the last-encountered breakpoint.
`.step`	(--)	Perform a specified action when a single step occurs (see `.breakpoint`).
`bpoff`	(--)	Remove all breakpoints.
`finish-loop`	(--)	Execute until the end of this loop.
`go`	(--)	Continue from a breakpoint. This can be used to go to an arbitrary address by setting up the processor's program counter before issuing `go`.
`gos`	(n --)	Execute `go` *n* times.
`hop`	(--)	(Like the `step` command.) Treat a subroutine call as a single instruction.
`hops`	(n --)	Execute `hop` *n* times.
`return`	(--)	Execute until the end of this subroutine.
`returnl`	(--)	Execute until the end of this leaf subroutine.

Table 50 Breakpoint Commands *(Continued)*

Command	Stack Diagram	Description
`skip`	(--)	Skip (do not execute) the current instruction.
`step`	(--)	Single-step one instruction.
`steps`	(n --)	Execute `step` *n* times.
`till`	(addr --)	Execute until the given address is encountered. Equivalent to `+bp go`.

To debug a program using breakpoints, use the following procedure.

1. Load the test program into memory.

   See Chapter 5, “Loading and Executing Programs” for more information. The register values are initialized automatically.

2. (Optional) Disassemble the downloaded program to verify a properly-loaded file.

3. Begin single-stepping the test program using the `step` command.

   You can also set a breakpoint, then execute (for example, using the commands *addr* `+bp` and `go`) or perform other variations.

The Forth Source-level Debugger

The Forth Source-level Debugger allows single-stepping and tracing of Forth programs. Each step represents the execution of one Forth word.

The debugger commands are shown in Table 51.

Table 51 Forth Source-level Debugger Commands

Command	Description
`c`	“Continue”. Switch from stepping to tracing, thus tracing the remainder of the execution of the word being debugged.
`d`	“Down a level”. Mark for debugging the word whose name was just displayed, then execute it.
`u`	“Up a level”. Un-mark the word being debugged, mark its caller for debugging, and finish executing the word that was previously being debugged.
`f`	Start a subordinate Forth interpreter with which Forth commands can be executed normally. When that interpreter is terminated (with `resume`), control returns to the debugger at the place where the `f` command was executed.
`g`	“Go.” Turn off the debugger and continue execution.

Table 51 Forth Source-level Debugger Commands *(Continued)*

Command	Description
`q`	"Quit". Abort the execution of the word being debugged and all its callers and return to the command interpreter.
`s`	"see". Decompile the word being debugged.
`$`	Display the *address,len* on top of the stack as a text string.
`h`	"Help". Display symbolic debugger documentation.
`?`	"Short Help". Display brief symbolic debugger documentation.
`debug` *name*	Mark the specified Forth word for debugging. Enter the Forth Source-level Debugger on all subsequent attempts to execute *name*. After executing `debug`, the execution speed of the system may decrease until debugging is turned off with `debug-off`. (Do not debug basic Forth words such as ".".)
`(debug`	Like `debug` except that `(debug` takes an execution token from the stack instead of a name from the input stream.
`debug-off`	Turn off the Forth Source-level Debugger so that no word is being debugged.
`resume`	Exit from a subordinate interpreter, and go back to the stepper (See the `f` command in this table).
`stepping`	Set "step mode" for the Forth Source-level Debugger, allowing the interactive, step-by-step execution of the word being debugged. Step mode is the default.
`tracing`	Set "trace mode" for the Forth Source-level Debugger. Tracing enables the execution of the word being debugged, while showing the name and stack contents for each word called by that word.
`<space-bar>`	Execute the word just displayed and proceed to the next word.

Every Forth word is defined as a series of one or more words that could be called "component" words. While debugging a specified word, the debugger displays information about the contents of the stack while executing each of the word's "component" words. Immediately before executing each component word, the debugger displays the contents of the stack and the name of the component word that is about to be executed.

In trace mode, that component word is then executed, and the process continues with the next component word.

In step mode (the default), the user controls the debugger's execution behavior. Before the execution of each component word, the user is prompted for one of the keystrokes specified in Table 51.

Using patch *and* (patch)

OpenBoot provides the ability to change the definition of a previously compiled Forth word using high-level Forth language. While the changes will typically be made in the appropriate source code, the patch facility provides a means of quickly correcting errors uncovered during debugging.

patch reads the input stream for the following information:

- The name of the new code to be inserted.
- The name of the old code to be replaced.
- The name of the word containing the old code.

For example, consider the following example in which the word test is replaced with the number 555:

```
ok : patch-me  test 0 do  i . cr  loop ;
ok patch 555 test patch-me
ok see patch-me
: patch-me
    h# 555 0 do
        i . cr
    loop
;
```

When using patch, some care must be taken to select the right word to replace. This is especially true if the word you are replacing is used several times within the target word and the occurrence of the word that you want to replace is not the first occurrence within the target word. In such a case, some subterfuge is required.

```
ok : patch-me2  dup dup dup ( This third dup should be drop) ;
ok : xx dup ;
ok patch xx dup patch-me2
ok patch xx dup patch-me2
ok patch drop dup patch-me2
ok see patch-me2
: patch-me2
    xx xx drop
;
```

Another use for `patch` is the case where the word to be patched contains some functionality that needs to be completely discarded. In this case, the word `exit` should be patched over the first word whose functionality is to be eliminated. For example, consider a word whose definition is:

```
ok : foo good bad unneeded ;
```

In this example, the functionality of `bad` is incorrect and the functionality of `unneeded` should be discarded. A first attempt to patch `foo` might be:

```
ok : right this that exit ;
ok patch right bad foo
```

on the expectation that the use of `exit` in the word `right` would prevent the execution of `unneeded`. Unfortunately, `exit` terminates the execution of the word which contains it, in this case `right`. The correct way to patch `foo` is:

```
ok : right this that ;
ok patch right bad foo
ok patch exit unneeded foo
```

`(patch)` is similar to `patch` except that `(patch)` obtains its arguments from the stack. The stack diagram for `(patch)` is:

```
( new-n1 num1? old-n2 num2? xt -- )
```

where:

- `new-n1` and `old-n2` can be either execution tokens or literal numbers.
- `num1?` and `num2?` are flags indicating whether `new-n1` or `old-n2`, respectively, are numbers.
- `xt` is the execution token of the word to be patched.

For example, consider the following example in which we reverse the affect of our first `patch` example by replacing the number 555 with `test`:

```
ok see patch-me
: patch-me
    h# 555 0 do
        i . cr
    loop
;
ok ['] test false 555 true ['] patch-me (patch)
ok see patch-me
: patch-me
    test 0 do
        i . cr
    loop
;
```

6

Using `ftrace`

The `ftrace` command shows the sequence of Forth words that were being executed at the time of the last exception. An example of `ftrace` follows.

```
ok : test1 1 ! ;
ok : test2 1 test1 ;
ok test2
Memory address not aligned
ok ftrace
!       Called from test1 at ffeacc5c
test1   Called from test2 at ffeacc6a
(ffe8b574) Called from (interpret at ffe8b6f8
execute    Called from catch at ffe8a8ba
    ffefeff0
    0
    ffefebdc
catch       Called from (fload) at ffe8ced8
    0
(fload)    Called from interact at ffe8cf74
execute Called from catch at ffe8a8ba
    ffefefd4
    0
    ffefebdc
catch   Called from (quit at ffe8cf98
```

In this example, `test2` calls `test1`, which tries to store a value to an unaligned address. This results in the exception: `Memory address not aligned`.

The first line of `ftrace`'s output shows the last command that caused the exception to occur. The next lines show locations from which the subsequent commands were being called.

The last few lines are usually the same in any `ftrace` output, because that is the calling sequence in effect when the Forth interpreter interprets a word from the input stream.

Setting Up a TIP Connection A

You can use the TTYA or TTYB ports on your SPARC system to connect to a second Sun workstation. By connecting two systems in this way, you can use a shell window on the Sun workstation as a terminal to your SPARC system. (See the on-line `tip` manpage for detailed information about terminal connection to a remote host.)

The TIP method is recommended (over simply connecting to a dumb terminal), since it lets you use windowing and operating system features when working with the boot PROM. A communications program or another non-Sun computer can be used in the same way, if the program can match the output baud rate used by the PROM TTY port.

Note – In the following pages, “SPARC system” refers to your system, and “Sun workstation” refers to the system you are connecting to your system.

Use the following procedure to set up the TIP connection.

1. Connect the Sun workstation TTYB serial port to your SPARC system TTYA serial port using a serial connection cable. Use a 3-wire Null Modem Cable, and connect wires 3-2, 2-3, and 7-7. (Refer to your system installation manual for specifications on null modem cables.)

2. At the Sun workstation, add the following lines to the `/etc/remote` file. If you are running a pre-Solaris 2.0 version of the operating environment, type:

```
hardwire:\
    :dv=/dev/ttyb:br#9600:el=^C^S^Q^U^D:ie=%$:oe=^D:
```

   If you are running version 2.0 or 2.1 of the Solaris operating environment, type:

```
hardwire:\
    :dv=/dev/term/b:br#9600:el=^C^S^Q^U^D:ie=%$:oe=^D:
```

3. In a Shell Tool window on the Sun workstation, type:

```
hostname% tip hardwire
connected
```

   The Shell Tool window is now a TIP window directed to the Sun workstation TTYB.

Note – Use a Shell Tool, not a Command Tool; some TIP commands may not work properly in a Command Tool window.

4. At your SPARC system, enter the Forth Monitor so that the `ok` prompt is displayed.

   If you do not have a video monitor attached to your SPARC system, connect the SPARC system TTYA to the Sun workstation TTYB and turn on the power to your SPARC system. Wait for a few seconds, and press `Stop-A` to

interrupt the power-on sequence and start the Forth Monitor. Unless the system is completely inoperable, the Forth Monitor is enabled, and you can continue with the next step in this procedure.

5. If you need to redirect the standard input and output to TTYA, type:

```
ok ttya io
```

There will be no echoed response.

