Volume Shadowing for OpenVMS

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This manual explains how to use Volume Shadowing for OpenVMS to replicate data transparently on multiple disks and provide high data availability.

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Software Version:	OpenVMS Alpha Version 7.3 OpenVMS VAX Version 7.3

Compaq Computer Corporation
Houston, Texas

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Preface

Intended Audience

This book is intended for system managers and system users who want to:

- Understand how Volume Shadowing for OpenVMS works
- Configure shadowed data storage subsystems to maximize data availability
- Set up and manage shadow sets
- Enhance shadow set performance

Although you do not need any previous volume shadowing experience to use the volume shadowing software or this documentation, you do need a familiarity with the OpenVMS operating system, the OpenVMS Mount utility or OpenVMS system services, and setting system parameters.

Document Structure

The *Volume Shadowing for OpenVMS* manual consists of the following chapters and appendix:

Chapter	Contents
Chapter 1	Introduces Volume Shadowing for OpenVMS and describes how it provides high data availability.
Chapter 2	Illustrates various shadow set configurations.
Chapter 3	Describes how to set up a volume shadowing environment, including information about setting shadowing system parameters, booting a system that uses a system disk in a shadow set, and booting satellite nodes from a shadowed system disk.
Chapter 4	Describes how to use DCL commands to create, mount, dismount, and dissolve shadow sets. The chapter also describes how to use the SHOW DEVICES command, the System Dump Analyzer, and the F$GETDVI lexical function to obtain information about shadow sets on a running system.
Chapter 5	Describes how to use the OpenVMS system services in a user-written program to create and manage shadow sets. The chapter also describes how to use the $GETDVI system service to obtain information about shadow sets.
Chapter 6	Describes how the copy and merge operations maintain data consistency and availability during changes in shadow set membership.
Chapter 7	Describes how the minicopy operation can be used, in a carefully controlled environment, to shorten the time required for a member to be returned to a shadow set. Typically, the member is removed for backing up data.

Chapter	Contents
Chapter 8	Describes how to perform system management tasks on shadow sets, including performing backup and upgrade operations, performing shadowing operations in OpenVMS Cluster systems, and handling crash dumps on the shadow set.
Chapter 9	Includes helpful information and guidelines for achieving better performance from shadow sets.
Appendix A	Lists messages related to volume shadowing that are returned by the Mount utility and the VOLPROC, shadow server, and OPCOM facilities.

Related Documents

The following documents contain information related to this manual:

- *OpenVMS License Management Utility Manual*
- *OpenVMS Cluster Systems*
- *Guidelines for OpenVMS Cluster Configurations*
- *OpenVMS DCL Dictionary*
- *OpenVMS System Manager's Manual*
- *OpenVMS System Management Utilities Reference Manual*
- *OpenVMS System Services Reference Manual*

For additional information about OpenVMS products and services, access the Compaq website at the following location:

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Conventions

The following conventions are used in this manual:

Return

In examples, a key name enclosed in a box indicates that you press a key on the keyboard. (In text, a key name is not enclosed in a box.)

In the HTML version of this document, this convention appears as brackets, rather than a box.

. . .

A horizontal ellipsis in examples indicates one of the following possibilities:

- Additional optional arguments in a statement have been omitted.
- The preceding item or items can be repeated one or more times.
- Additional parameters, values, or other information can be entered.

.
.
.

A vertical ellipsis indicates the omission of items from a code example or command format; the items are omitted because they are not important to the topic being discussed.

( )

In command format descriptions, parentheses indicate that you must enclose the options in parentheses if you choose more than one.

[ ]

In command format descriptions, brackets indicate optional elements. You can choose one or more options, or no options. (Note, however, that brackets are not optional in the syntax of a directory name in an OpenVMS file specification or in the syntax of a substring specification in an assignment statement.)

[|]

In command format descriptions, vertical bars separate choices within brackets or braces. Within brackets, the choices are optional; within braces, at least one choice is required. Do not type the vertical bars on the command line.

{ }

In command format descriptions, braces indicate required elements; you must choose one of the options listed.

bold text

This text style represents the introduction of a new term or the name of an argument, an attribute, or a reason.

italic text

Italic text indicates important information, complete titles of manuals, or variables. Variables include information that varies in system output (Internal error *number*), in command lines (/PRODUCER=*name*), and in command parameters in text (where *dd* represents the predefined code for the device type).

UPPERCASE TEXT

Uppercase text indicates a command, the name of a routine, the name of a file, or the abbreviation for a system privilege.

`Monospace text`

Monospace type indicates code examples and interactive screen displays.

In the C programming language, monospace type in text identifies the following elements: keywords, the names of independently compiled external functions and files, syntax summaries, and references to variables or identifiers introduced in an example.

- A hyphen at the end of a command format description, command line, or code line indicates that the command or statement continues on the following line.

numbers All numbers in text are assumed to be decimal unless otherwise noted. Nondecimal radixes—binary, octal, or hexadecimal—are explicitly indicated.

1 Introduction to Volume Shadowing for OpenVMS

This chapter introduces Volume Shadowing for OpenVMS and describes how volume shadowing, sometimes referred to as disk mirroring, achieves high data availability.

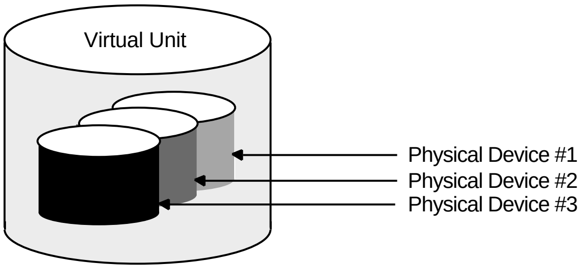
1.1 Overview

Volume Shadowing for OpenVMS ensures that data is available to your applications and end users by duplicating data on multiple disks. Because the same data is recorded on multiple disk volumes, if one disk fails, the remaining disk or disks can continue to service I/O requests.

An implementation of RAID 1 (redundant arrays of independent disks) technology, Volume Shadowing for OpenVMS prevents a disk device failure from interrupting system and application operations. By duplicating data on multiple disks, volume shadowing transparently prevents your storage subsystems from becoming a single point of failure because of media deterioration or communication path failure, or through controller or device failure.

You can mount one, two, or three compatible disk volumes, including the system disk, to form a **shadow set**. Compatible disk volumes are those with the same number of physical blocks (see Section 1.3.2). Each disk in the shadow set is a shadow set **member**. Volume Shadowing for OpenVMS logically binds the shadow set disks together and represents them as a single virtual device called a **virtual unit**. This means that the multiple members of the shadow set, represented by the virtual unit, appear to applications and users as a single, highly available disk.

Note that the term disk and device are used interchangeably throughout this manual to refer to a disk volume. A disk volume is a disk that was prepared for use by placing a new file structure on it.



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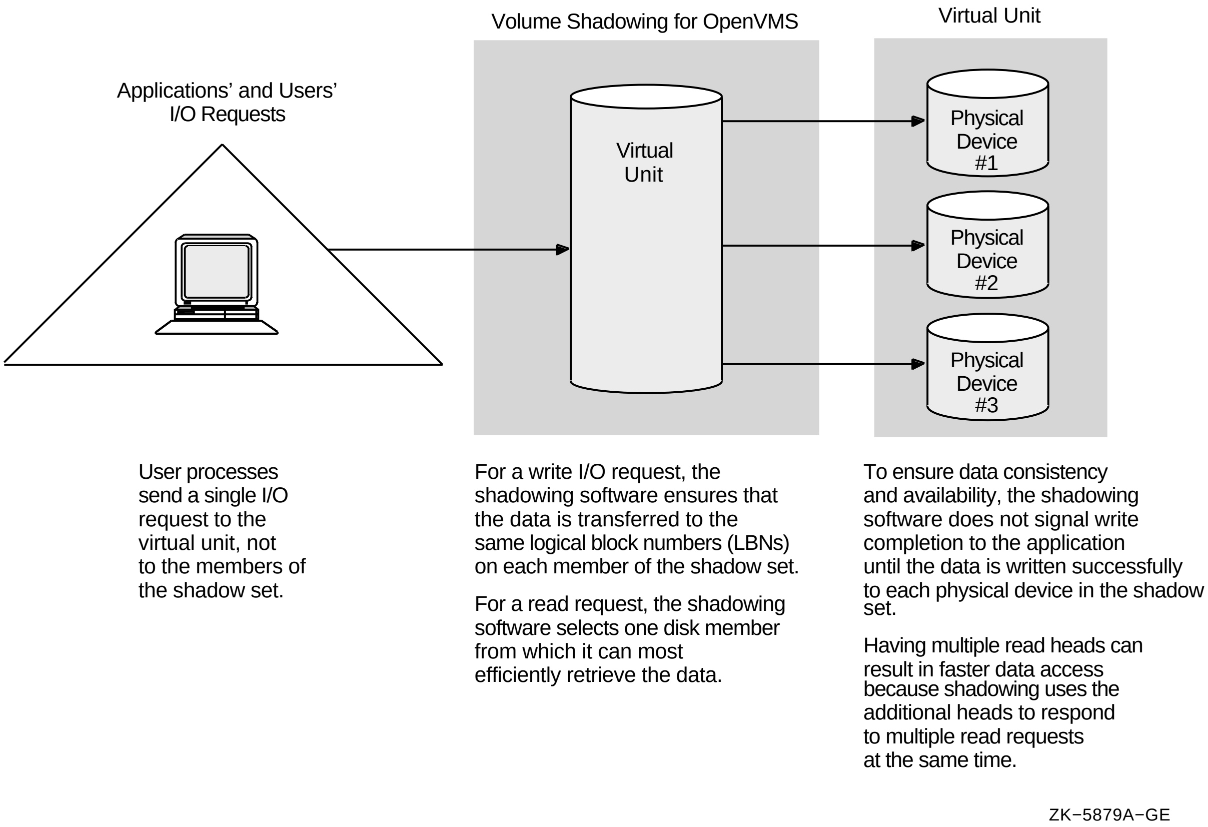
Applications and users read and write data to and from a shadow set using the same commands and program language syntax and semantics that are used for nonshadowed I/O operations. System managers manage and monitor shadow sets using the same commands and utilities they use for nonshadowed disks. The only difference is that access is through the virtual unit, not to individual disks.

Figure 1–1 shows how Volume Shadowing for OpenVMS propagates data through the virtual unit to three individual shadow set members.

Figure 1–1 Elements of a Shadow Set


Volume Shadowing for OpenVMS
Virtual Unit
Applications' and Users' I/O Requests
Virtual Unit
Physical Device #1
Physical Device #2
Physical Device #3
User processes send a single I/O request to the virtual unit, not to the members of the shadow set.
For a write I/O request, the shadowing software ensures that the data is transferred to the same logical block numbers (LBNs) on each member of the shadow set.
For a read request, the shadowing software selects one disk member from which it can most efficiently retrieve the data.
To ensure data consistency and availability, the shadowing software does not signal write completion to the application until the data is written successfully to each physical device in the shadow set.
Having multiple read heads can result in faster data access because shadowing uses the additional heads to respond to multiple read requests at the same time.
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An additional benefit of volume shadowing is its potential role in repairing data. For example, if data on a shadow set member becomes unreadable, the shadowing software can read the data from another member. Before the good data is returned to the process, it is written to the member that could not originally read it.

Note

Remember that volume shadowing protects against hardware problems that cause a disk volume to be a single point of failure for both applications and systems that use the disk. Volume shadowing does not provide for recovery from software-related incidents, such as the accidental deletion of files or errant software corrupting the contents of a disk file. Do not use volume shadowing as a substitute for regular backup or journaling.

Volume Shadowing for OpenVMS is sometimes referred to as phase II shadowing or host-based shadowing. Support for phase I shadowing (controller-based shadowing) was discontinued as of OpenVMS Version 6.2.

1.2 Volume Shadowing Tasks and Operations

The primary volume shadowing operations used to create shadow sets and to maintain consistent data on each member are mount, copy, assisted copy, minicopy (introduced with OpenVMS Version 7.3), merge, and minimerge. When these operations are in progress, the system continues to process read and write requests, thus providing continuous availability.