6. Press Return on the Sun workstation keyboard. The `ok` prompt appears in the TIP window.

Typing ~# in the TIP window is equivalent to typing `Stop-A` at the SPARC system.

Note – *Do not* type `Stop-A` from a Sun workstation being used as a TIP window to your SPARC system. Doing so will abort the operating system on the workstation. (If you accidentally type `Stop-A`, you can recover by immediately typing `go` at the `ok` prompt.)

---

7. When you are finished using the TIP window, end your TIP session and exit the window:

   a. Redirect the input and output to the screen and keyboard, if needed, by typing:

```
ok screen output keyboard input
```

Note – When entering ~ (tilde character) commands in the TIP window, ~ must be the first character entered on the line. To ensure that you are at the start of a new line, press Return first.

A

Common Problems with TIP

This section describes solutions for TIP problems occurring in pre-Solaris 2.0 operating environments.

Problems with TIP may occur if:

- The lock directory is missing or incorrect.
  There should be a directory named `/usr/spool/uucp`. The owner should be `uucp` and the mode should be `drwxr-sr-x`.

- TTYB is enabled for logins.
  The status field for TTYB (or the serial port you are using) must be set to `off` in `/etc/ttytab`. Be sure to execute `kill -HUP 1` (see `init(8)`) as root if you have to change this entry.

- `/dev/ttyb` is inaccessible.
  Sometimes, a program will have changed the protection of `/dev/ttyb` (or the serial port you are using) so that it is no longer accessible. Make sure that `/dev/ttyb` has the mode set to `crw-rw-rw-`.

- The serial line is in tandem mode.
  If the TIP connection is in tandem mode, the operating system sometimes sends XON (^S) characters (particularly when programs in other windows are generating lots of output). The XON characters are detected by the Forth word `key?`, and can cause confusion. The solution is to turn off tandem mode with the `~s !tandem` TIP command.

- The `.cshrc` file generates text.
  TIP opens a sub-shell to run `cat`, thus causing text to be attached to the beginning of your loaded file. If you use `dl` and see any unexpected output, check your `.cshrc` file.

Building A Bootable Floppy Disk B

This appendix outlines the steps necessary to create a bootable floppy disk. Information about the OS commands can be found in the `man` pages. Refer to the specific OS release for information about particular files and their locations within the file system.

1. **Format the diskette.**
   The `fdformat` command is an example of a utility for formatting floppy disks.

2. **Create the diskette's file systems.**
   If available, you can use the `newfs` command.

3. **Mount the diskette to a temporary partition.**
   If available, you can use the `mount` command to do this.

4. **Copy the second-level disk booter to the diskette, using the `cp` command.**
   `boot` and `ufsboot` are examples of second-level booters.

5. **Install a boot block on the floppy.**
   If available, you can use the `installboot` command.

6. **Copy the file that you want to boot to the mounted diskette, using the `cp` command.**

7. **Unmount the diskette, using `umount`, if available.**

8. **You can now remove the diskette from the drive.**
   Use `eject floppy`, if it's available.

B

Troubleshooting Guide C

What do you do if your system fails to boot properly? This appendix discusses some common failures and ways to alleviate them.

Power-on Initialization Sequence

Familiarize yourself with the system power-on initialization messages. You can then identify problems more accurately because these messages show you the types of functions the system performs at various stages of system start-up. They also show the transfer of control from POST to OpenBoot to the Booter to the kernel.

The example that follows shows the OpenBoot initialization sequence in a Sun Ultra 1 system. The messages before the banner appear on TTYA only if the `diag-switch?` parameter is true.

Note – The actual OpenBoot initialization sequence is system dependent. The messages on your system may be different.

```
...

ttya initialized                                        (At this point, POST has finished execution
                                                         and has transferred control to OpenBoot)
Probing Memory Bank #0 16 + 16 : 32 Megabytes           (Probe memory)
Probing Memory Bank #1 0 + 0 : 0 Megabytes
Probing Memory Bank #2 0 + 0 : 0 Megabytes
Probing Memory Bank #3 0 + 0 : 0 Megabytes
                                                        (If use-nvramrc? is true, the firmware
                                                         executes NVRAMRC commands. The
                                                         firmware then checks for Stop-x commands,
                                                         and probes the devices. The Keyboard LEDs
                                                         are then flashed.)
Probing UPA Slot at le,0 Nothing there                  (Probe devices)
Probing /sbus@lf,0 at 0,0 cgsix
Probing /sbus@lf,0 at 1,0 Nothing there
Probing /sbus@lf,0 at 2,0 Nothing there


Sun Ultra 1 UPA/SBus (UltraSPARC 167 MHz), Keyboard Present(Display the banner)
OpenBoot 3.0, 32 MB memory installed, Serial #7570016
Ethernet address 8:0:20:73:82:60, Host ID: 80738260.

ok boot disk3
Boot device: /sbus/espdma@e,8400000/esp@e,8800000/sd@3,0(The firmware is TFTP-ing the boot
                                                         program)
sd@3,0 File and args:                                  (Control is transferred to the booter after this
                                                         message is displayed)
FCode UFS Reader 1.8 01 Feb 1995 17:07:00,IEEE 1275 Client Interface.(Booter starts executing)
Loading: /platform/sun4u/ufsboot
cpu0: SUNW,UltraSPARC (upaid 0 impl 0x0 ver 0x0 clock 143 MHz)
SunOS Release 5.5 Version quick_gate_build:04/13/95 (UNIX(R) System V Release 4.0)
                                                        (Control is passed to the kernel after this message
                                                         is displayed)
Copyright (c) 1983-1995, Sun Microsystems, Inc.         (The kernel starts to execute)
DEBUG enabled

                      (More kernel messasges)
```

Emergency Procedures

Some OpenBoot systems provide the capability of commanding OpenBoot by means of depressing a combination of keys on the system's keyboard (i.e. a "keyboard chord").

Table C-1 describes the keyboard chords provided by SPARC-compatible systems. When issuing any of these commands, hold down the keys immediately after turning on the power to the SPARC system, and keep them pressed for a few seconds until the keyboard LEDs flash.

Table C-1 SPARC-Compatible System Keyboard Chords

Command	Description
`Stop`	Bypass POST. This command does not depend on security-mode. (Note: some systems bypass POST as a default; in such cases, use `Stop-D` to start POST.)
`Stop-A`	Abort.
`Stop-D`	Enter diagnostic mode (set `diag-switch?` to `true`).
`Stop-F`	Enter Forth on TTYA instead of probing. Use `fexit` to continue with the initialization sequence. Useful if hardware is broken.
`Stop-N`	Reset NVRAM contents to default values.

Note – These commands are disabled if the PROM security is on. Also, if your system has `full` security enabled, you cannot apply any of the suggested commands unless you have the password to get to the `ok` prompt.

Preserving Data After a System Crash

The `sync` command forces any information on its way to the hard disk to be written out immediately. This is useful if the operating system has crashed, or has been interrupted without preserving all data first.

`sync` actually returns control to the operating system, which then performs the data saving operations. After the disk data has been synchronized, the operating system begins to save a core image of itself. If you do not need this core dump, you can interrupt the operation with the `Stop-A` key sequence.

Common Failures

This section describes some common failures and how you can fix them.

Blank Screen - No Output

Problem: Your system screen is blank and does not show any output.

Here are possible causes for this problem:

- Hardware has failed.

  Refer to your system documentation.

- Keyboard is not attached.

  If the keyboard is not plugged in, the output goes to TTYA instead. To fix this problem, power down the system, plug in the keyboard, and power on again.

- Monitor is not turned on or is not plugged in.

  Check the power cable on the monitor. Make sure the monitor cable is plugged into the system frame buffer; then turn the monitor on.

- `output-device` is set to TTYA or TTYB.

  This means the NVRAM parameter `output-device` is set to `ttya` or `ttyb` instead of being set to `screen`. Connect a terminal to TTYA and reset the system. After getting to the `ok` prompt on the terminal, type: `screen output` to send output to the frame buffer. Use `setenv` to change the default display device, if needed.

- System has multiple frame buffers.

  If your system has several plugged-in frame buffers, or it has a built-in frame buffer and one or more plugged-in frame buffers, then it is possible that the wrong frame buffer is being used as the console device. See “Setting the Console to a Specific Monitor” on page 123.

System Boots From the Wrong Device

Problem: Your system is supposed to boot from the disk; instead, it boots from the net.

There are two possible causes for this:

- The `diag-switch?` NVRAM parameter is set to `true`.

  Interrupt the booting process with `Stop-A`. Type the following commands at the `ok` prompt:

```
ok setenv diag-switch? false
ok boot
```

  The system should now start booting from the disk.

- The `boot-device` NVRAM parameter is set to `net` instead of `disk`.

  Interrupt the booting process with `Stop-A`. Type the following commands at the `ok` prompt:

```
ok setenv boot-device disk
ok boot
```

  Note that the preceding commands cause the system to boot from the disk defined as `disk` in the device aliases list. If you want to boot from another service, set `boot-device` accordingly.

Problem: Your system is booting from a disk instead of from the net.

- `boot-device` is not set to `net`.

  Interrupt the booting process with `Stop-A`. Type the following commands at the `ok` prompt:

```
ok setenv boot-device net
ok boot
```

Problem: Your system is booting from the wrong disk. (For example, you have more than one disk in your system. You want the system to boot from `disk2`, but the system is booting from `disk1` instead.)

- `boot-device` is not set to the correct disk.

  Interrupt the booting process with `Stop-A`. Type the following commands at the `ok` prompt:

```
ok setenv boot-device disk2
ok boot
```

System Will Not Boot From Ethernet

Problem: Your system fails to boot from the net.

The problem could be one of the following:

- NIS maps are out-of-date.

  Report the problem to your system administrator.

- Ethernet cable is not plugged in.

  Plug in the ethernet cable. The system should continue with the booting process.

- Server is not responding: `no carrier` messages.

  Report the problem to your system administrator.

- `tpe-link-test` is disabled.

  Refer to the troubleshooting information in your system documentation. (Note: systems that do not have Twisted Pair Ethernet will not have the `tpe-link-test` parameter.)

System Will Not Boot From Disk

Problem: You are booting from a disk and the system fails with the message: `The file just loaded does not appear to be executable.`

- The boot block is missing or corrupted.

Install a new boot block.

Problem: You are booting from a disk and the system fails with the message: `Can't open boot device.`

- The disk may be powered down (especially if it is an external disk).

  Turn on power to the disk, and make sure the SCSI cable is connected to the disk and the system.

SCSI Problems

Problem: Your system has more than one disk installed, and you get SCSI-related errors.

- Your system might have duplicate SCSI target number settings.

  Try the following procedure:

  a. Unplug all but one of the disks.

  b. At the `ok` prompt, type:

```
ok probe-scsi
```

  Note the target number and its corresponding unit number.

  c. Plug in another disk and perform Step b again.

  d. If you get an error, change the target number of this disk to be one of the unused target numbers.

  e. Repeat Steps b, c, and d until all the disks are plugged back in.

Setting the Console to a Specific Monitor

Problem: You have more than one monitor attached to the system, and the console is not set to the intended monitor.

- If you have more than one monitor attached to the system, OpenBoot always assigns the console to the frame buffer specified by the `output-device` NVRAM parameter. The default value of `output-device` is `screen`, which is an alias for one of the frame buffers found by the firmware.

A common way to change this default is to change `output-device` to the appropriate frame buffer:

```
ok nvalias myscreen /sbus/cgsix
ok setenv output-device myscreen
ok reset-all
```

Another way of setting the console to a specific monitor is to change the `sbus-probe-list` NVRAM parameter.

```
ok show sbus-probe-list     (Display the current and default values)
```

If the frame buffer that you are choosing as the console is in slot 2, change `sbus-probe-list` to probe slot 2 first:

```
ok setenv sbus-probe-list 2013
ok reset-all
```

If a non-SBus frame buffer is installed, this second method may not work.

Forth Word Reference D

This appendix contains the Forth commands supported by OpenBoot.

For the most part, the commands are listed in the order in which they were introduced in the chapters. Some of the tables in this appendix show commands that are not listed elsewhere in this manual. These additional commands (such as memory mapping or output display primitives, or machine-specific register commands) are also part of the set of words in the OpenBoot implementation of Forth; they are included with relevant groups of commands.

Table D-1 Stack Item Notation

Notation	**Description**
|	Alternate stack results shown with space, e.g. (input -- addr len false | result true).
|	Alternate stack items shown without space, e.g. (input -- addr len|0 result).
???	Unknown stack item(s).
…	Unknown stack item(s). If used on both sides of a stack comment, means the same stack items are present on both sides.
< > <space>	Space delimiter. Leading spaces are ignored.
a-addr	Variable-aligned address.
addr	Memory address (generally a virtual address).
addr len	Address and length for memory region
byte *bxxx*	8-bit value (low order byte in a 32-bit word).
char	7-bit value (low order byte), high bit unspecified.

Table D-1 Stack Item Notation *(Continued)*

Notation	Description
cnt len size	Count or length.
d*xxx*	Double (extended-precision) numbers. 2 stack items, hi quadlet on top of stack.
<eol>	End-of-line delimiter.
false	0 (false flag).
ihandle	Pointer for an instance of a package.
n n1 n2 n3	Normal signed values (32-bit).
nu nu1	Signed or unsigned values (32-bit).
<nothing>	Zero stack items.
phandle	Pointer for a package.
phys	Physical address (actual hardware address).
phys.lo phys.hi	Lower / upper cell of physical address
pstr	Packed string.
quad q*xxx*	Quadlet (32-bit value).
qaddr	Quadlet (32-bit) aligned address
{text}	Optional text. Causes default behavior if omitted.
"text<*delim*>"	Input buffer text, parsed when command is executed. Text delimiter is enclosed in <>.
[text<*delim*>]	Text immediately following on the same line as the command, parsed immediately. Text delimiter is enclosed in <>.
true	-1 (true flag).
u*xxx*	Unsigned value, positive values (32-bit).
virt	Virtual address (address used by software).
waddr	Doublet (16-bit) aligned address
word w*xxx*	Doublet (16-bit value, low order two bytes in a 32-bit word).
x x1	Arbitrary stack item.
x.lo x.hi	Low / high significant bits of a data item
xt	Execution token.
xxx?	Flag. Name indicates usage (e.g. done? ok? error?).
xyz-str xyz-len	Address and length for unpacked string.
xyz-sys	Control-flow stack items, implementation-dependent.

Table D-1 Stack Item Notation *(Continued)*

Notation	Description
(C: --)	Compilation stack diagram
(--) (E: --)	Execution stack diagram
(R: --)	Return stack diagram

Table D-2 Examining and Creating Device Aliases

Command	Description
`devalias`	Display all current device aliases.
`devalias` *alias*	Display the device path name corresponding to *alias*.
`devalias` *alias device-path*	Define an alias representing *device-path*. If an alias with the same name already exists, the new value supersedes the old.

Table D-3 Commands for Browsing the Device Tree

Command	Description
`.properties`	Display the names and values of the current node's properties.
`dev` *device-path*	Choose the specified device node, making it the current node.
`dev` *node-name*	Search for a node with the specified name in the subtree below the current node, and choose the first such node found.
`dev ..`	Choose the device node that is the parent of the current node.
`dev /`	Choose the root machine node.
`device-end`	Leave the device tree.
`"` *device-path*`" find-device`	Choose the specified device node, similar to `dev`.
`ls`	Display the names of the current node's children.
`pwd`	Display the device path name that names the current node.
`see` *wordname*	Decompile the specified word.

Table D-3 Commands for Browsing the Device Tree *(Continued)*

Command	Description
`show-devs` [*device-path*]	Display all the devices known to the system directly beneath a given device in the device hierarchy. `show-devs` used by itself shows the entire device tree.
`words`	Display the names of the current node's methods.
`"` *device-path*`" select-dev`	Select the specified device and make it the active node.

Table D-4 Help Commands

Command	Description
`help`	List main help categories.
`help` *category*	Show help for all commands in the category. Use only the first word of the category description.
`help` *command*	Show help for an individual command (where available).

Table D-5 Common Options for the `boot` Command

Parameter	Description
`boot` [*device-specifier*] [*filename*] [*options*]	
[*device-specifier*]	The name (full path name or alias) of the boot device. Typical values include: `cdrom` (CD-PROM drive) `disk` (hard disk) `floppy` (3-1/2" diskette drive) `net` (Ethernet) `tape` (SCSI tape)
[*filename*]	The name of the program to be booted (for example, `stand/diag`). *filename* is relative to the root of the selected device and partition (if specified). If *filename* is not specified, the boot program uses the value of the `boot-file` NVRAM parameter (see Chapter 3).
[*options*]	(These options are specific to the operating system, and may differ from system to system.)

Table D-6 Diagnostic Test Commands

Command	Description
`probe-scsi`	Identify devices attached to a SCSI bus.
`test` *device-specifier*	Execute the specified device's self-test method. For example: `test floppy` - test the floppy drive, if installed `test /memory` - test the number of megabytes specified by the `test net` - test the network connection
`test-all` [*device-specifier*]	Test all devices (that have a built-in self-test method) below the specified device tree node. (If *device-specifier* is absent, the root node is used.)
`watch-clock`	Test the clock function.
`watch-net`	Monitor the network connection.

Table D-7 System Information Display Commands

Command	Description
`banner`	Display power-on banner.
`show-sbus`	Display list of installed and probed SBus devices.
`.enet-addr`	Display current Ethernet address.
`.idprom`	Display ID PROM contents, formatted.
`.traps`	Display a list of SPARC trap types.
`.version`	Display version and date of the boot PROM.
`.speed`	Display CPU and bus speeds.
`show-devs`	Display all installed and probed devices.

Table D-8 Standard Configuration Variables

Parameter	Typical Default	Description
`auto-boot?`	true	If true, boot automatically after power on or reset.
`boot-command`	boot	Command that is executed if `auto-boot?` is true.
`boot-device`	disk net	Device from which to boot.

Table D-8 Standard Configuration Variables *(Continued)*

Parameter	Typical Default	Description
boot-file	empty string	File to boot (an empty string lets secondary booter choose default).
diag-device	net	Diagnostic boot source device.
diag-file	empty string	File from which to boot in diagnostic mode.
diag-switch?	false	If true, run in diagnostic mode.
diag-level	min	Level of diagnostics to run.
fcode-debug?	false	If true, include name fields for plug-in device FCodes.
input-device	keyboard	Power-on input device (usually keyboard, ttya, or ttyb).
nvramrc	empty	Contents of NVRAMRC.
oem-banner	empty string	Custom OEM banner (enabled by oem-banner? true).
oem-banner?	false	If true, use custom OEM banner.
oem-logo	no default	Byte array custom OEM logo (enabled by oem-logo? true). Displayed in hexadecimal.
oem-logo?	false	If true, use custom OEM logo (else, use Sun logo).
output-device	screen	Power-on output device (usually screen, ttya, or ttyb).
screen-#columns	80	Number of on-screen columns (characters/line).
screen-#rows	34	Number of on-screen rows (lines).
security-#badlogins	no default	Number of incorrect security password attempts.
security-mode	none	Firmware security level (options: none, command, or full).
security-password	no default	Firmware security password (never displayed). *Do not set this variable directly.*
use-nvramrc?	false	If true, execute commands in NVRAMRC during system start-up.
sbus-probe-list	01	Which SBus slots to probe and in what order.

Table D-9 Viewing / Changing Configuration Variables

Command	Description
`printenv`	Display all current parameters and current default values. (Numbers are usually shown as decimal values.) `printenv` *parameter* shows the current value of the named parameter.
`setenv` *parameter value*	Set parameter to the specified decimal or text value. (Changes are permanent, but usually only take effect after a reset.)
`set-default` *parameter*	Reset the value of the named parameter to the factory default.
`set-defaults`	Reset parameter values to the factory defaults.
`password`	Set `security-password`.