All volume shadowing operations, except for merges and minimerges, are under the control of the system manager. Merges and minimerges are started automatically by the volume shadowing software if a hardware or software failure occurs that could affect the consistency of the data on the shadow set members.

System managers turn on volume shadowing with the SHADOWING system parameter. They can control the number of concurrent merge or copy operations on a given node by the SHADOW_MAX_COPY system parameter. These volume shadowing system parameters, and all other system parameters used with volume shadowing, are described in Section 3.2 and in Section 3.3.

Volume Shadowing for OpenVMS is never invoked directly. Instead, you invoke the DCL commands MOUNT and DISMOUNT. The MOUNT command works with the volume shadowing software to create shadow sets. The DISMOUNT command works with the volume shadowing software to remove shadow set members and to dissolve entire shadow sets.

HSJ and HSC controllers, when present in a configuration, provide software assists for the minimerge and assisted copy operations.

OpenVMS also provides a programming interface for creating and managing shadow sets with the $MOUNT, $DISMOU, and $GETDVI system services. This programming interface is described in Chapter 5.

Table 1–1 shows the main volume shadowing tasks, the operations associated with them, and the software used to perform the operation. These operations are described in more detail in Chapter 4, Chapter 6, and Chapter 7.

Table 1–1 Main Volume Shadowing Tasks, Operation Name, and Related Software

Task	Operation	Software Used
Create a shadow set.	Copy	MOUNT/SHADOW command with the SHADOWING system parameter set, which starts the copy automatically. When a second or third member is added, the shadowing software starts a copy operation.
Remove a member from a shadow set.	Dismount a disk	DISMOUNT command.
Dissolve a shadow set.	Dismount the shadow set (specify its virtual unit name)	DISMOUNT command.

(continued on next page)

Table 1–1 (Cont.) Main Volume Shadowing Tasks, Operation Name, and Related Software

Task	Operation	Software Used
Ensure that the data is identical on all shadow set members in the event of a hardware failure.	Merge or minimerge	Shadowing software does this automatically when it detects a hardware or software failure. If an HSJ or HSC controller is present in the configuration, a minimerge might be done.
Return a dismounted shadow set member to the shadow set.	Copy, assisted copy, or minicopy	MOUNT command, with shadowing software that initiates either a copy or, if properly configured, a minicopy.

1.3 Hardware Environment

Volume Shadowing for OpenVMS does not depend on specific hardware in order to operate. All shadowing functions, with the exception of minicopy, can be performed on Alpha and VAX computers using the OpenVMS operating system. The minicopy operation can be performed only on an OpenVMS Alpha system. However, an OpenVMS VAX system can be a member of an OpenVMS Cluster system that uses this feature.

Volume shadowing requires a minimum of:

- One CPU
- One mass storage controller
- One of the following kinds of disk drives:
  - Digital Storage Architecture (DSA)
  - Small Computer Systems Interface (SCSI)
  - Fibre Channel

The following sections generically describe hardware support. See the most recent Volume Shadowing for OpenVMS *Software Product Description* 27.29.*xx* for more information.

1.3.1 Memory Requirements

Starting with OpenVMS Version 7.3, the following additional memory is required to run Volume Shadowing for OpenVMS:

- 24 KB per node are required on OpenVMS Alpha systems; 5 KB per node are required on OpenVMS VAX systems. These requirements are in effect even if you do not use Volume Shadowing for OpenVMS.

  If this memory is not available, the node will not boot.

- 4.5 KB per shadow set per node is required.

  This amount of memory is required before a write bitmap can be created. If this memory is not available, the mount fails (that is, the shadow set is not mounted on the node). The MOUNT command that fails will issue the following message:

  ```
  %MOUNT-F-INSFMEM, insufficient dynamic memory
  ```

- For every gigabyte of storage of a shadow set member, 2.1 KB per node is required for the write bitmaps for each shadow set mounted on a node. (Each shadow set can have up to six write bitmaps.) When calculating memory requirements, note that a two-member shadow set with 50 GB per member counts as 50 GB, not 100 GB.

  For example, for a shadow set with 200 GB of storage per member, 420 KB of memory is required for its write bitmaps for every node in the cluster. If this memory is not available on the node where the write bitmap request occurs, the write bitmap is not created.

  If the master write bitmap is created but sufficient memory is not available on another node on which the shadow set is subsequently mounted, a local write bitmap is not created. If the WBM_OPCOM_LVL system parameter is set to 1 (the default) or 2, the following OPCOM message is displayed:

  ```
  Unable to allocate local bitmap - running in degraded mode.
  ```

  Writes from nodes without local bitmaps are registered with the node on which the shadow set was first mounted.

These memory requirements are cumulative. For example, a system with 10 shadow sets mounted, with each shadow set consisting of 50-GB member disks, would require an additional 1,119 KB of memory. The calculation follows:

```
  24 KB per node (regardless of whether you use volume shadowing)
  45 KB (10 shadow sets x 4.5 KB per unit mounted on the system)
1050 KB (50 x 2.1 KB (per GB of disk size) x 10 shadow sets
1119 KB total memory required
```

1.3.2 Supported Devices

The compatibility requirements for the physical disks that form a shadow set follow:

- Each disk must have the **same number of physical blocks**. You can determine the block size for each disk with the SHOW DEVICE /FULL command. The block size is displayed as `Total blocks` *nnnnnnnn*.

  Note

  Starting with OpenVMS Version 7.2 (and available for OpenVMS Version 7.2-1 in a remedial kit), disks of different types and different geometries are supported in the same shadow set provided they have the same number of physical blocks.

- Disks must be Files-11 On-Disk Structure Level 2 (ODS-2) or On-Disk Structure Level 5 (ODS-5) data disks. The Files-11 structure prepares a volume to receive and store data so that the operating system can locate it easily. Volume shadowing accepts I/O requests from users and applications through the Files-11 interface and shadows data to the individual shadow set members.
- Disks and controllers must be one of the following types:
  - StorageWorks Fibre Channel
  - StorageWorks SCSI
  - MSCP (mass storage control protocol) conformant

- Disk volumes cannot have hardware write protection enabled. Hardware write protection stops volume shadowing software from maintaining identical volumes.
- SCSI disks that do not implement READL and WRITEL have limited support because these disks do not provide for shadowing data repair (disk bad block errors) features. Such disks can cause members to be removed from the shadow set, if certain error conditions arise that cannot be corrected. See Section 4.9.4.1 for how to determine if a SCSI disk supports READL and WRITEL commands.

1.4 Supported Configurations

Volume Shadowing for OpenVMS provides data availability across the full range of configurations—from single nodes to large OpenVMS Cluster systems—so you can provide data availability where you need it most.

There are no restrictions on the location of shadow set members beyond the valid disk configurations defined in the SPDs for the OpenVMS operating system and for OpenVMS Cluster systems:

- For the OpenVMS Operating System: SPD 25.01.*xx*
- For OpenVMS Cluster Software: SPD 29.78.*xx*

If an individual disk volume is already mounted as a member of an active shadow set, the disk volume cannot be mounted as a standalone disk on another node.

1.4.1 Maximum Number of Shadow Sets

You can mount a maximum of 500 disks in two- or three-member shadow sets on a standalone system or in an OpenVMS Cluster system. A limit of 10,000 single member shadow sets is allowed on a standalone system or on an OpenVMS Cluster system. Dismounted shadow sets, unused shadow sets, and shadow sets with no write bitmaps allocated to them are included in this total. These limits are independent of controller and disk type. The shadow sets can be mounted as public or private volumes.

1.4.2 Shadowing System Disks

You can shadow system disks as well as data disks. Thus, a system disk need not be a single point of failure for any system that boots from that disk. System disk shadowing becomes especially important for OpenVMS Cluster systems that use a common system disk from which multiple computers boot. Volume shadowing makes use of the OpenVMS distributed lock manager, and the quorum disk must be accessed before locking is enabled. Note that you cannot shadow quorum disks.

Alpha and VAX systems can share data on shadowed data disks, but separate system disks are required — one for Alpha systems and one for VAX systems.

1.4.2.1 Obtaining Dump Files of Shadowed System Disk When Minicopy Is Used

Additional steps are required to access the dump file from a system disk shadow set in which a minicopy operation was used to return a member to the shadow set.

After a crash dump is written to one member of a system disk shadow set, if minicopy is used to return a member to that shadow set, then you must take certain steps to properly analyze or copy that SYSDUMP.DMP file. When the primitive file system writes a crash dump, the writes are not recorded in the write bitmap data structure. Therefore, perform the following steps:

1. Check the console output at the time of the system crash to determine which device contains the system dump file.
2. Assign a low value to the member to which the dump was written, by issuing the following command:

   ```
   SET DEVICE/READ_COST=nnn $allo_class$ddcu
   ```

   The console displays the device to which the crash dump was written. That shadow set member contains the only full copy of that file. By setting the /READ_COST to a very low value on that member, any reads done by SDA or the COPY command are directed to that member. Compaq recommends setting READ_COST to 1.
3. After you have analyzed or copied the system dump, you *must* return the read cost values of the shadow set member to the previous setting — either the default settings assigned automatically by the volume shadowing software or different values, if you had assigned different values. If you do not perform this action, all read I/O is directed to that member, which can unnecessarily degrade read performance. To change the READ_COST settings of the shadow set members to their default values, issue the following command:

   ```
   $ SET DEVICE /READ_COST=0 DSAnnnn
   ```

   Note

   SDA and CLUE will be modified in a future release. When those modifications are done, you will not need to adjust the read cost values of the shadow set members to accurately read the dump file.

1.4.3 Using Minicopy in a Mixed-Version OpenVMS Cluster System

To use the minicopy feature, introduced in OpenVMS Version 7.3, every node in the cluster must use a version of OpenVMS that contains this feature. Soon after the release of OpenVMS Version 7.3, an update for OpenVMS Version 7.2-*xx* will be available, which will include support for minicopy. Until then, minicopy *cannot* be used in a mixed-version OpenVMS Cluster system.

1.4.4 Using Minicopy in a Mixed-Architecture OpenVMS Cluster System

If you intend to use the minicopy feature in a mixed-architecture OpenVMS Cluster system, Compaq advises you to set the SHADOW_MAX_COPY system parameter to zero on all VAX systems. This setting prevents a copy from being performed on a VAX when the intent was to perform a minicopy on an Alpha. In a mixed-architecture cluster, it is possible, although highly unlikely, that a VAX system could be assigned the task of adding a member to a shadow set. Because a VAX system cannot perform a minicopy, it would perform a full copy instead. For more information about SHADOW_MAX_COPY, see Section 3.2.

1.4.5 Shadow Sets, Bound Volume Sets, and Stripe Sets

Shadow sets also can be constituents of a bound volume set or a stripe set. A bound volume set consists of one or more disk volumes that have been bound into a volume set by specifying the /BIND qualifier with the MOUNT command. Section 1.5 describes shadowing across OpenVMS Cluster systems. Chapter 9 contains more information about striping and how RAID (redundant arrays of independent disks) technology relates to volume shadowing.

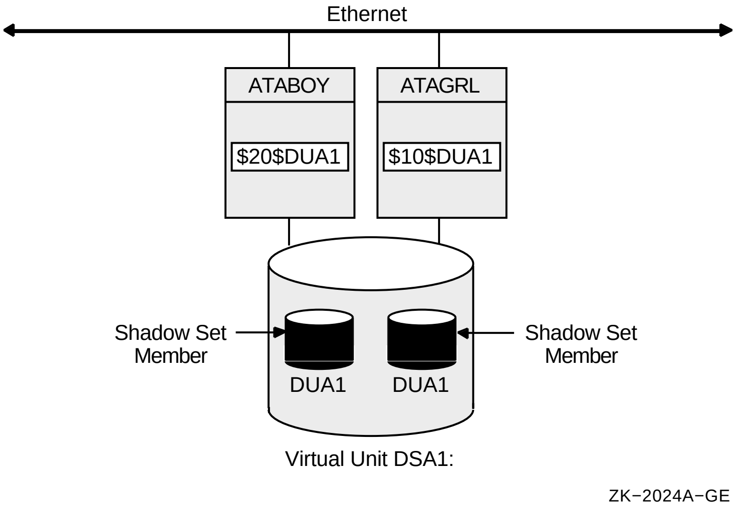
1.5 Shadowing Disks Across an OpenVMS Cluster System

The host-based implementation of volume shadowing allows disks that are connected to multiple physical controllers to be shadowed in an OpenVMS Cluster system. There is no requirement that all members of a shadow set be connected to the same controller. Controller independence allows you to manage shadow sets regardless of their controller connection or their location in the OpenVMS Cluster system and helps provide improved data availability and flexible configurations.