Table D-10 Configuration Variable Command Primitives

Command	Stack Diagram	Description
`nodefault-bytes` *parameter*	(len --) (E: -- addr len)	Create custom NVRAM parameter. Use this command in NVRAMRC to make the parameter permanent.
`$setenv`	(data-addr data-len name-str name-len --)	Set the configuration variable *name-string* to *data*.

Table D-11 System Start-up Control Primitives

Command	Description
`suppress-banner`	When included in the script, suppresses the execution of the sequence `probe-all install-console banner` in the system start-up sequence. Consequently, the sequence `probe-all install-console banner` can then be used inside the script, possibly interspersed with other commands, without having those commands re-executed after the script finishes.

Table D-12 NVRAMRC Editor Commands

Command	Description
`nvalias` *alias device-path*	Store the command "`devalias` *alias device-path*" in NVRAMRC. The alias persists until the `nvunalias` or `set-defaults` commands are executed.
`nvedit`	Enter the NVRAMRC editor. If data remains in the temporary buffer from a previous `nvedit` session, resume editing those previous contents. If not, read the contents of NVRAMRC into the temporary buffer and begin editing it.
`nvquit`	Discard the contents of the temporary buffer, without writing it to NVRAMRC. Prompt for confirmation.
`nvrecover`	Recover the contents of NVRAMRC if they have been lost as a result of the execution of `set-defaults`; then enter the editor as with `nvedit`. `nvrecover` fails if `nvedit` is executed between the time that the NVRAMRC contents were lost and the time that `nvrecover` is executed.
`nvrun`	Execute the contents of the temporary buffer.
`nvstore`	Copy the contents of the temporary buffer to NVRAMRC; discard the contents of the temporary buffer.
`nvunalias` *alias*	Delete the corresponding alias from NVRAMRC.

Table D-13 NVRAM Script Editor Keystroke Commands

Keystroke	Description
`Control-B`	Moves backward one character.
`Escape B`	Moves backward one word.
`Control-F`	Moves forward one character.
`Escape F`	Moves forward one word.
`Control-A`	Moves backward to beginning of the line.
`Control-E`	Moves forward to end of the line.
`Control-N`	Moves to the next line of the script editing buffer.
`Control-P`	Moves to the previous line of the script editing buffer.
`Return (Enter)`	Inserts a newline at the cursor position and advances to the next line.
`Control-O`	Inserts a newline at the cursor position and stays on the current line.
`Control-K`	Erases from the cursor position to the end of the line, storing the erased characters in a save buffer. If at the end of a line, joins the next line to the current line (i.e. deletes the newline).

Table D-13 NVRAM Script Editor Keystroke Commands *(Continued)*

Keystroke	Description
`Delete`	Erases the previous character.
`Backspace`	Erases the previous character.
`Control-H`	Erases the previous character.
`Escape H`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-W`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-D`	Erases the next character.
`Escape D`	Erases from the cursor to the end of the word, storing the erased characters in a save buffer.
`Control-U`	Erases the entire line, storing the erased characters in a save buffer.
`Control-Y`	Inserts the contents of the save buffer before the cursor.
`Control-Q`	Quotes the next character (i.e. allows you to insert control characters).
`Control-R`	Retypes the line.
`Control-L`	Displays the entire contents of the editing buffer.
`Control-C`	Exits the script editor, returning to the OpenBoot command interpreter. The temporary buffer is preserved, but is not written back to the script. (Use `nvstore` afterwards to write it back.)

Table D-14 Stack Manipulation Commands

Command	Stack Diagram	Description
`clear`	(??? --)	Empty the stack.
`depth`	(-- u)	Return the number of items on the stack.
`drop`	(x --)	Remove top item from the stack.
`2drop`	(x1 x2 --)	Remove 2 items from the stack.
`3drop`	(x1 x2 x3 --)	Remove 3 items from the stack.
`dup`	(x -- x x)	Duplicate th e top stack item.
`2dup`	(x1 x2 -- x1 x2 x1 x2)	Duplicate 2 stack items.
`3dup`	(x1 x2 x3 -- x1 x2 x3 x1 x2 x3)	Duplicate 3 stack items.
`?dup`	(x -- x x | 0)	Duplicate the top stack item if it is non-zero.
`nip`	(x1 x2 -- x2)	Discard the second stack item.
`over`	(x1 x2 -- x1 x2 x1)	Copy second stack item to top of stack.
`2over`	(x1 x2 x3 x4 -- x1 x2 x3 x4 x1 x2)	Copy second 2 stack items.
`pick`	(xu … x1 x0 u -- xu … x1 x0 xu)	Copy *u*-th stack item (`1 pick` = `over`).

Table D-14 Stack Manipulation Commands *(Continued)*

Command	Stack Diagram	Description
`>r`	(x --) (R: -- x)	Move a stack item to the return stack.
`r>`	(-- x) (R: x --)	Move a return stack item to the stack.
`r@`	(-- x) (R: x -- x)	Copy the top of the return stack to the stack.
`roll`	(xu ... x1 x0 u -- xu-1 ... x1 x0 xu)	Rotate `u` stack items (`2 roll` = `rot`).
`rot`	(x1 x2 x3 -- x2 x3 x1)	Rotate 3 stack items.
`-rot`	(x1 x2 x3 -- x3 x1 x2)	Inversely rotate 3 stack items.
`2rot`	(x1 x2 x3 x4 x5 x6 -- x3 x4 x5 x6 x1 x2)	Rotate 3 pairs of stack items.
`swap`	(x1 x2 -- x2 x1)	Exchange the top 2 stack items.
`2swap`	(x1 x2 x3 x4 -- x3 x4 x1 x2)	Exchange 2 pairs of stack items.
`tuck`	(x1 x2 -- x2 x1 x2)	Copy top stack item below second item.

Table D-15 Single-Precision Arithmetic Functions

Command	Stack Diagram	Description
`+`	(nu1 nu2 -- sum)	Add *nu1* + *nu2*.
`-`	(nu1 nu2 -- diff)	Subtract *nu1* - *nu2*.
`*`	(nu1 nu2 -- prod)	Multiply *nu1* * *nu2*.
`*/`	(n1 n2 n3 -- quot)	Calculates *nu1* * *nu2* / *n3*.
`/`	(n1 n2 -- quot)	Divide *n1* by *n2*; remainder is discarded.
`1+`	(nu1 -- nu2)	Add 1.
`1-`	(nu1 -- nu2)	Subtract 1.
`2+`	(nu1 -- nu2)	Add 2.
`2-`	(nu1 -- nu2)	Subtract 2.
`abs`	(n -- u)	Absolute value.
`bounds`	(n count -- n+count n)	Prepare arguments for `do` or `?do` loop.
`even`	(n -- n | n+1)	Round to nearest even integer >= *n*.
`max`	(n1 n2 -- n1|n2)	Return the maximum of *n1* and *n2*.
`min`	(n1 n2 -- n1|n2)	Return the minimum of *n1* and *n2*.
`mod`	(n1 n2 -- rem)	Remainder of *n1* / *n2*.
`*/mod`	(n1 n2 n3 -- rem quot)	Remainder, quotient of *n1* * *n2* / *n3*.
`/mod`	(n1 n2 -- rem quot)	Remainder, quotient of *n1* / *n2*.

Table D-15 Single-Precision Arithmetic Functions *(Continued)*

Command	Stack Diagram	Description
`negate`	(n1 -- n2)	Change the sign of *n1*.
`u*`	(u1 u2 -- uprod)	Multiply 2 unsigned numbers yielding an unsigned product.
`u/mod`	(u1 u2 -- urem uquot)	Divide unsigned number by an unsigned number; yield remainder and quotient.

Table D-16 Bit-wise Logical Operators

Command	Stack Diagram	Description
`2*`	(x1 -- x2)	Multiply by 2.
`2/`	(x1 -- x2)	Divide by 2.
`>>a`	(x1 u -- x2)	Arithmetic right-shift *x1* by *u* bits.
`and`	(x1 x2 -- x3)	Bitwise logical AND.
`invert`	(x1 -- x2)	Invert all bits of *x1*.
`lshift`	(x1 u -- x2)	Left-shift *x1* by *u* bits. Zero-fill low bits.
`or`	(x1 x2 -- x3)	Bitwise logical OR.
`rshift`	(x1 u -- x2)	Right-shift *x1* by *u* bits. Zero-fill high bits.
`u2/`	(x1 -- x2)	Logical right shift 1 bit; zero shifted into high bit.
`xor`	(x1 x2 -- x3)	Bitwise exclusive OR.

Table D-17 Double Number Arithmetic Functions

Command	Stack Diagram	Description
`d+`	(d1 d2 -- d.sum)	Add *d1* to *d2* yielding double number *d.sum*.
`d-`	(d1 d2 -- d.diff)	Subtract *d2* from *d1* yielding double number *d.diff*.
`fm/mod`	(d n -- rem quot)	Divide *d* by *n*.
`m*`	(n1 n2 -- d)	Signed multiply with double-number product.
`s>d`	(n1 -- d1)	Convert a number to a double number.
`sm/rem`	(d n -- rem quot)	Divide *d* by *n*, symmetric division.
`um*`	(u1 u2 -- ud)	Unsigned multiply yielding unsigned double number product.
`um/mod`	(ud u -- urem uprod)	Divide *ud* by *u*.

.

Table D-18 32-Bit Data Type Conversion Functions

Command	Stack Diagram	Description
bljoin	(b.low b2 b3 b.hi -- quad)	Join four bytes to form a quadlet
bwjoin	(b.low b.hi -- word)	Join two bytes to form a doublet.
lbflip	(quad1 -- quad2)	Reverse the bytes within a quadlet
lbsplit	(quad -- b.low b2 b3 b.hi)	Split a quadlet into four bytes.
lwflip	(quad1 -- quad2)	Swap the doublets within a quadlet.
lwsplit	(quad -- w.low w.hi)	Split a quadlet into two doublets.
wbflip	(word1 -- word2)	Swap the bytes within a doublet.
wbsplit	(word -- b.low b.hi)	Split a doublet into two bytes.
wljoin	(w.low w.hi -- quad)	Join two doublets to form a quadlet.