For clusterwide shadowing, members can be located anywhere in an OpenVMS Cluster system and served by MSCP servers across any supported OpenVMS Cluster interconnect, including the CI (computer interconnect), Ethernet (10/100 and Gigabit), ATM, Digital Storage Systems Interconnect (DSSI), and Fiber Distributed Data Interface (FDDI). For example, OpenVMS Cluster systems using FDDI and wide area network services can be hundreds of miles apart, which further increases the availability and disaster tolerance of a system.

Figure 1–2 shows how shadow-set members are on line to local adapters located on different nodes. In the figure, a disk volume is local to each of the nodes ATABOY and ATAGRL. The MSCP server provides access to the shadow set members over the Ethernet. Even though the disk volumes are local to different nodes, the disks are members of the same shadow set. A member that is local to one node can be accessed by the remote node via the MSCP server.

Figure 1–2 Shadow Sets Accessed Through the MSCP Server



The shadowing software maintains shadow sets in a distributed fashion on each node that mounts the shadow set in the OpenVMS Cluster system. In an OpenVMS Cluster environment, each node creates and maintains shadow sets independently. The shadowing software on each node maps each shadow set, represented by its virtual unit name, to its respective physical units. Shadow sets are not served to other nodes. When a shadow set must be accessed by multiple nodes, each node creates an identical shadow set. The shadowing software maintains clusterwide membership coherence for shadow sets mounted on multiple nodes.

For shadow sets that are mounted on an OpenVMS Cluster system, mounting or dismounting a shadow set on one node in the cluster does not affect applications or user functions executing on other nodes in the system. For example, you can dismount the shadow set from one node in an OpenVMS Cluster system and leave the shadow set operational on the remaining nodes on which it is mounted.

1.6 Installation

Volume Shadowing for OpenVMS is a System Integrated Product (SIP) that you install at the same time that you install the operating system. Volume Shadowing requires its own license that is separate from the OpenVMS base operating system license. To use the volume shadowing software, you must install this license. All nodes booting from shadowed system disks must have shadowing licensed and enabled. See the instructions included in your current OpenVMS upgrade and installation manual.

See Section 3.1 for more information about licensing Volume Shadowing for OpenVMS.

2

Configuring Your System for High Data Availability

System availability is a critical requirement in most computing environments. A dependable environment enables users to interact with their system when they want and in the way they want.

A key component of overall system availability is availability or accessibility of data. Volume Shadowing for OpenVMS provides high levels of data availability by allowing shadow sets to be configured on a single-node system or on an OpenVMS Cluster system, so that continued access to data is possible despite failures in the disk media, disk drive, or disk controller. For shadow sets whose members are local to different OpenVMS Cluster nodes, if one node serving a shadow set member shuts down, the data is still accessible through an alternate node.

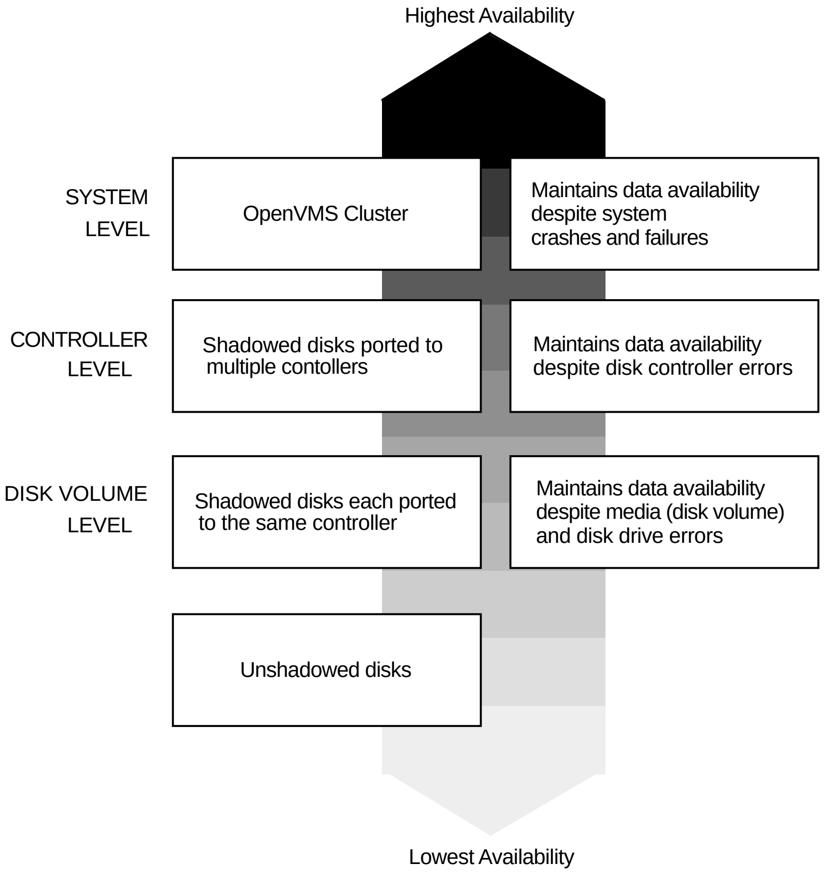
Although you can create a virtual unit, the system representation of a shadow set, that consists of only one disk volume, you must mount two or more disk volumes in order to "shadow"—maintain multiple copies of the same data. This configuration protects against either failure of a single disk drive or deterioration of a single volume. For example, if one member fails out of a shadow set, the remaining member can be used as a **source** disk whose data can be accessed by applications at the same time the data is being copied to a newly mounted **target** disk. Once the data is copied, both disks contain identical information and the target disk becomes a source member of the shadow set.

Using two controllers provides a further guarantee of data availability in the event of a single-controller failure. When setting up a system with volume shadowing, you should connect each disk drive to a different controller I/O channel whenever possible. Separate connections help protect against either failure of a single controller or of the communication path used to access it.

Using an OpenVMS Cluster system (as opposed to a single-node environment) and multiple controllers provides the greatest data availability. Disks that are connected to different local controllers and disks that are MSCP-served by other OpenVMS systems can be combined into a single shadow set, provided the disks are compatible and no more than three are combined.

Figure 2–1 provides a qualitative, high-level classification of how you can achieve increasing levels of physical data availability in different types of configurations.

Figure 2–1 Levels of Availability


Highest Availability
SYSTEM LEVEL
OpenVMS Cluster
Maintains data availability despite system crashes and failures
CONTROLLER LEVEL
Shadowed disks ported to multiple contollers
Maintains data availability despite disk controller errors
DISK VOLUME LEVEL
Shadowed disks each ported to the same controller
Maintains data availability despite media (disk volume) and disk drive errors
Unshadowed disks
Lowest Availability

VM-0702A-AI

Section 2.1 describes how you can configure your shadowed system to achieve high data availability despite physical failures.

2.1 Repair and Recovery from Failures

Volume shadowing failures, some of which are automatically recoverable by the volume shadowing software, are grouped into the following categories:

- Controller errors
- Device errors
- Data errors
- Connectivity failures

The handling of shadow set recovery and repair depends on the type of failure that occurred and the hardware configuration. In general, devices that are inaccessible tend to fail over to other controllers whenever possible. Otherwise, they are removed from the shadow set. Errors that occur as a result of media defects can often be repaired automatically by the volume shadowing software.

Table 2–1 describes these failure types and recovery mechanisms.

Table 2–1 Types of Failures

Type	Description
Controller error	Results from a failure in the controller. If the failure is recoverable, processing continues and data availability is not affected. If the failure is nonrecoverable, shadow set members connected to the controller are removed from the shadow set, and processing continues with the remaining members. In configurations where disks are dual-pathed between two controllers, and one controller fails, the shadow set members fail over to the remaining controller and processing continues.
Device error	Signifies that the mechanics or electronics in the device failed. If the failure is recoverable, processing continues. If the failure is nonrecoverable, the node that detects the error removes the device from the shadow set.
Data errors	Results when a device detects corrupt data. Data errors usually result from media defects that do not cause the device to be removed from a shadow set. Depending on the severity of the data error (or the degree of media deterioration), the controller: • Corrects the error and continues. • Corrects the data and, depending on the device and controller implementation, may revector it to a new logical block number (LBN). When data cannot be corrected by the controller, volume shadowing replaces the lost data by retrieving it from another shadow set member and writing the data to a different LBN of the member with the incorrect data. This repair operation is synchronized within the cluster and with the application I/O stream.

(continued on next page)

Table 2–1 (Cont.) Types of Failures

Type	Description
Connectivity failures	When a connectivity failure occurs, the first node to detect the failure must decide how to recover from the failure in a manner least likely to affect the availability or consistency of the data. As each node discovers the recoverable device failure, it determines its course of action as follows: • If at least one member of the shadow set is accessible by the node that detected the error, that node will attempt to recover from the failure. The node repeatedly attempts to access the failed shadow set member within the period of time specified by the system parameter SHADOW_MBR_TIMEOUT. (This time period could be either the default setting or a different value previously set by the system manager.) If access to the failed disk is not established within the time specified by SHADOW_MBR_TIMEOUT, the disk is removed from the shadow set. • If no members of a shadow set can be accessed by the node, that node does not attempt to make any adjustments to the shadow set membership. Rather, it assumes that another node, which does have access to the shadow set, will make appropriate corrections. The node will attempt to access the shadow set members until the period of time designated by the system parameter MVTIMEOUT expires. (This time period could be the default setting or a different value previously set by the system manager.) After the time expires, all application I/O is returned with the following error status message: `-SYSTEM-F-VOLINV, Volume is not software enabled`

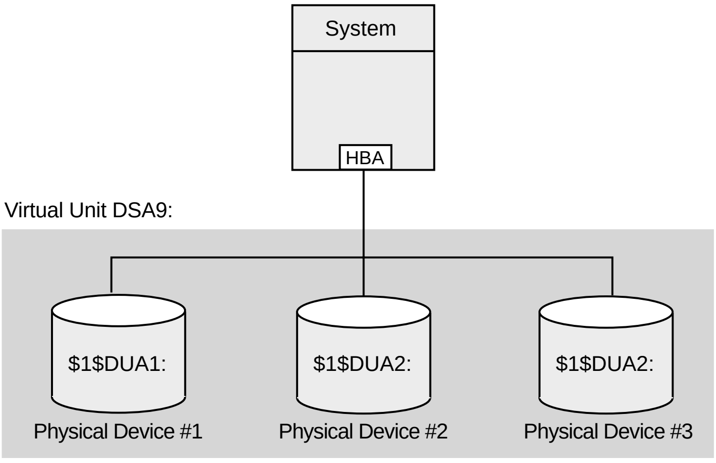
2.2 Shadow Set Configurations

To illustrate the varyious levels of data availability obtainable through Volume Shadowing for OpenVMS, this section provides a representative sample of hardware configurations. Figures 2–2 through 2–7 show possible system configurations for shadow sets. The hardware used to describe the sample systems, while intended to be representative, is hypothetical; they should be used only for general observations about availability and not as a suggestion for any specific configurations or products.

In all of the following examples, the shadow set members use the $*allocation-class*$*ddcu*: naming convention. The virtual unit uses the DSA*n*: format, where *n* represents a number between 0 and 9999. These naming conventions are described in more detail in Section 4.2.

Figure 2–2 shows one system with one host-based adapter (HBA). The shadow set consists of three disks. This configuration provides coverage against media errors and against the failure of one or two disks.

Figure 2–2 Configuration of a Shadow Set (One System, One Adapter)

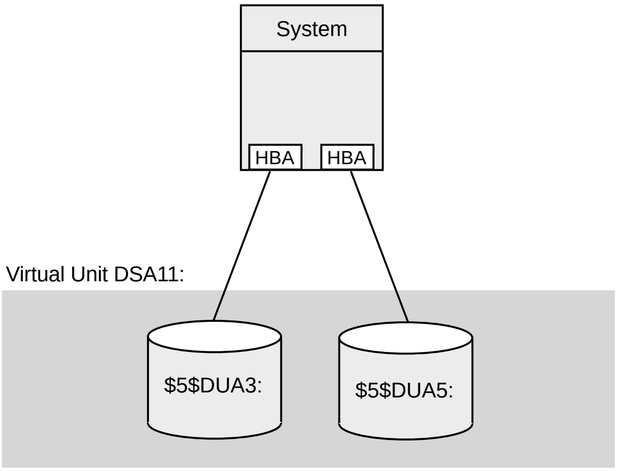


VM-0554A-AI

Figure 2–3 shows one system with two adapters. In this configuration, each disk in the shadow set is connected to a different adapter.

In addition to providing coverage against media errors or disk failures, this type of configuration provides continued access to data in spite of the failure of either one of the adapters.

Figure 2–3 Configuration of a Shadow Set (One System, Two Adapters)



VM-0555A-AI

Figure 2–4 shows two systems, both connected to the same three-member shadow set. Each shadow set member is connected by dual paths to two adapters. The shadow set is accessible with either one or both systems operating. In this configuration, a disk can be on line to only one adapter at a time. For example, $2$DKA5 is on line (primary path) to System A. As a result, System B accesses $2$DKA5 by means of the MSCP server on System A. If System A fails, $2$DKA5 fails over to the adapter on System B.

Different members of the shadow set can fail over between adapters independently of each other. The satellite nodes access the shadow set members by means of the MSCP servers on each system. Satellites access all disks over primary paths, and failover is handled automatically.

Figure 2–4 Configuration of a Shadow Set (OpenVMS Cluster, Dual Adapters)

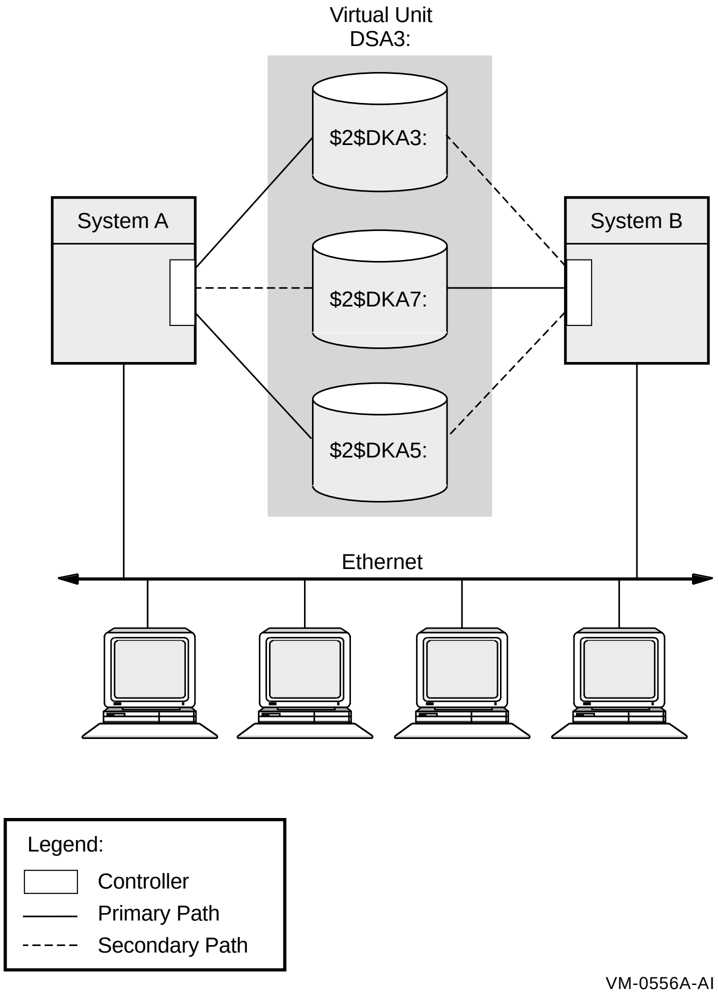


Figure 2–5 shows an OpenVMS Cluster system with two systems connected to multiple disks. Virtual units DSA1: and DSA2: represent the two shadow sets and are accessible through either system. This configuration offers both an availability and a performance advantage. The shadow sets in this configuration are highly available because the satellite nodes have access through either system. Thus, if one system fails, the satellites can access the shadowed disks through the remaining system.

In addition, this configuration offers a performance advantage by using another interconnect for I/O traffic that is separate from the Ethernet. In general, you can expect better I/O throughput from this type of configuration than from an Ethernet-only OpenVMS Cluster system.

Figure 2–5 Configuration of a Shadow Set (Highly Available OpenVMS Cluster)

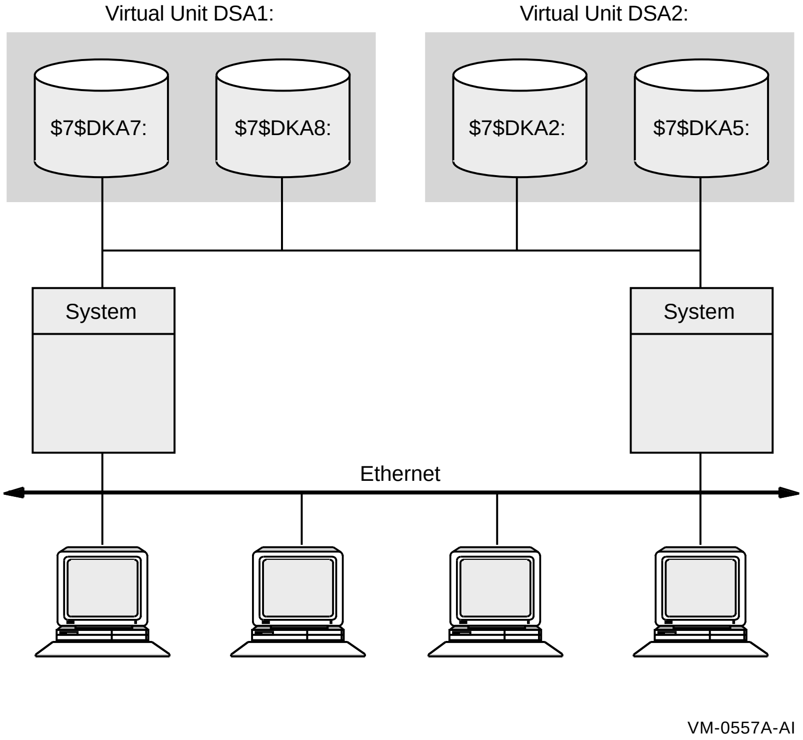
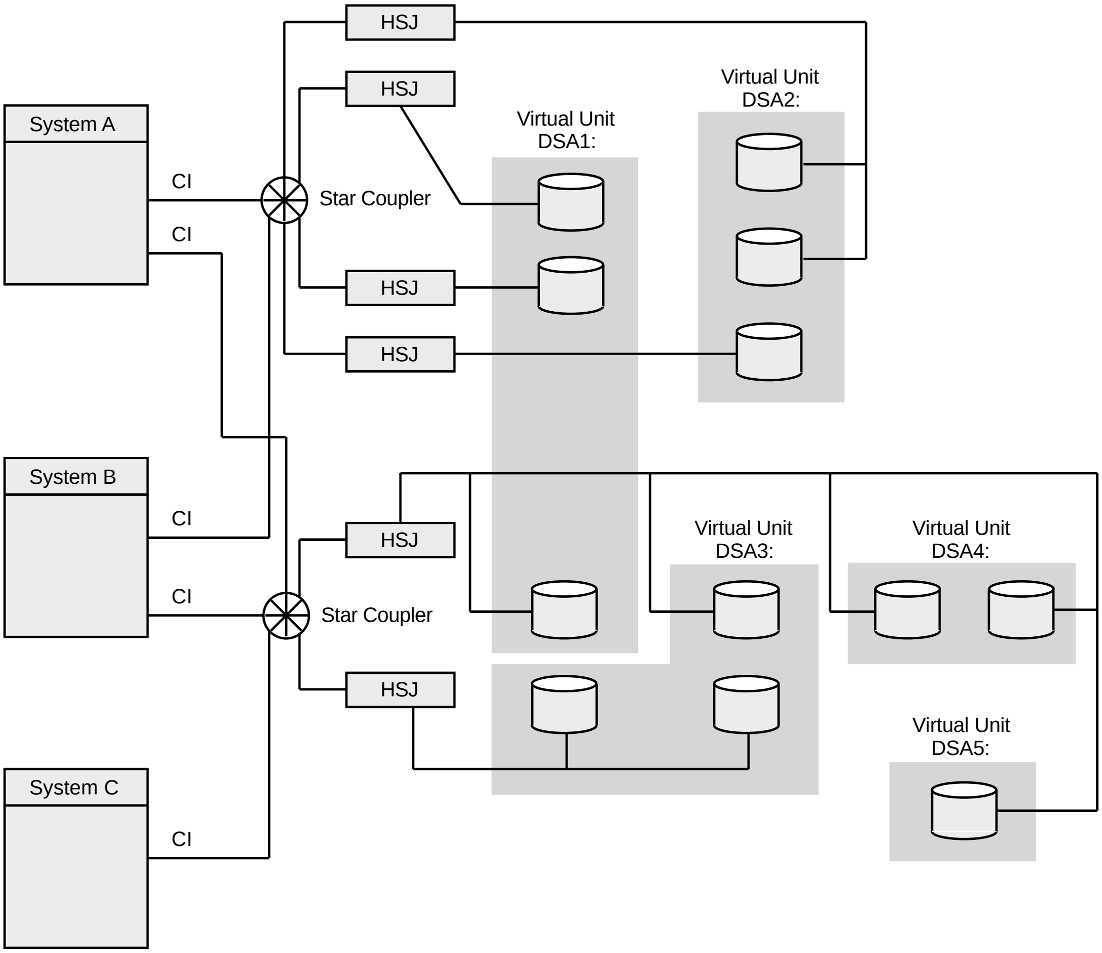


Figure 2–6 illustrates how shadowed disks can be located anywhere in an OpenVMS Cluster system. The figure presents a cluster system with three nodes, multiple HSJ controllers, and multiple shadow sets that are accessible by any node. The shadow sets are accessible when three nodes, two nodes, and, in some cases, only one node is operating. The exception is if System A and System B fail, leaving only System C running. In this case, access to the secondary star coupler is lost, preventing access to the DSA2: shadow set. Note that DSA1: would still be accessible, but it would be reduced to a one-member shadow set.