Table D-19 64-Bit Data Type Conversion Functions

Command	Stack Diagram	Description
bxjoin	(b.lo b.2 b.3 b.4 b.5 b.6 b.7 b.hi -- o)	Join 8 bytes to form an octlet.
lxjoin	(quad.lo quad.hi -- o)	Join 2 quadlets to form an octlet.
wxjoin	(w.lo w.2 w.3 w.hi -- o)	Join four doublets to form an octlet.
xbflip	(oct1 -- oct2)	Reverse the bytes within an octlet.
xbflips	(oaddr len --)	Reverse the bytes within each octlet in the given region.The behavior is undefined if *len* is not a multiple of /x.
xbsplit	(o -- b.lo b.2 b.3 b.4 b.5 b.6 b.7 b.hi)	Split an octlet into 8 bytes.
xlflip	(oct1 -- oct2)	Reverse the quadlets within an octlet. The bytes within each quadlet are not reversed.
xlflips	(oaddr len --)	Reverse the quadlets within each octlet in the given region. The bytes within each quadlet are not reversed. The behavior is undefined if *len* is not a multiple of /x.
xlsplit	(o -- quad.lo quad.hi)	Split on octlet into 2 quadlets.

Table D-19 64-Bit Data Type Conversion Functions *(Continued)*

Command	Stack Diagram	Description
xwflip	(oct1 -- oct2)	Reverse the doublets within an octlet. The bytes within each doublet are not reversed.
xwflips	(oaddr len --)	Reverse the doublets within each octlet in the given region. The bytes within each doublet are not reversed. The behavior is undefined if *len* is not a multiple of /x.
xwsplit	(o -- w.lo w.2 w.3 w.hi)	Split an octlet into 4 doublets.

Table D-20 Address Arithmetic Functions

Command	Stack Diagram	Description
aligned	(n1 -- n1 | a-addr)	Increase *n1* if necessary to yield a variable aligned address.
/c	(-- n)	The number of address units to a byte: 1.
/c*	(nu1 -- nu2)	Synonym for chars.
ca+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /c.
ca1+	(addr1 -- addr2)	Synonym for char+.
char+	(addr1 -- addr2)	Increment *addr1* by the value of /c.
cell+	(addr1 -- addr2)	Increment *addr1* by the value of /n.
chars	(nu1 -- nu2)	Multiply *nu1* by the value of /c.
cells	(nu1 -- nu2)	Multiply *nu1* by the value of /n.
/l	(-- n)	Number of address units to a quadlet; typically 4.
/l*	(nu1 -- nu2)	Multiply *nu1* by the value of /l.
la+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /l.
la1+	(addr1 -- addr2)	Increment *addr1* by the value of /l.
/n	(-- n)	Number of address units in a cell.
/n*	(nu1 -- nu2)	Synonym for cells.
na+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /n.
na1+	(addr1 -- addr2)	Synonym for cell+.
/w	(-- n)	Number of address units to a doublet; typically 2.
/w*	(nu1 -- nu2)	Multiply *nu1* by the value of /w.
wa+	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of /w.
wa1+	(addr1 -- addr2)	Increment *addr1* by the value of /w.

Table D-21 64-Bit Address Arithmetic Functions

Command	Stack Diagram	Description
`/x`	(-- n)	Number of address units in an octlet, typically eight.
`/x*`	(nu1 -- nu2)	Multiply *nu1* by the value of `/x`.
`xa+`	(addr1 index -- addr2)	Increment *addr1* by *index* times the value of `/x`.
`xa1+`	(addr1 -- addr2)	Increment *addr1* by the value of `/x`.

Table D-22 Memory Access Commands

Command	Stack Diagram	Description
`!`	(x a-addr --)	Store a number at *a-addr*.
`+!`	(nu a-addr --)	Add *nu* to the number stored at *a-addr*.
`@`	(a-addr -- x)	Fetch a number from *a-addr*.
`2!`	(x1 x2 a-addr --)	Store 2 numbers at *a-addr*, *x2* at lower address.
`2@`	(a-addr -- x1 x2)	Fetch 2 numbers from *a-addr*, *x2* from lower address.
`blank`	(addr len --)	Set *len* bytes of memory beginning at *addr* to the space character (decimal 32).
`c!`	(byte addr --)	Store *byte* at *addr*.
`c@`	(addr -- byte)	Fetch a *byte* from *addr*.
`cpeek`	(addr -- false | byte true)	Attempt to fetch the byte at *addr*. Return the data and `true` if the access was successful. Return `false` if a read access error occurred.
`cpoke`	(byte addr -- okay?)	Attempt to store the *byte* to *addr*. Return `true` if the access was successful. Return `false` if a write access error occurred.
`comp`	(addr1 addr2 len -- diff?)	Compare two byte arrays. *diff?* is 0 if the arrays are identical, *diff?* is -1 if the first byte that is different is lesser in the string at *addr1*, *diff?* is 1 otherwise.
`dump`	(addr len --)	Display *len* bytes of memory starting at *addr*.
`erase`	(addr len --)	Set *len* bytes of memory beginning at *addr* to `0`.
`fill`	(addr len byte --)	Set *len* bytes of memory beginning at *addr* to the value *byte*.
`l!`	(quad qaddr --)	Store a quadlet *q* at *qaddr*.
`l@`	(qaddr -- quad)	Fetch a quadlet *q* from *qaddr*.
`lbflips`	(qaddr len --)	Reverse the bytes within each quadlet in the specified region.

Table D-22 Memory Access Commands *(Continued)*

Command	Stack Diagram	Description
`lwflips`	(qaddr len --)	Swap the doublets within each quadlet in specified region.
`lpeek`	(qaddr -- false | quad true)	Attempt to fetch the 32-bit quantity at *qaddr*. Return the data and `true` if the access was successful. Return `false` if a read access error occurred.
`lpoke`	(quad qaddr -- okay?)	Attempt to store the 32-bit quantity at *qaddr*. Return `true` if the access was successful. Return `false` if a a write access error occurred.
`move`	(src-addr dest-addr len --)	Copy *len* bytes from *src-addr* to *dest-addr*.
`off`	(a-addr --)	Store `false` at *a-addr*.
`on`	(a-addr --)	Store `true` at *a-addr*.
`unaligned-l!`	(quad addr --)	Store a quadlet *q*, any alignment
`unaligned-l@`	(addr -- quad)	Fetch a quadlet *q*, any alignment.
`unaligned-w!`	(w addr --)	Store a doublet *w*, any alignment.
`unaligned-w@`	(addr -- w)	Fetch a doublet *w*, any alignment.
`w!`	(w waddr --)	Store a doublet *w* at *waddr*.
`w@`	(waddr -- w)	Fetch a doublet *w* from *waddr*.
`<w@`	(waddr -- n)	Fetch doublet *w* from *waddr*, sign-extended.
`wbflips`	(waddr len --)	Swap the bytes within each doublet in the specified region.
`wpeek`	(waddr -- false | w true)	Attempt to fetch the 16-bit quantity at *waddr*. Return the data and `true` if the access was successful. Return `false` if a read access error occurred.
`wpoke`	(w waddr -- okay?)	Attempt to store the 16-bit quantity to *waddr*. Return `true` if the access was successful. Return `false` if a write access error occurred.

Table D-23 64-Bit Memory Access Functions

Command	Stack Diagram	Description
`<l@`	(qaddr -- n)	Fetch quadlet from qaddr, sign-extended.
`x,`	(o --)	Compile an octlet, o, into the dictionary (doublet-aligned).
`x@`	(oaddr -- o)	Fetch octlet from an octlet aligned address.
`x!`	(o oaddr --)	Store octlet to an octlet aligned address.
`xbflips`	(oaddr len --)	Reverse the bytes within each octlet in the given region.The behavior is undefined if *len* is not a multiple of `/x`.
`xlflips`	(oaddr len --)	Reverse the quadlets within each octlet in the given region. The bytes within each quadlet are not reversed. The behavior is undefined if *len* is not a multiple of `/x`.
`xwflips`	(oaddr len --)	Reverse the doublets within each octlet in the given region. The bytes within each doublet are not reversed. The behavior is undefined if *len* is not a multiple of `/x`.

Table D-24 Memory Mapping Commands

Command	Stack Diagram	Description
`alloc-mem`	(size -- virt)	Allocate and map *size* bytes of available memory; return the virtual address. Unmap with `free-mem`.
`free-mem`	(virt size --)	Free memory allocated by `alloc-mem`.
`map?`	(virt --)	Display memory map information for the virtual address.

Table D-25 Defining Words

Command	Stack Diagram	Description
`:` *new-name*	(--) (E: ... -- ???)	Start a new colon definition of the word *new-name*.
`;`	(--)	End a colon definition.
`alias` *new-name old-name*	(--) (E: ... -- ???)	Create *new-name* with the same behavior as *old-name*.
`buffer:` *name*	(size --) (E: -- a-addr)	Create a named array in temporary storage.

Table D-25 Defining Words *(Continued)*

Command	Stack Diagram	Description
`constant` *name*	(n --) (E: -- n)	Define a constant (for example, `3 constant bar`).
`2constant` *name*	(n1 n2 --) (E: -- n1 n2)	Define a 2-number constant.
`create` *name*	(--) (E: -- a-addr)	Generic defining word.
`defer` *name*	(--) (E: ... -- ???)	Define a word for forward references or execution vectors using execution token.
`does>`	(... -- ... a-addr) (E: ... -- ???)	Start the run-time clause for defining words.
`field` *name*	(offset size -- offset+size) (E: addr -- addr+offset)	Create a named offset pointer.
`struct`	(-- 0)	Initialize for `field` creation.
`value` *name*	(n --) (E: -- n)	Create a changeable, named quantity.
`variable` *name*	(--) (E: -- a-addr)	Define a variable.