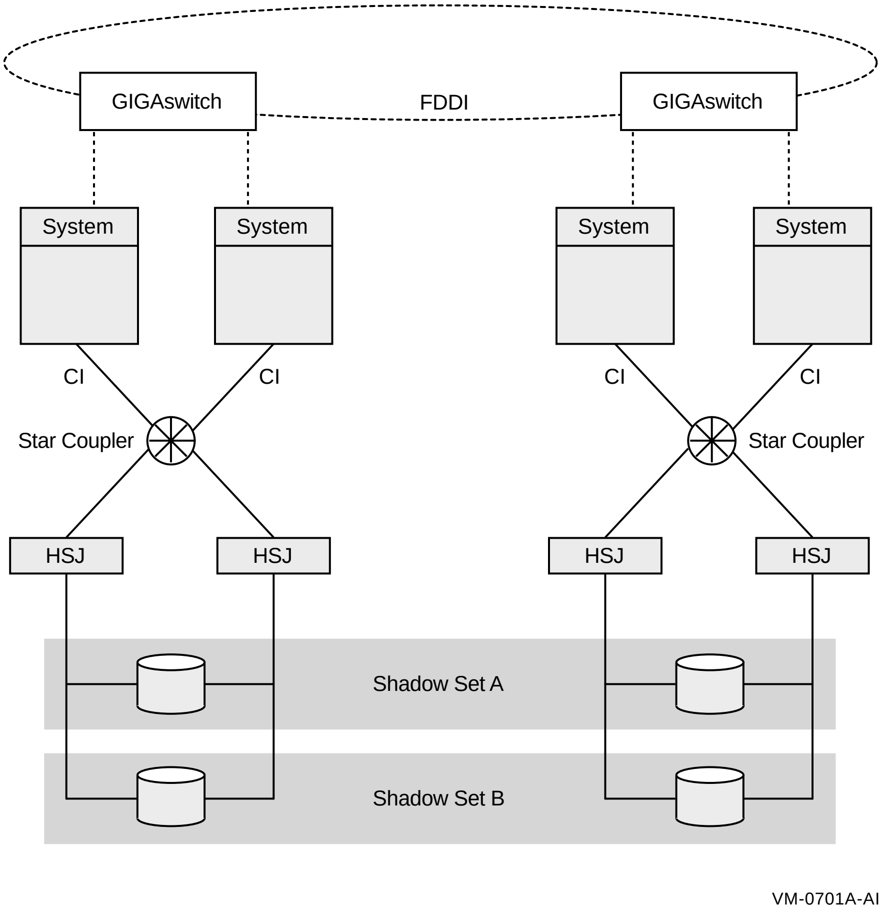
Figure 2–6 Configuration of a Shadow Set (Multiple Star Couplers, Multiple HSJ Controllers)



VM-0405A-AI

Figure 2–7 illustrates how the FDDI (Fiber Distributed Data Interface) interconnect allows you to shadow data disks over long distances. Members of each shadow set are configured between two distinct and widely separated locations — a multiple-site OpenVMS Cluster system. The OpenVMS systems and shadowed disks in both locations function as a single OpenVMS Cluster system and shadow set configuration. If a failure occurs at either site, the critical data is still available at the remaining site.

Figure 2–7 Configuration of a Shadowed FDDI Multiple-Site Cluster

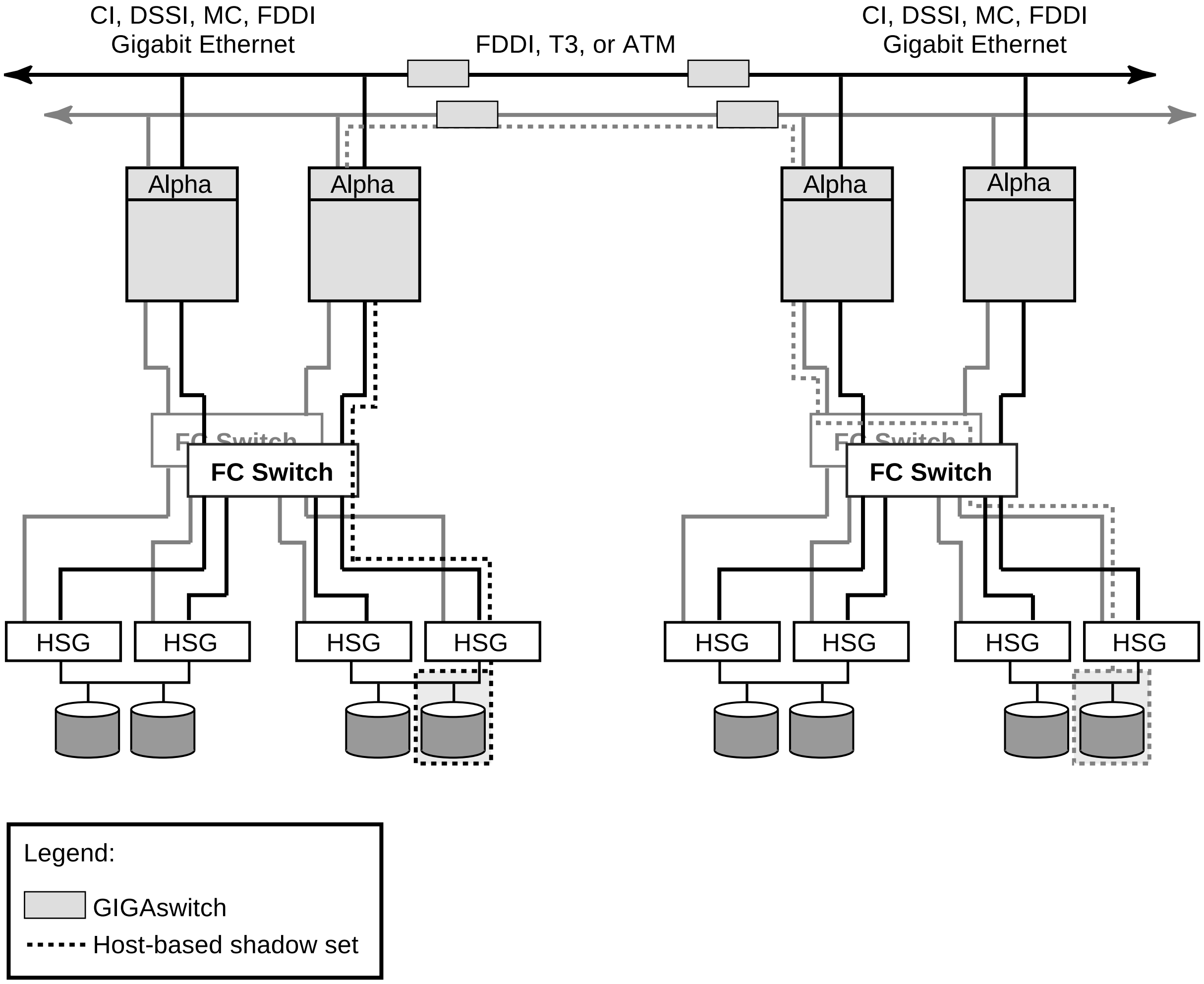


Note

Systems other than satellite nodes are unable to boot from disks that are located remotely across an Ethernet or FDDI LAN. Therefore, these systems require local access to their system disk. Note that this restriction limits the ability to create system disk shadow sets across an FDDI or Ethernet LAN.

Figure 2–8 shows the use of shared Fibre Channel storage in a multiple-site OpenVMS Cluster system with shadowed disks. Members of the shadow set are configured between two widely separated locations. The configuration is similar to that in Figure 2–7, except that the systems at each site use shared Fibre Channel storage.

Figure 2–8 Configuration of a Shadowed Fibre Channel Multiple-Site Cluster



3 Preparing to Use Volume Shadowing

This chapter explains the system management tasks required for using volume shadowing on your system, including licensing, setting system parameters, and booting.

Once you have determined how to configure your shadow set, perform the following steps:

- If you are running OpenVMS VAX and phase I volume shadowing, migrate to phase II shadowing. Support for phase I shadowing was eliminated as of OpenVMS Version 6.2.
- Select which of your disk drives you want to shadow. Prepare the selected volumes for mounting by physically placing the volumes in the drives (for removable media disks). Ensure the disks are not write locked.
- Consider whether or not you want to initialize the volumes you have chosen to shadow. Do not initialize volumes that contain useful data.

  If you are creating a *new* shadow set, you can initialize one volume at a time, or multiple volumes with one command, which can streamline the creation of a shadow set (see Section 4.3). When you initialize one volume at a time, you can give it a volume label that you want to use for the shadow set. When you later mount additional volumes into the shadow set, each volume will be initialized and will be given the same volume label automatically.
- Install the Volume Shadowing for OpenVMS licenses. See Section 3.1 for more information.
- Set the SHADOWING parameter to enable volume shadowing on each node that will use volume shadowing. See Section 3.2 for more information.

  Setting the SHADOWING parameter requires that you reboot the system.
- Set the ALLOCLASS parameter to 1. This parameter enables the use of allocation classes in device names. You must include a nonzero allocation class in the device name of shadowed disks. For more information, see Section 4.2.
- Dismount the disk drives you selected for the shadow set and remount them (along with the additional shadow set disk drives) as shadow set members. Note that:
  - You do not need to change the device volume labels and logical names.
  - If you use mount command files, ensure that the commands mount the physical devices using the appropriate naming syntax for virtual units (DSA*n*:).
- See Chapter 4 for more information on the MOUNT command.

System disks can be shadowed. All nodes booting from that system disk must have shadowing licensed and enabled.

3.1 Licensing Volume Shadowing for OpenVMS

To use the volume shadowing product, you must purchase the license separately from the OpenVMS operating system even though the volume shadowing software is part of the OpenVMS operating system.

Volume shadowing licenses are available in two options:

- Per disk license, which enables you to license each disk that you plan to include in the shadow set. One example of how this option might be more cost effective is in a cluster where you intend to shadow only a small number of disks.
- Capacity license (per CPU), which may be more attractive to those who have larger systems with many more disks to shadow.

Both options work on the same systen or in an OpenVMS Cluster that contains both Alpha and VAX computers.

After licensing the OpenVMS operating system by registering a OpenVMS Product Authorization Key (PAK), you must license Volume Shadowing for OpenVMS with a separate volume shadowing PAK. The PAK provides information that defines the Volume Shadowing for OpenVMS license contract you have with Compaq Computer Corporation. Obtain a PAK from your Compaq sales representative.

When you enter information from the PAK into the online LICENSE database, the OpenVMS License Management Facility (LMF) authorizes the use of volume shadowing.

If you have a per disk license, you must register and activate a license for each shadowed disk. Starting with Volume Shadowing for OpenVMS Version 7.1, a license check for each disk that is shadowed using the per-disk volume shadowing license is included. Per-disk volume shadowing licenses apply to full shadow set members only. When the number of shadow set members exceeds the number of per-disk licenses for five minutes, shadowing issues an OPCOM warning message. You can have this message also sent to an E-mail account by defining the system logical SHADOW_SERVER$MAIL_NOTIFICATION to a standard OpenVMS Mail address or a UNIX (internet) address. An invalid address will not generate a failure message.

Shadowing issues notification again 59 minutes after noncompliant shadow set members are mounted. One minute later, shadow set members are automatically removed from shadow sets until the number of members equals the number of licenses. Members are removed systematically from multiple-member shadow sets; single-member shadow sets will not be affected.

Disks that are the target of a copy operation do not consume a license unit until the copy is complete. Thus it is always possible to obtain a copy of a single-member shadow set.

If you are using capacity licenses, you must register and activate a license for Volume Shadowing for OpenVMS on each node that mounts a shadow set, including satellites in an OpenVMS Cluster system. If you do not register and activate nodes or disks that will use volume shadowing, subsequent shadow set mount operations will not succeed and will display the error messages like the one in Example 3–1.

Example 3–1 Nodes Not Registered to Use Volume Shadowing

```
%LICENSE-E-NOAUTH, DEC VOLSHAD use is not authorized on this node
-LICENSE-F-NOLICENSE, no license is active for this software product
-LICENSE-I-SYSMGR, please see your system manager
```

For more information about the License Management Facility, refer to the OpenVMS Operating System *Software Product Description* 25.01.*xx*.

You can also consult the *OpenVMS License Management Utility Manual*.

After you register the volume shadowing PAK, you must set the shadowing parameters on each node where you want to enable shadowing.

3.2 Volume Shadowing Parameters

Table 3–1 lists the system parameters that you can use to tailor the shadowing software on your system. These parameters were introduced with OpenVMS Version 7.1, except SHADOW_MAX_UNIT, which was introduced in OpenVMS Version 7.3. The term **dynamic** in Table 3–1 means that the active value can be changed on a running system. See the *OpenVMS System Manager's Manual* for more information about setting system parameters.

OpenVMS Version 7.3 introduced four write bitmap system parameters (described in Table 3–3) and the volume shadowing system parameter SHADOW_MAX_UNIT. These system parameters support the shadowing minicopy operation, which is described in Chapter 7.

Table 3–1 Volume Shadowing Parameters

Parameter	Function	Range	Default	Dynamic
SHADOWING	Enables phase II volume shadowing. See Table 3–2 for a description of parameter values.	0, 2[1]	0	No
SHADOW_MAX_COPY	Limits the number of concurrent merge or copy operations on a given node.	0–200	4	Yes
SHADOW_MBR_TMO	Controls the amount of time the system tries to fail over physical members of a shadow set.	1–65,535 seconds	120	Yes
SHADOW_MAX_UNIT	Specifies the maximum number of shadow sets that can exist on a node. Dismounted shadow sets, unused shadow sets, and shadow sets with no write bitmaps allocated to them are included in this total.	10–10,000	100 on VAX; 500 on Alpha	No
SHADOW_SYS_DISK	Allows system disk to be a shadow set and, optionally, enables a minimerge to occur. If a minimerge is enabled, the system must also be configured for writing to a nonshadowed, nonsystem disk of your choice.	0, 1, 4097[1]	0	Yes

[1] All other values are reserved for use by Compaq.