Table D-26 Dictionary Searching Commands

Command	Stack Diagram	Description
`'` *name*	(-- xt)	Find the named word in the dictionary. Returns the execution token. Use outside definitions.
`[']` *name*	(-- xt)	Similar to `'` but is used either inside or outside definitions.
`.calls`	(xt --)	Display a list of all words that call the word whose execution token is *xt*.
`$find`	(str len -- str len false | xt true)	Search for word named by *str,len*. If found, leave *xt* and *true* on stack. If not found, leave name string and *false* on stack.
`find`	(pstr -- pstr false | xt n)	Search for word named by *pstr*. If found, leave *xt* and *true* on stack. If not found, leave name string and *false* on stack. (Recommend using `$find` to avoid use of packed string.)
`see` *thisword*	(--)	Decompile the named command.
`(see)`	(xt --)	Decompile the word indicated by the execution token.

Table D-26 Dictionary Searching Commands *(Continued)*

Command	Stack Diagram	Description
`sift`	(pstr --)	Display names of all dictionary entries containing the string pointed to by *pstr*.
`sifting` *ccc*	(--)	Display names of all dictionary entries containing the sequence of characters. *ccc* contains no spaces.
`words`	(--)	Display all visible words in the dictionary.

Table D-27 Dictionary Compilation Commands

Command	Stack Diagram	Description
`,`	(n --)	Place a number in the dictionary.
`c,`	(byte --)	Place a byte in the dictionary.
`w,`	(word --)	Place a 16-bit number in the dictionary.
`l,`	(quad --)	Place a 32-bit number in the dictionary.
`[`	(--)	Enter interpretation state.
`]`	(--)	End interpreting, enter compilation state.
`allot`	(n --)	Allocate *n* bytes in the dictionary.
`>body`	(xt -- a-addr)	Find the data field address from the execution token.
`body>`	(a-addr -- xt)	Find the execution token from the data field address.
`compile`	(--)	Compile the next word at run time. (Recommend using `postpone` instead.)
`[compile]` *name*	(--)	Compile the next (immediate) word. (Recommend using `postpone` instead.)
`forget` *name*	(--)	Remove word from dictionary and all subsequent words.
`here`	(-- addr)	Address of top of dictionary.
`immediate`	(--)	Mark the last definition as immediate.
`to` *name*	(n --)	Install a new action in a `defer` word or `value`.
`literal`	(n --)	Compile a number.
`origin`	(-- addr)	Return the address of the start of the Forth system.

Table D-27 Dictionary Compilation Commands *(Continued)*

Command	Stack Diagram	Description
`patch` *new-word old-word word-to-patch*	(--)	Replace *old-word* with *new-word* in *word-to-patch*.
`(patch)`	(new-n old-n xt --)	Replace *old-n* with *new-n* in word indicated by *xt*.
`postpone` *name*	(--)	Delay the execution of the word *name*.
`recursive`	(--)	Make the name of the colon definition being compiled visible in the dictionary, and thus allow the name of the word to be used recursively in its own definition.
`state`	(-- addr)	Variable that is non-zero in compile state.

Table D-28 Assembly Language Programming

Command	Stack Diagram	Description
`code` *name*	(-- code-sys) (E: ... -- ???)	Begin the creation of an assembly language routine called *name*. Commands that follow are interpreted as assembler mnemonics. Note that if the assembler is not installed, `code` is still present, except that machine code must be entered numerically (for example, in hex) with ",".
`c;`	(code-sys --)	End the creation of an assembly language routine. Automatically assemble the Forth interpreter "next" function so that the created assembly-code word, when executed, returns control to the calling routine as usual.
`label` *name*	(-- code-sys) (E: -- a-addr)	Begin the creation of an assembly language routine called *name*. Words created with `label` leave the address of the code on the stack when executed. The commands that follow are interpreted as assembler mnemonics. As with `code`, `label` is present even if the assembler is not installed.
`end-code`	(code-sys --)	End the assembly language patch started with `label`.

Table D-29 Basic Number Display

Command	Stack Diagram	Description
`.`	(n --)	Display a number in the current base.
`.r`	(n size --)	Display a number in a fixed width field.
`.s`	(--)	Display contents of data stack.
`showstack`	(--)	Execute `.s` automatically before each `ok` prompt.
`noshowstack`	(--)	Turn off automatic display of the stack before each `ok` prompt.
`u.`	(u --)	Display an unsigned number.
`u.r`	(u size --)	Display an unsigned number in a fixed width field.

Table D-30 Changing the Number Base

Command	Stack Diagram	Description
`.d`	(n --)	Display *n* in decimal without changing base.
`.h`	(n --)	Display *n* in hex without changing base.
`base`	(-- addr)	Variable containing number base.
`decimal`	(--)	Set the number base to 10.
`d#` *number*	(-- n)	Interpret *number* in decimal; base is unchanged.
`hex`	(--)	Set the number base to 16.
`h#` *number*	(-- n)	Interpret *number* in hex; base is unchanged.

Table D-31 Numeric Output Word Primitives

Command	Stack Diagram	Description
#	(+l1 -- +l2)	Convert a digit in pictured numeric output.
#>	(l-- addr +n)	End pictured numeric output.
<#	(--)	Initialize pictured numeric output.
`(.)`	(n --)	Convert a number to a string.
`(u.)`	(-- addr len)	Convert unsigned to string.
`digit`	(char base -- digit true | char false)	Convert a character to a digit.

Table D-31 Numeric Output Word Primitives *(Continued)*

Command	Stack Diagram	Description
`hold`	(char --)	Insert the char in the pictured numeric output string.
`$number`	(addr len -- true | n false)	Convert a string to a number.
`#s`	(l -- 0)	Convert the rest of the digits in pictured numeric output.
`sign`	(n --)	Set sign of pictured output.

Table D-32 Controlling Text Input

Command	Stack Diagram	Description
`(` *ccc* `)`	(--)	Begin a comment.
`\` *rest-of-line*	(--)	Skip the rest of the line.
`ascii` *ccc*	(-- char)	Get numerical value of first ASCII character of next word.
`accept`	(addr len1 -- len2)	Get a line of edited input from the console input device; store at *addr.len1* is the maximum allowed length. *len2* is the actual length received.
`expect`	(addr len --)	Get and display a line of input from the console; store at *addr.* (Recommend using `accept` instead.)
`key`	(-- char)	Read a character from the console input device.
`key?`	(-- flag)	True if a key has been typed on the console input device.
`parse`	(char -- str len)	Parse text from the input buffer delimited by *char.*
`parse-word`	(-- str len)	Skip leading spaces and parse text from the input buffer delimited by white space.
`safe-parse-word`	(-- str len)	Similar to `parse-word` but intended for use in cases where the null string as input is indicative of an error.
`word`	(char -- pstr)	Collect a string delimited by *char* from the input buffer and place it as a packed string in memory at *pstr.* (Recommend using `parse` instead.)

Table D-33 Displaying Text Output

Command	Stack Diagram	Description
." *ccc*"	(--)	Compile a string for later display.
(cr	(--)	Move the output cursor back to the beginning of the current line.
cr	(--)	Terminate a line on the display and go to the next line.
emit	(char --)	Display the character.
exit?	(-- flag)	Enable the scrolling control prompt: `More [<space>,<cr>,q] ?` The return flag is `true` if the user wants the output to be terminated.
space	(--)	Display a `space` character.
spaces	(+n --)	Display +*n* spaces.
type	(addr +n --)	Display *n* characters.

Table D-34 Formatted Output

Command	Stack Diagram	Description
#lines	(-- rows)	Value holding the number of lines on the output device.
#out	(-- a-addr)	Variable holding the column number on the output device.

Table D-35 Manipulating Text Strings

Command	Stack Diagram	Description
",	(addr len --)	Compile an array of bytes from *addr* of length *len*, at the top of the dictionary as a packed string.
" *ccc*"	(-- addr len)	Collect an input stream string, either interpreted or compiled. Within the string, `"(00,ff…)` can be used to include arbitrary byte values.
.(*ccc*)	(--)	Display a string immediately.
-trailing	(addr +n1 -- addr +n2)	Remove trailing spaces.
bl	(-- char)	ASCII code for the space character; decimal 32.

Table D-35 Manipulating Text Strings *(Continued)*

Command	Stack Diagram	Description
`count`	(pstr -- addr +n)	Unpack a packed string.
`lcc`	(char -- lowercase-char)	Convert a character to lowercase.
`left-parse-string`	(addr len char -- addrR lenR addrL lenL)	Split a string at *char* (which is discarded).
`pack`	(addr len pstr -- pstr)	Make a packed string from *addr len*; place it at *pstr*.
`p" ccc"`	(-- pstr)	Collect a string from the input stream; store as a packed string.
`upc`	(char -- uppercase-char)	Convert a character to uppercase.

Table D-36 I/O Redirection Commands

Command	Stack Diagram	Description
`input`	(device --)	Select device (`keyboard`, or *device-specifier*) for subsequent input.
`io`	(device --)	Select device for subsequent input and output.
`output`	(device --)	Select device (`screen`, or *device-specifier*) for subsequent output.

Table D-37 ASCII Constants

Command	Stack Diagram	Description
`bell`	(-- n)	ASCII code for the bell character; decimal 7.
`bs`	(-- n)	ASCII code for the backspace character; decimal 8.

Table D-38 Command Line Editor Keystroke Commands

Keystroke	Description
`Control-B`	Moves backward one character.
`Escape B`	Moves backward one word.
`Control-F`	Moves forward one character.
`Escape F`	Moves forward one word.
`Control-A`	Moves backward to beginning of line.