(continued on next page)

Table 3–1 (Cont.) Volume Shadowing Parameters

Parameter	Function	Range	Default	Dynamic
SHADOW_SYS_TMO	Controls the amount of time members of a system disk shadow set have to return to the set.	1–65,535 seconds	120	Yes
SHADOW_SYS_UNIT	Contains the virtual unit number of the system disk.	0–9999	0	No
SHADOW_SYS_WAIT	This parameter applies only to shadow sets that are currently mounted in the cluster. Controls the amount of time a booting system will wait for all members of a mounted system disk shadow set to become available.	1–65,535 seconds	480	Yes

3.2.1 Guidelines for Using Volume Shadowing Parameters

This section provides guidelines for using volume shadowing parameters.

SHADOWING

The SHADOWING parameter enables or disables specific phases of volume shadowing on your system.

Table 3–2 describes these settings in detail.

Table 3–2 SHADOWING Parameter Settings

Setting	Effect
0	Shadowing is not enabled. This is the default value.
2	Enables host-based shadowing. This setting provides shadowing of all disks that are located on a standalone system or on an OpenVMS Cluster system. Set SHADOWING to 2 on every node that will mount a shadow set, including satellite nodes.

SHADOW_MAX_COPY

The SHADOW_MAX_COPY parameter controls how many parallel copy and merge operations are allowed on a given node. (Copy and merge operations are described in Chapter 6.) This parameter provides a way to limit the number of copy and merge operations in progress at any one time.

The value of SHADOW_MAX_COPY can range from 0 to 200. The default value is specific to the OpenVMS version. You can determine the default value by looking at the parameter setting. When the value of the SHADOW_MAX_COPY parameter is 4, and you mount five multivolume shadow sets that all need a copy operation, only four copy operations can proceed. The fifth copy operation must wait until one of the first four copies completes.

Consider the following when choosing a value for the SHADOW_MAX_COPY parameter:

- CPU power
- Disk controller bandwidth
- Interconnect controller bandwidth

- Other work loads on the system

For example, the default value of 4 may be too high for a small node. (In particular, satellite nodes should have SHADOW_MAX_COPY set to a value of 0.) Too low a value for SHADOW_MAX_COPY unnecessarily restricts the number of operations your system can effectively handle and extends the amount of time it takes to merge all of the shadow sets.

SHADOW_MAX_COPY is a dynamic parameter. Changes to the parameter affect only future copy and merge operations; current operations (pending or already in progress) are not affected.

SHADOW_MAX_UNIT

The SHADOW_MAX_UNIT specifies the maximum number of shadow sets that can exist on a node. The important thing to note about this value is that any shadow set that has been created, regardless of whether it is in use, is included in this total. Because this is not a dynamic system parameter, you should be very careful when determining the value to use. If you need to change this parameter, you must reboot the system. Furthermore, any attempt to mount more shadow sets than the value specified will fail.

Note that this parameter does not affect the naming of shadow sets. For example, with the default value of 100, a device name such as DSA999 is still valid.

SHADOW_MBR_TMO

The SHADOW_MBR_TMO parameter controls the amount of time the system tries to fail over physical members of a shadow set before removing them from the set. SHADOW_MBR_TMO is a dynamic parameter that you can change on a running system.

With the SHADOW_MBR_TMO parameter, you specify the number of seconds, from 1 to 65,535, during which recovery of a shadow set member is attempted.

Note

> The value of SHADOW_MBR_TMO should not exceed the value of the parameter MVTIMEOUT.

If you specify zero, a default delay is used. The default delay is specific to the version of OpenVMS running on your system. For shadow sets in an OpenVMS Cluster configuration, the value of SHADOW_MBR_TMO should be set to the same value on each node.

Determining the correct value for SHADOW_MBR_TMO is a trade-off between rapid recovery and high availability. If rapid recovery is required, set SHADOW_MBR_TMO to a low value. This ensures that failing shadow set members are removed from the shadow set quickly and that user access to the shadow set continues. However, removal of shadow set members reduces data availability and, after the failed member is repaired, a full copy operation is required when it is mounted back into the shadow set.

If high availability is paramount, set SHADOW_MBR_TMO to a high value. This allows the shadowing software additional time to regain access to failed members. However, user access to the shadow set is stalled during the recovery process. If recovery is successful, access to the shadow set continues without the need for a full copy operation, and data availability is not degraded. Setting SHADOW_

MBR_TMO to a high value may be appropriate when shadow set members are configured across LANs that require lengthy bridge recovery time.

Shadowing uses a timer to adhere to the number of seconds specified by the SHADOW_MBR_TMO parameter. For directly connected SCSI devices that have been powered down or do not answer to polling, the elapsed time before a device is removed from a shadow set can take several minutes.

SHADOW_SYS_DISK

A SHADOW_SYS_DISK parameter value of 1 enables shadowing of the system disk. A value of 0 disables shadowing of the system disk. A value of 4097 enables a minimerge. The default value is 0.

If you enable a minimerge of the system disk, you must also configure your system to write a dump to a nonshadowed, nonsystem disk of your choice. This is known as dump off system disk (DOSD). For more information on DOSD, see the *OpenVMS System Manager's Manual: Tuning, Monitoring, and Complex Systems* manual.

In addition, you should specify a system-disk, shadow-set virtual unit number with the SHADOW_SYS_UNIT system parameter, unless the desired system disk virtual unit number is DSA0.

SHADOW_SYS_TMO

You can use the SHADOW_SYS_TMO parameter in two ways: during the booting process and during normal operations. SHADOW_SYS_TMO is a dynamic parameter that you can change on a running system.

During the booting process, you can use this parameter on the *first* node in the cluster to boot and to create a specific shadow set. If the proposed shadow set is not currently mounted in the cluster, use this parameter to extend the time a booting system will wait for all former members of the system disk shadow set to become available.

The second use of this parameter comes into effect once the system successfully mounts the shadow set and begins normal operations. Just as the SHADOW_MBR_TMO parameter controls the time the operating system waits for failing members of an application disk shadow set to rejoin the shadow set, the SHADOW_SYS_TMO parameter controls how long the operating system will wait for failing members of a system disk shadow set. All nodes using a particular system disk shadow set should have their SHADOW_SYS_TMO parameter equal to the same value, after normal operations begin. Therefore, after booting, this parameter applies only to members of the system disk shadow set.

The default value is OpenVMS version specific. You can set a range of up to 65,535 seconds if you want the system to wait longer than the default for all members to join the shadow set.

SHADOW_SYS_UNIT

The SHADOW_SYS_UNIT parameter, which must be used when the SHADOW_SYS_DISK parameter is set to 1, contains the virtual unit number of the system disk.

The SHADOW_SYS_UNIT parameter is an integer value that contains the virtual unit number of the system disk. The default value is 0. The maximum value allowed is 9999. This parameter is effective only when the SHADOW_SYS_DISK parameter has a value of 1. This parameter must be set to the same value on all nodes that boot off a particular system disk shadow set. SHADOW_SYS_UNIT is not a dynamic parameter.

SHADOW_SYS_WAIT

Use the SHADOW_SYS_WAIT parameter to extend the time a booting system will wait for all current members of a mounted system disk shadow set to become available to *this* node. SHADOW_SYS_WAIT is a dynamic parameter that you can change on a running system (for debugging purposes only). The shadow set must already be mounted by at least one other cluster node for this parameter to take effect. The default value is 256 seconds. Change this parameter to a higher value if you want the system to wait more than the 256-second default for all members to join the shadow set. This parameter has a range of 1 through 65,535 seconds.

3.3 Write Bitmap System Parameters

Starting with OpenVMS Version 7.3, system parameters are available for managing update traffic between a master write bitmap and its corresponding local write bitmaps in an OpenVMS Cluster system. Another system parameter controls whether write bitmap system messages are sent to the operator console and, if they are to be sent, the volume of messages. These system parameters are dynamic; that is, they can be changed on a running system. They are shown in Table 3–3 and described in detail in Section 7.9. These system parameters support the minicopy operation (see Chapter 7).

Table 3–3 Write Bitmap System Parameters

Parameter	Meaning	Unit	Min	Max[1]	Default
WBM_MSG_INT	In single-message mode, the time interval between assessment of the most suitable write bitmap message mode. In buffered-message mode, the maximum time a message waits before it is sent.	msec	10	-1	10
WBM_MSG_UPPER	The upper threshold for the number of messages sent during the test interval that will initiate buffered-message mode.	msgs/interval	0	-1	100
WBM_MSG_LOWER	The lower threshold for the number of messages sent during the test interval that will initiate single-message mode.	msgs/interval	0	-1	10
WBM_OPCOM_LVL	Controls whether write bitmap messages are provided to the operator console: 0 means messages are turned off; 1 means messages are provided when write bitmaps are started, deleted, and renamed, and when the SCS message mode (buffered or single) changes; 2 means that all messages for a setting of 1 are provided along with detailed messages for debugging purposes.	n/a	0	2	1

[1] The maximum value of -1 corresponds to the maximum positive value that can be represented by a longword.

3.3.1 Setting System Parameters

To set or modify volume shadowing parameters, edit the [SYS*n*.SYSEXE]MODPARAMS.DAT file or the appropriate AUTOGEN include file. After editing the file, execute SYS$UPDATE:AUTOGEN as described in the *OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems*. If you have an OpenVMS Cluster system, ensure that the system parameters are updated on each node. Example 3–2 illustrates a

MODPARAMS.DAT file that includes assignment statements to set shadowing parameters.

Example 3–2 MODPARAMS.DAT File

```
   .
   .
   .
! Volume Shadowing Parameters:
SHADOWING=2             ! Enables phase II shadowing

SHADOW_SYS_DISK=1       ! Enables system disk shadowing

SHADOW_SYS_UNIT=7       ! Specifies 7 as the virtual unit number
                          of the system disk

SHADOW_MAX_COPY=4       ! Specifies that 4 parallel copies can occur at one time

SHADOW_MBR_TMO=120      ! Allows 120 seconds for physical members to fail over
                        ! before removal from the shadow set

   .
   .
   .
```

See the *OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems* for complete information about invoking AUTOGEN and specifying the appropriate command qualifiers to perform the desired AUTOGEN operations.

3.3.2 Displaying System Parameters

It is sometimes useful to use the SYSGEN command SHOW to display the values of system parameters.

You do not need special privileges to invoke the SYSGEN utility. You can use either a qualifier or the name of a system parameter with the SHOW command, or you can use the SHOW/ALL command to display information about all system parameters. (Enter HELP SHOW at the SYSGEN> prompt for more information about the SHOW command.) The following example illustrates how you can check the current default, minimum, and maximum values for the SHADOWING parameter.

```
$ MCR SYSGEN
SYSGEN> SHOW SHADOWING
Parameter Name   Current  Default  Minimum  Maximum  Unit        Dynamic
--------------   -------  -------  -------  -------  ----        -------
SHADOWING              2        0        0        3  Coded-value

SYSGEN>
```

3.4 Booting from a System Disk Shadow Set

When multiple nodes boot from a common system disk shadow set, ensure that all nodes specify a physical disk that is a source member of the system disk shadow set.