Table D-38 Command Line Editor Keystroke Commands *(Continued)*

Keystroke	Description
`Control-E`	Moves forward to end of line.
`Delete`	Erases previous character.
`Backspace`	Erases previous character.
`Control-H`	Erases previous character.
`Escape H`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-W`	Erases from beginning of word to just before the cursor, storing erased characters in a save buffer.
`Control-D`	Erases next character.
`Escape D`	Erases from cursor to end of the word, storing erased characters in a save buffer.
`Control-K`	Erases from cursor to end of line, storing erased characters in a save buffer.
`Control-U`	Erases entire line, storing erased characters in a save buffer.
`Control-R`	Retypes the line.
`Control-Q`	Quotes next character (allows you to insert control characters).
`Control-Y`	Inserts the contents of the save buffer before the cursor.
`Control-P`	Selects and displays the previous line for subsequent editing.
`Control-N`	Selects and displays the next line for subsequent editing.
`Control-L`	Displays the entire contents of the editing buffer.

Table D-39 Command Completion Keystroke Commands

Keystroke	Description
`Control-Space`	Complete the name of the current word.
`Control-/`	Display all possible matches for the current word.

Table D-40 Comparison Commands

Command	Stack Diagram	Description
<	(n1 n2 -- flag)	True if *n1* < *n2*.
<=	(n1 n2 -- flag)	True if *n1* <= *n2*.
<>	(n1 n2 -- flag)	True if *n1* is not equal to *n2*.

Table D-40 Comparison Commands *(Continued)*

Command	Stack Diagram	Description
=	(n1 n2 -- flag)	True if *n1* = n2.
>	(n1 n2 -- flag)	True if *n1* > n2.
>=	(n1 n2 -- flag)	True if *n1* >= n2.
0<	(n -- flag)	True if *n* < 0.
0<=	(n -- flag)	True if *n* <= 0.
0<>	(n -- flag)	True if *n* <> 0.
0=	(n -- flag)	True if *n* = 0 (also inverts any flag).
0>	(n -- flag)	True if *n* > 0.
0>=	(n -- flag)	True if *n* >= 0.
between	(n min max -- flag)	True if *min* <= *n* <= *max*.
false	(-- 0)	The value FALSE, which is 0.
true	(-- -1)	The value TRUE, which is -1.
u<	(u1 u2 -- flag)	True if *u1* < *u2*, unsigned.
u<=	(u1 u2 -- flag)	True if *u1* <= *u2*, unsigned.
u>	(u1 u2 -- flag)	True if *u1* > *u2*, unsigned.
u>=	(u1 u2 -- flag)	True if *u1* >= *u2*, unsigned.
within	(n min max -- flag)	True if *min* <= *n* < *max*.

Table D-41 if…then…else Commands

Command	Stack Diagram	Description
if	(flag --)	Execute the following code when *flag* is true.
else	(--)	Execute the following code when *flag* is false.
then	(--)	Terminate if…then…else.

Table D-42 `case` Statement Commands

Command	Stack Diagram	Description
`case`	(selector -- selector)	Begin a `case`…`endcase` conditional.
`endcase`	(selector | {empty} --)	Terminate a `case`…`endcase` conditional.
`endof`	(--)	Terminate an `of`…`endof` clause within a `case`…`endcase`
`of`	(selector test-value -- selector | {empty})	Begin an `of`…`endof` clause within a `case` conditional.

Table D-43 `begin` (Conditional) Loop Commands

Command	Stack Diagram	Description
`again`	(--)	End a `begin`…`again` infinite loop.
`begin`	(--)	Begin a `begin`…`while`…`repeat`, `begin`…`until`, or `begin`…`again` loop.
`repeat`	(--)	End a `begin`…`while`…`repeat` loop.
`until`	(flag --)	Continue executing a `begin`…`until` loop until *flag* is true.
`while`	(flag --)	Continue executing a `begin`…`while`…`repeat` loop while *flag* is true.

Table D-44 `do` (Counted) Loop Commands

Command	Stack Diagram	Description
`+loop`	(n --)	End a `do`…`+loop` construct; add *n* to loop index and return to `do` (if *n* < 0, index goes from *start* to *end*, inclusive).
`?do`	(end start --)	Begin `?do`…`loop` to be executed 0 or more times. Index goes from *start* to *end*-1, inclusive. If *end* = *start*, loop is not executed.
`?leave`	(flag --)	Exit from a `do`…`loop` if *flag* is non-zero.
`do`	(end start --)	Begin a `do`…`loop`. Index goes from *start* to *end*-1, inclusive. Example: `10 0 do i . loop` (prints 0 1 2…d e f).
`i`	(-- n)	Leaves the loop index on the stack.

Table D-44 do (Counted) Loop Commands *(Continued)*

Command	Stack Diagram	Description
j	(-- n)	Leaves the loop index for next outer enclosing loop.
leave	(--)	Exit from do…loop.
loop	(--)	End of do…loop.

Table D-45 Program Execution Control Commands

Command	Stack Diagram	Description
abort	(--)	Abort current execution and interpret keyboard commands.
abort" *ccc*"	(abort? --)	If *abort?* is true, abort and display message.
eval	(… str len -- ???)	Synonym for evaluate.
evaluate	(… str len -- ???)	Interpret Forth source text from the specified string.
execute	(xt --)	Execute the word whose execution token is on the stack.
exit	(--)	Return from the current word. (Cannot be used in counted loops.)
quit	(--)	Same as abort, but leave stack intact.

Table D-46 File Loading Commands

Command	Stack Diagram	Description
?go	(--)	Execute Forth, FCode, or binary programs.
boot [*specifiers*] -h	(--)	Load file from specified source.
byte-load	(addr span --)	Interpret loaded FCode binary file. *span* is usually 1.
dl	(--)	Load a Forth file over a serial line with tip and interpret. Type: **~C cat** *filename* **^-D**
dlbin	(--)	Load a binary file over a serial line with tip. Type: **~C cat** *filename*
dload *filename*	(addr --)	Load the specified file over Ethernet at the given address.
eval	(addr len --)	Interpret loaded Forth text file.
go	(--)	Begin executing a previously-loaded binary program, or resume executing an interrupted program.

Table D-46 File Loading Commands *(Continued)*

Command	Stack Diagram	Description
`init-program`	(--)	Initialize to execute a binary file.
`load` *device-specifier argument*	(--)	Load data from specified device into memory at the address given by `load-base`.
`load-base`	(-- addr)	Address at which `load` places the data it reads from a device.

Table D-47 Disassembler Commands

Command	Stack Diagram	Description
`+dis`	(--)	Continue disassembling where the last disassembly left off.
`dis`	(addr --)	Begin disassembling at the specified address.

Table D-48 Breakpoint Commands

Command	Stack Diagram	Description
`+bp`	(addr --)	Add a breakpoint at the given address.
`-bp`	(addr --)	Remove the breakpoint at the given address.
`--bp`	(--)	Remove the most-recently-set breakpoint.
`.bp`	(--)	Display all currently set breakpoints.
`.breakpoint`	(--)	Perform a specified action when a breakpoint occurs. This word can be altered to perform any desired action. For example, to display registers at every breakpoint, type: `['] .registers is .breakpoint`. The default behavior is `.instruction`. To perform multiple behaviors, create a single definition which calls all desired behaviors, then load that word into `.breakpoint`.
`.instruction`	(--)	Display the address, opcode for the last-encountered breakpoint.
`.step`	(--)	Perform a specified action when a single step occurs. (See `.breakpoint`).
`bpoff`	(--)	Remove all breakpoints.
`finish-loop`	(--)	Execute until the end of this loop.
`go`	(--)	Continue from a breakpoint. This can be used to go to an arbitrary address by setting up the processor's program counter before issuing `go`.
`gos`	(n --)	Execute `go` *n* times.

Table D-48 Breakpoint Commands *(Continued)*

Command	Stack Diagram	Description
`hop`	(--)	(Like the `step` command.) Treat a subroutine call as a single instruction.
`hops`	(n --)	Execute `hop` *n* times.
`return`	(--)	Execute until the end of this subroutine.
`returnl`	(--)	Execute until the end of this leaf subroutine.
`skip`	(--)	Skip (do not execute) the current instruction.
`step`	(--)	Single-step one instruction.
`steps`	(n --)	Execute `step` *n* times.
`till`	(addr --)	Execute until the given address is encountered. Equivalent to `+bp go`.

Table D-49 Forth Source-level Debugger Commands

Command	Description
`c`	“Continue”. Switch from stepping to tracing, thus tracing the remainder of the execution of the word being debugged.
`d`	“Down a level”. Mark for debugging the word whose name was just displayed, then execute it.
`u`	“Up a level”. Un-mark the word being debugged, mark its caller for debugging, and finish executing the word that was previously being debugged.
`f`	Start a subordinate Forth interpreter. When that interpreter exits (with `resume`), control returns to the debugger at the place where the `f` command was executed.
`g`	“Go.” Turn off the debugger and continue execution.
`q`	“Quit”. Abort the execution of the word being debugged and all its callers and return to the command interpreter.
`s`	“see”. Decompile the word being debugged.
`$`	Display the *address,len* on top of the stack as a text string.
`h`	“Help”. Display symbolic debugger documentation.
`?`	“Short Help”. Display brief symbolic debugger documentation.
`debug` *name*	Mark the specified Forth word for debugging. Enter the Forth Source-level Debugger on all subsequent attempts to execute *name*. After executing `debug`, the execution speed of the system may decrease until debugging is turned off with `debug-off`. (Do not debug basic Forth words such as `“dup”`.)
`(debug`	Like `debug` except that `(debug` takes an execution token from the stack instead of a name from the input stream.

Table D-49 Forth Source-level Debugger Commands *(Continued)*

Command	Description
`debug-off`	Turn off the Forth Source-level Debugger so that no word is being debugged.
`resume`	Exit from a subordinate interpreter, and go back to the stepper (See the `f` command in this table.)
`stepping`	Set step mode for the Forth Source-level Debugger, allowing the interactive, step-by-step execution of the word being debugged. Step mode is the default.
`tracing`	Set trace mode for the Forth Source-level Debugger. Tracing enables the execution of the word being debugged, while showing the name and stack contents for each word called by that word.
`<space-bar>`	Execute the word just displayed and proceed to the next word.

Table D-50 Time Utilities

Command	Stack Diagram	Description
`get-msecs`	(-- ms)	Return the approximate current time in milliseconds.
`ms`	(n --)	Delay for *n* milliseconds. Resolution is 1 millisecond.

Table D-51 Miscellaneous Operations

Command	Stack Diagram	Description
`callback` *string*	(value --)	Call Solaris with the given value and string.
`catch`	(... xt -- ??? error-code | ??? false)	Execute *xt*; return `throw` error code or 0 if `throw` is not called.
`eject-floppy`	(--)	Eject the diskette from the floppy drive.
`firmware-version`	(-- n)	Return major/minor CPU firmware version (that is, 0x00030001 = firmware version 3.1).
`forth`	(--)	Restore main Forth vocabulary to top of search order.
`ftrace`	(--)	Show calling sequence when exception occurred.
`noop`	(--)	Do nothing.

Table D-51 Miscellaneous Operations *(Continued)*

Command	Stack Diagram	Description
`reset-all`	(--)	Reset the entire system (similar to a power-cycle).
`sync`	(--)	Call the operating system to write any pending information to the hard disk. Also boot after syncing file systems.
`throw`	(error-code --)	Return given error code to `catch`.

Table D-52 Multiprocessor Commands

Command	Stack Diagram	Description
`switch-cpu`	(cpu# --)	Switch to indicated CPU.

Table D-53 Memory Mapping Commands

Command	Stack Diagram	Description
`map?`	(virt --)	Display memory map information for the virtual address.
`memmap`	(phys space size -- virt)	Map a region of physical addresses; return the allocated virtual address. Unmap with `free-virtual`.
`obio`	(-- space)	Specify the device address space for mapping.
`obmem`	(-- space)	Specify the onboard memory address space for mapping.
`sbus`	(-- space)	Specify the SBus address space for mapping.

Table D-54 Memory Mapping Primitives

Command	Stack Diagram	Description
`iomap?`	(virt --)	Display IOMMU page map entry for the virtual address.
`iomap-page`	(phys space virt --)	Map physical page given by *phys* and *space* to the virtual address.
`iomap-pages`	(phys space virt size --)	Perform consecutive `iomap-page`s to map a region of memory given by *size*.
`iopgmap@`	(virt -- pte | 0)	Return IOMMU page map entry for the virtual address.
`iopgmap!`	(pte virt --)	Store a new page map entry for the virtual address.

Table D-54 Memory Mapping Primitives *(Continued)*

Command	Stack Diagram	Description
`map-page`	(phys space virt --)	Map one page of memory starting at address *phys* on to virtual address *virt* in the specified address *space*. All addresses are truncated to lie on a page boundary.
`map-pages`	(phys space virt size --)	Perform consecutive `map-page`s to map a region of memory to the specified *size*.
`map-region`	(region# virt --)	Map a region.
`map-segments`	(smentry virt len --)	Perform consecutive `smap!` operations to map a region of memory.
`pgmap!`	(pmentry virt --)	Store a new page map entry for the virtual address.
`pgmap?`	(virt --)	Display the page map entry (decoded and in English) corresponding to the virtual address.
`pgmap@`	(virt -- pmentry)	Return the page map entry for the virtual address.
`pagesize`	(-- size)	Return the *size* of a page.
`rmap!`	(rmentry virt --)	Store a new region map entry for the virtual address.
`rmap@`	(virt -- rmentry)	Return the region map entry for the virtual address.
`segmentsize`	(-- size)	Return the *size* of a segment.
`smap!`	(smentry virt --)	Store a new segment map entry for the virtual address.
`smap?`	(virt --)	Formatted display of the segment map entry for the virtual address.
`smap@`	(virt -- smentry)	Return the segment map entry for the virtual address.

Table D-55 Cache Manipulation Commands

Command	Stack Diagram	Description
`clear-cache`	(--)	Invalidate all cache entries.
`cache-off`	(--)	Disable the cache.
`cache-on`	(--)	Enable the cache.
`ecdata!`	(data offset --)	Store the *data* at the cache *offset*.
`ecdata@`	(offset -- data)	Fetch (return) *data* from the cache *offset*.
`ectag!`	(value offset --)	Store the tag *value* at the cache *offset*.
`ectag@`	(offset -- value)	Return the tag *value* at the cache *offset*.
`flush-cache`	(--)	Write back any pending data from the cache.

Table D-56 Reading / Writing Machine Registers in Sun-4u Machines

Command	Stack Diagram	Description
aux!	(data --)	Write auxiliary register.
aux@	(-- data)	Read auxiliary register.

Table D-57 Alternate Address Space Access Commands

Command	Stack Diagram	Description
spacec!	(byte addr asi --)	Store the *byte* in *asi* at *addr.*
spacec?	(addr asi --)	Display the *byte* in *asi* at *addr.*
spacec@	(addr asi -- byte)	Fetch the *byte* from *asi* at *addr.*
spaced!	(quad1 quad2 addr asi --)	Store the two quadlets in *asi* at *addr.* Order is implementation-dependent.
spaced?	(addr asi --)	Display the two quadlets in *asi* at *addr.* Order is implementation-dependent.
spaced@	(addr asi -- quad1 quad2)	Fetch the two quadlets from *asi* at *addr.* Order is implementation-dependent.
spacel!	(quad addr asi --)	Store the quadlet in *asi* at *addr.*
spacel?	(addr asi --)	Display the quadlet in *asi* at *addr.*
spacel@	(addr asi -- quad)	Fetch the quadlet from *asi* at *addr.*
spacew!	(w addr asi --)	Store the doublet in *asi* at *addr.*
spacew?	(addr asi --)	Display the doublet in *asi* at *addr.*
spacew@	(addr asi -- w)	Fetch the doublet from *asi* at *addr.*
spacex!	(x addr asi --)	Store the number in *asi* at *addr.*
spacex?	(addr asi --)	Display the word in *asi* at *addr.*
spacex@	(addr asi -- x)	Fetch the word from *asi* at *addr.*

Table D-58 SPARC Register Commands

Command	Stack Diagram	Description
`%g0` through `%g7`	(-- value)	Return the value in the specified global register.
`%i0` through `%i7`	(-- value)	Return the value in the specified input register.
`%l0` through `%l7`	(-- value)	Return the value in the specified local register.
`%o0` through `%o7`	(-- value)	Return the value in the specified output register.
`%pc %npc %y`	(-- value)	Return the value in the specified register.
`%f0` through `%f31`	(-- value)	Return the value in the specified floating point register.
`.fregisters`	(--)	Display the values in `%f0` through `%f31.`
`.locals`	(--)	Display the values in the `i`, `l` and `o` registers.
`.registers`	(--)	Display values in processor registers.
`.window`	(window# --)	Same as `w .locals`; display the desired window.
`ctrace`	(--)	Display the return stack showing C subroutines.
`set-pc`	(new-value --)	Set `%pc` to *new-value*, and set `%npc` to (*new-value*+4).
`to` *regname*	(new-value --)	Change the value stored in any of the above registers. Use in the form: *new-value* `to` *regname*.
`w`	(window# --)	Set the current window for displaying `%i`*x*, `%l`*x*, or `%o`*x*.

Table D-59 SPARC V9 Register Commands

Command	Stack Diagram	Description

`%fprs`
`%asi`
`%pstate`
`%tl-c`
`%pil`
`%tstate`
`%tt`
`%tba`
`%cwp`
`%cansave`
`%canrestore`
`%otherwin`
`%wstate`
`%cleanwin`
	(-- value)	Return the value in the specified register.

`.pstate`	(--)	Formatted display of the processor state register.
`.ver`	(--)	Formatted display of the version register.
`.ccr`	(--)	Formatted display of the `ccr` register.
`.trap-registers`	(--)	Display trap-related registers.

Table D-60 Emergency Keyboard Commands

Command	Description
`Stop`	Bypass POST. This command does not depend on security-mode. (Note: some systems bypass POST as a default; in such cases, use `Stop-D` to start POST.)
`Stop-A`	Abort.
`Stop-D`	Enter diagnostic mode (set `diag-switch?` to `true`).
`Stop-F`	Enter Forth on TTYA instead of probing. Use `fexit` to continue with the initialization sequence. Useful if hardware is broken.
`Stop-N`	Reset NVRAM contents to default values.

D

Index

Symbols

Numerics

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Reader Comment Card

Your comments and suggestions are important to us. Please let us know what you think about the *OpenBoot 3.x Command Reference*, part number 802-3242-10.

1. Were the procedures well documented? Yes ❑ No ❑

   Please explain: _____

   _____

2. Were the tasks easy to follow? Yes ❑ No ❑

   Please explain: _____

   _____

3. Was the information complete and easy to find? Yes ❑ No ❑

   Please explain: _____

   _____

4. Do you have additional comments about the OpenBoot 3.x Command Reference?
   You can send detailed comments via email to `smcc-docs@sun.com`, or send a fax to *SMCC Doc Feedback* at (415) 786-6443.

   _____

   _____

   _____

   _____

   _____

   _____

   _____

Your Name: _____

Title: _____

Company Name: _____

Address: _____

City: _____ State / Province: _____

Country: _____ Zip / Postal Code: _____

Email Address: _____

Telephone: _____

Part No.: 802-3242-10
Revision A, November 1995

Thank you.

AIR MAIL
PAR AVION

IBRS/CCRI No. 808

Sun

NE PAS AFFRANCHIR

NO POSTAGE
NECESSARY
IF MAILED
TO THE
UNITED STATES

INTERNATIONAL BUSINESS REPLY MAIL/REPONSE PAYEE

PERMIT NO. 808 MOUNTAIN VIEW CA

POSTAGE WILL BE PAID BY ADDRESSEE

INFORMATION PRODUCTS
M/S MPK14-108
SUN MICROSYSTEMS INC
2550 GARCIA AVE
MOUNTAIN VIEW CA 94043-9551
UNITED STATES OF AMERICA