At boot time, the volume shadowing software attempts to construct a complete system disk shadow set based on the shadowing membership information contained in the **storage control block (SCB)** of the boot device. The SCB is an ODS-2 or ODS-5 file system data structure that resides on each storage device and contains information about shadow set membership (described in

Section 6.1). Depending on what information is in the SCB at boot time, the following scenarios are possible:

- If the boot device was not formerly a member of a shadow set, the system creates a new shadow set containing only the boot device. You can manually mount additional disks into the shadow set after the system boot procedure completes. (See the Caution that follows.)
- If the boot device is already a valid member of an existing shadow set (for instance, if it is already an up-to-date member of a shadow set mounted by another node in the cluster), the shadowing software automatically locates all the members of the set.
- When booting the first node in a cluster, information stored in the SCB of the physical boot device is used to locate other members of the shadow set and to create the complete system disk shadow set.
- The shadowing software detects boot attempts from a physical disk that is inconsistent with currently active shadow set members. In this case, the boot attempt detects the existence of the other shadow set members and determines (using the information in the SCB) that the boot device is not a valid member of the shadow set. When this occurs, the boot attempt fails with a SHADBOOTFAIL bugcheck message on the system console, and a dump file is written to the boot device.

  The system bugchecks because it can boot only from a currently valid member of the system disk shadow set. If the boot device fails out of or is otherwise removed from the system disk shadow set, you must either mount the boot device back into the shadow set (and wait for the copy operation to complete) or modify the boot command file to boot from a current shadow set member.

The boot process automatically locates all the members of a system disk shadow set. You should not add system disk shadow set members in startup procedures as formerly recommended when phase I shadowing was supported.

Caution

Do not add members to a system disk shadow set in startup procedures. Doing so can result in loss of data under the following circumstances:

1. A system is operating normally with a multiple member system disk shadow set.
2. The original boot device is removed from the shadow set but remains as a functioning disk.
3. The system continues with the remaining members.
4. The system is shut down or it fails.
5. The system is rebooted using the original boot device (which is now out of date).
6. The boot process determines that the boot device is not consistent with the other shadow set members and, therefore, does not add them into the shadow set. This behavior preserves the up-to-date data on the other members.
7. A MOUNT command in the startup procedure adds the other shadow set members to the system disk shadow set.
8. A copy operation from the boot device to the other shadow set members is initiated, thereby overwriting them.

If the boot device fails, the following console warning message displays:

```
virtual-unit: does not contain the member named to VMB.
System may not reboot.
```

After the boot device has been repaired, manually add it back into the system disk shadow set.

3.5 Booting Satellite Nodes from an MSCP Served System Disk Shadow Set

The OpenVMS operating system uses the Maintenance Operations Procedure (MOP) protocol to boot satellite nodes. The MOP protocol is provided by either the LANCP utility or by DECnet. The network software (LANCP or DECnet) must be configured on your system before you can use either LANCP or DECnet commands. You must also define a satellite's system disk using the LANCP or DECnet commands of the network software you are using for satellite booting. If the system disk is shadowed, the commands should specify the virtual unit or the virtual unit logical name rather than any physical unit.

The MOP server accesses the system disk shadow set (using the virtual unit defined) to perform downline load operations to the satellite. These operations include downline loading the physical boot device name to the satellite. When downline loading is complete, the satellite is able to connect to an MSCP server and access the physical boot device directly. The satellite's shadowing parameters are then used in the same way as a nonsatellite node.

You can use the SYS$MANAGER:CLUSTER_CONFIG_LAN.COM procedure or the SYS$MANAGER:CLUSTER_CONFIG.COM procedure to set MOP server, MSCP server, and satellite parameters automatically. When configuring satellite nodes with the cluster configuration command procedure, you can specify a shadowed system disk virtual unit as the satellite's system disk. The cluster configuration command procedure then automatically sets the satellite's system parameters SHADOW_SYS_DISK and SHADOW_SYS_UNIT for you. The values of these parameters are transferred automatically to the system parameter file VAXVMSSYS.PAR for VAX satellites and to ALPHAVMSSYS.PAR for Alpha satellites. (See the *OpenVMS Cluster Systems* manual for more information about using this command procedure.)

Example 3–3 shows the commands to enter to display the LANCP satellite database entries.

Example 3–3 LANCP Database Example of a Satellite Node

```
$ MCR LANCP
LANCP> LIST DEVICE/MOPDLL


Device Listing, permanent database:
  --- MOP Downline Load Service Characteristics ---
Device    State   Access Mode      Client            Data Size
------    -----   -----------      ------            ---------
ESA0    Disabled NoExlusive  NoKnownClientsOnly     246 bytes
FCA0    Disabled NoExlusive  NoKnownClientsOnly     246 bytes

LANCP> EXIT
```

For DECnet–Plus commands, see the *DECnet–Plus* documentation.

Example 3–4 shows the NCP commands you should enter on a MOP server to display a satellite DECnet database entry. Note that the load assist parameter displays the shadow set virtual unit name that downline loads the satellite node HIWAY1. Example 3–4 uses an explicit virtual unit name. However, you might prefer to use a logical name that translates to the virtual unit.

Example 3–4 DECnet Database Example of a Satellite Node

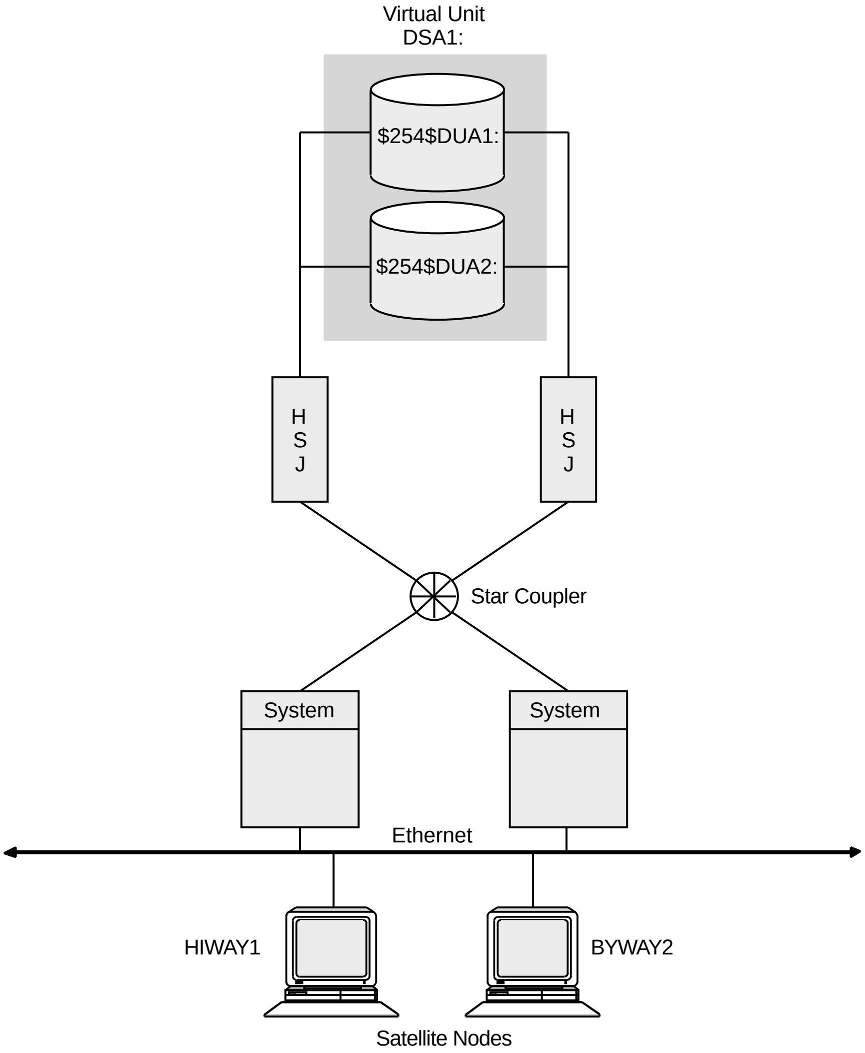
```
$ MCR NCP
NCP> SHOW NODE HIWAY1 CHAR
Node Volatile Characteristics as of 12-MAR-2000 14:53:59

Remote node =   19.891 (HIWAY1)

Hardware address         = 03-03-03-03-03-BC
Tertiary loader          = SYS$SYSTEM:TERTIARY_VMB.EXE
Load Assist Agent        = SYS$SHARE:NISCS_LAA.EXE
Load Assist Parameter    = DSA1:<SYS4C.>

NCP> EXIT
```

You may need to adjust the settings of the SHADOW_MBR_TMO and SHADOW_MAX_COPY parameters on satellite nodes. These parameters are not automatically set by the cluster configuration command procedure. See Section 3.2 for more information.

The cluster configuration command procedure automatically enables shadowing on satellite nodes when you want to shadow the system disk. If you do not want to shadow the system disk but need to enable shadowing, you must do so manually after the cluster configuration command procedure completes. Set shadowing parameters in the satellite node's MODPARAMS.DAT file and execute AUTOGEN as described in Section 3.2 and in Section 3.3.1.

Figure 3–1 shows two satellite nodes with shadowed system disk volumes located in an OpenVMS Cluster system configuration. In this configuration, the devices $254$DUA1 and $254$DUA2 make up a two-member shadow set. The satellites HIWAY1 and BYWAY2 access shadow set members across the Ethernet via the MSCP servers in the two boot nodes.

Figure 3–1 Booting Satellite Nodes



VM-0658A-AI

When a satellite node in Figure 3–1 is booted, the boot node (MOP server) downline loads initial bootstrap code from the virtual unit DSA1. The boot node points the satellite to use either $254$DUA1 or $254$DUA2 as a boot device for the remainder of the boot process. Note that the boot node must have the virtual unit mounted. The satellite then forms the system disk shadow set locally according to the shadow set membership information stored in the SCB on the boot device.

The following SHOW DEVICES command displays how the shadow set appears after the satellite node HIWAY1 is booted. In this example, the physical disk devices are accessed through the MSCP server node BTNODE.

```
$ SHOW DEVICES DSA1

Device                Device           Error   Volume    Free   Trans Mnt
Name                  Status           Count   Label     Blocks Count Cnt
DSA1:                 Mounted            0     MYVOLUME  181779   194  37
$254$DUA1:  (BTNODE)  ShadowSetMember    0     (member of DSA1:)
$254$DUA2:  (BTNODE)  ShadowSetMember    0     (member of DSA1:)
$
```

3.6 Creating and Managing Shadow Sets

You can create, mount, and manage shadow sets interactively at the DCL command level, or in user-written programs:

- At the DCL command level, you can use the MOUNT command to create and add members to shadow sets, and the commands SHOW DEVICES and DISMOUNT to display and remove them. Also you may use the lexical function F$GETDVI to access information about shadow set devices. These commands are described in Chapter 4.
- In application programs, you can use the system service routine $MOUNT to create and add members to shadow sets, and $GETDVI and $DISMOU to display and remove them. These system services are described in Chapter 5.

4
Creating and Managing Shadow Sets Using DCL Commands

This chapter describes how to create, mount, dismount, and **dissolve** shadow sets using interactive DCL commands. It also describes how to use the DCL command SET DEVICE to specify management attributes for shadow set members located at different sites in a multiple-site OpenVMS Cluster system. In addition, it describes how to use the DCL command SHOW DEVICE and the lexical function F$GETDVI to access current information about the state of shadow sets.

Volume Shadowing for OpenVMS improves data availability by ensuring that corresponding logical block numbers (LBNs) on multiple disk volumes contain the same information. Upon receiving a command to mount or dismount disks in a shadow set, the volume shadowing software may need to reconcile data differences and ensure that corresponding LBNs contain the same information.

An understanding of the copy and merge operations used for data reconciliation is essential to the discussions in this chapter. Therefore, you may find it helpful to refer to Chapter 6 to understand how Volume Shadowing for OpenVMS ensures data availability and consistency during changes in shadow set membership.

4.1 Allocating Devices

To avoid the possibility of another user mounting a particular device before you enter the MOUNT command, you can optionally allocate the device before issuing the MOUNT command. Use the DCL command ALLOCATE to provide your process with exclusive access to a physical device until you either deallocate the device or terminate your process. Optionally, you can associate a logical name with the device. The format for the ALLOCATE command is as follows:

ALLOCATE device-name[:] logical-name[:]

4.2 Creating a Shadow Set

To create a shadow set, you must use the MOUNT command with the /SHADOW qualifier to mount at least one physical disk into a shadow set and assign a virtual unit name to the set, as shown in Example 4–1.

Example 4–1 Creating a Shadow Set

```
$  MOUNT DSA23:❶ /SHADOW❷ =$4$DUA9:❸ volume-label❹ logical-name❺
```

This example forms a shadow set represented by the virtual unit DSA23, and includes one shadow set member, $4$DUA9.

❶ You must use the DSA*n*: format to specify the shadow set virtual unit, where *n* represents a unique number from 0 through 9999. The prefix DSA indicates that phase II shadowing is being used. If you do not include a number after the DSA prefix, MOUNT automatically assigns the highest unit number available. Numbering starts at 9999 and decrements to 0; the first virtual unit mounted is numbered 9999, the second 9998, and so on.

Each virtual unit number must be unique across the system, regardless of whether or not the unit is mounted for public (mounted with the /SYSTEM qualifier) or private access. Virtual units are named independently of the controllers involved.

❷ The /SHADOW qualifier is required when specifying a physical device. You must name at least one physical device as a parameter to the /SHADOW qualifier. Although one-member shadow sets are valid, you should mount one or two additional disks in order for the shadowing software to maintain duplicate data. Adding disks to an existing shadow set is discussed in Section 4.5.

❸ You must use a nonzero allocation class for each physical device in the shadow set. Use the allocation class naming format $*allocation-class*$*ddcu*, where:

- *allocation-class* is a numeric value from 1 to 255.
- *dd* describes the device type of the physical device (for example, DU, DK, or DG).
- *c* is a letter from A to Z that represents the controller designation.
- *u* is the unit number of the device.

See *OpenVMS Cluster Systems* for more information about allocation classes.

❹ Specify a 1- to 12-character volume label for the virtual unit.

❺ Optionally, specify a 1- to 255-alphanumeric-character logical name string for the shadow set.

In addition, you can specify /SYSTEM, /GROUP, or /CLUSTER to make the shadow set available to all users of a system, all members of a group, or all nodes in a cluster on which shadowing is enabled.

To create a three-member shadow set, you can add two members in a single MOUNT command to an existing one-member shadow set. This method optimizes the I/O operation because both members are copied at the same time. (See the example in Section 4.4.4.)

You can also streamline the process of creating a shadow set by initialized multiple devices in one command, using INITIALIZE/SHADOW/ERASE, as described in Section 4.3.

Upon receiving a command to create a shadow set, the volume shadowing software may perform a copy or a merge operation to reconcile data differences. If you are not sure which disks might be targets of copy operations, you can specify the /CONFIRM or /NOCOPY qualifiers as a precaution against overwriting important data when you mount a disk. These and other MOUNT command qualifiers are discussed in Section 4.4.

4.3 Using INITIALIZE/SHADOW/ERASE to Streamline the Formation of a Shadow Set

You can use the DCL command INITIALIZE with the /SHADOW and /ERASE command qualifiers to initialize multiple members of a a future shadow set. Initializing multiple members in this way eliminates the requirement of a full copy when you later create a shadow set.

The INITIALIZE command with the /SHADOW and /ERASE qualifiers performs the following operations:

- Formats up to six devices with one command, so that any three can be subsequently mounted together as members of a new host-based shadow set
- Writes a label on each volume
- Deletes all information from the devices except for the system files containing identical file structure information.

  All former contents of the disks are lost.

You can then mount up to three of the devices that you have initialized in this way as members of a new host-based shadow set.

Compaq strongly recommends that you use the /ERASE qualifier. By using the /ERASE qualifier, no merge operation is required when you create the shadow set with the MOUNT command.

All the devices must have identical, nonzero values for `Total Blocks`. You can view the `Total Blocks` value by entering the SHOW DEVICE/FULL command. If a device has never been mounted or initialized on this system, the SHOW DEVICE/FULL command for the device will not display a value for `Total Blocks`. To correct this condition, either mount and then dismount the device, or initialize the device. The `Total Blocks` value will then be displayed by SHOW DEVICE/FULL.

The use of INITIALIZE/SHADOW requires the VOLPRO privilege.

Note that the INITIALIZE/SHADOW command should not be used to initialize a disk to be added to an *existing* shadow set, since there is no benefit to be gained.

The format of this command follows:

INITIALIZE/SHADOW=(*device_name1, device_name2, device_name3*) *label*

The following example shows *correct* use of this command. Note that the command specifies multiple devices on the same line.

```
$ INITIALIZE /ERASE /SHADOW=($4$MDA1300, $4$MDA1301) VOLATILE
```

```
$ MOUN/SYS DSA42 /SHAD=( $4$MDA1300 , $4$MDA1301 ) VOLATILE
%MOUNT-I-MOUNTED, VOLATILE MOUNTED ON _DSA42:
%MOUNT-I-SHDWMEMSUCC, _$4$MDA1300: (WILD3) IS NOW A VALID MEMBER OF THE SHADOW SET
%MOUNT-I-SHDWMEMSUCC, _$4$MDA1301: (WILD4) IS NOW A VALID MEMBER OF THE SHADOW SET
$ SHO DEV DSA42:

DEVICE               DEVICE           ERROR    VOLUME         FREE  TRANS MNT
 NAME                STATUS           COUNT     LABEL        BLOCKS COUNT CNT
DSA42:               MOUNTED              0  VOLATILE      5799600     1   1
$4$MDA1300: (WILD3)  SHADOWSETMEMBER      0  (MEMBER OF DSA42:)
$4$MDA1301: (WILD4)  SHADOWSETMEMBER      0  (MEMBER OF DSA42:)
```

The following example shows *incorrect* use of this command. Do not use a separate command to initialize each device.

```
$ INITIALIZE /ERASE /SHADOW=  $4$MDA1300 VOLATILE
$ INITIALIZE /ERASE /SHADOW=  $4$MDA1301 VOLATILE

$ MOUN/SYS DSA42 /SHAD=( $4$MDA1300 , $4$MDA1301 ) VOLATILE
%MOUNT-I-MOUNTED, VOLATILE MOUNTED ON _DSA42:
%MOUNT-I-SHDWMEMSUCC, _$4$MDA1300: (WILD3) IS NOW A VALID MEMBER OF THE SHADOW SET
%MOUNT-I-SHDWMEMSUCC, _$4$MDA1301: (WILD4) IS NOW A VALID MEMBER OF THE SHADOW SET
$ SHO DEV DSA42:

DEVICE               DEVICE           ERROR    VOLUME         FREE  TRANS MNT
 NAME                STATUS           COUNT     LABEL        BLOCKS COUNT CNT
DSA42:               MOUNTED              0  VOLATILE       5799600     1   1
$4$MDA1300:    (WILD3)  ShadowSetMember      0  (member of DSA42:)
$4$MDA1301:    (WILD4)  ShadowCopying        0  (copy trgt DSA42:   0% copied)
```

If you omit the /ERASE qualifier, then the portions of the volume that do not contain file system data structures will contain indeterminate data. This data can differ from one shadow set member to another. Make sure to take this into account when using utilities that compare all of the LBNs between shadow set members.

The next time a full merge operation occurs, the presence of this indeterminate data will cause the merge to take much longer than it would have without use of the INITIALIZE/SHADOW/ERASE command. When this full merge completes, the LBNs will contain identical data, and the storage control block (SCB) will no longer indicate that the /ERASE qualifier was omitted from the INITIALIZE/SHADOW command.

4.4 MOUNT Command Qualifiers for Shadowing

This section briefly describes the MOUNT command qualifiers that are useful for shadow set management. Refer also to the *OpenVMS System Management Utilities Reference Manual* for complete information about these and other DCL commands.

You must use the /SHADOW qualifier when you create a new shadow set or when you add a member to an existing shadow set. You can also use the optional qualifiers described in Table 4–1 and in Table 4–2. These qualifiers require the VOLPRO and OPER privileges, or your user identification code (UIC) must match the owner UIC of the volume being mounted. To mount a shadow set throughout the system, you must also have the SYSNAM privilege.

Detailed examples and descriptions of how to use these qualifiers are included in Section 4.5. In addition to the shadowing-specific qualifiers described in Table 4–1, the /NOASSIST, /SYSTEM, /GROUP, and /CLUSTER qualifiers are also frequently used when mounting shadow sets, as described in Table 4–2 and in Section 4.4.2.

4.4.1 MOUNT Command Qualifiers Specific to Shadowing

The MOUNT command qualifiers described in Table 4–1 are specific to shadowing.

Table 4–1 MOUNT Command Qualifiers (Shadowing Specific)

Qualifier	Function
/[NO]CONFIRM	Controls whether the Mount utility issues a request to confirm a copy operation when mounting a shadow set. The default is /NOCONFIRM.
/[NO]COPY	Enables or disables copy operations on physical devices named when mounting or adding to a shadow set. The default is /COPY.
/[NO]INCLUDE	Automatically mounts and reinstates a shadow set to the way it was before the shadow set was dissolved. The default is /NOINCLUDE.
/OVERRIDE=NO_ FORCED_ERROR	Directs the Mount utility to proceed with shadowing, even though the device or controller does not support forced error handling. Using unsupported SCSI disks can cause members to be removed from a shadow set if certain error conditions arise that cannot be corrected, because some SCSI disks do not implement READL and WRITEL commands that support disk bad-block repair. If the SCSI device does not support READL and WRITEL commands, the SCSI disk class driver sets a NOFE (no forced error) bit in a System Dump Analyzer display. See Section 4.9.4.1 for more information.
/OVERRIDE=SHADOW_ MEMBERSHIP	Mounts a former shadow set member and zeroes the disk's shadow set generation number so that the disk is no longer marked as having been a member of the shadow set.

(continued on next page)

Table 4–1 (Cont.) MOUNT Command Qualifiers (Shadowing Specific)

Qualifier	Function
/POLICY= [NO]MINICOPY [=OPTIONAL]	Controls the setup and use of the shadowing minicopy function. The meaning of [NO]MINICOPY[=OPTIONAL] depends on the status of the shadow set. If the shadow set is not mounted, either on a standalone system or on any cluster member, and MINICOPY=OPTIONAL is specified, the shadow set is mounted and a write bitmap is created. (A write bitmap enables a shadowing minicopy operation.) MOUNT/POLICY=MINICOPY[=OPTIONAL] must be specified on the initial mount of a shadow set, either on a standalone system or in a cluster, to enable the shadowing minicopy operation. The OPTIONAL keyword allows the mount to continue, even if the system was unable to start the write bitmap. A bitmap could fail to start properly because of an improperly dismounted shadow set, a shadow set that requires a merge operation, or various resource problems. If the OPTIONAL keyword is omitted and the system is unable to start the write bitmap, the shadow set will not be mounted. If you specify /POLICY=MINICOPY=OPTIONAL and the shadow set was already mounted on another node in the cluster without this qualifier and keyword, the MOUNT command will succeed but a write bitmap will not be created. If NOMINICOPY is specified, the shadow set will be mounted but a write bitmap will not be created. If a former member of the the shadow set is returned to the shadow set, which has minicopy enabled, then a minicopy is started instead of a full copy. This is the default behavior and will occur even if you omit /POLICY=MINICOPY[=OPTIONAL]. If a minicopy successfully starts and then fails for some reason, a full copy will be performed. If a minicopy cannot be started and the keyword OPTIONAL was omitted, the mount will fail. If NOMINICOPY is specified, then a minicopy will not be performed, even if one is possible.
/POLICY=REQUIRE_ MEMBERS	Controls whether every physical device specified with the /SHADOW qualifier must be accessible when the MOUNT command is issued in order for the MOUNT command to take effect. The proposed members are either specified in the command line or found on the disk by means of the /INCLUDE qualifier. The default behavior is that if one or more members is not accessible for any reason (such as a connectivity failure), then the virtual unit will be created with the remaining members. This option is especially useful in disaster-tolerant clusters because it ensures that the correct member is selected as the master member after an event.

(continued on next page)

Table 4–1 (Cont.) MOUNT Command Qualifiers (Shadowing Specific)

Qualifier	Function
/POLICY=VERIFY_LABEL	Requires that any member to be added to the shadow set have a volume label of SCRATCH_DISK. This helps ensure that the wrong disk is not added to a shadow set by mistake. If you plan to use VERIFY_LABEL, then before using this qualifier you must either initialize the disk to be added to the set with the label SCRATCH_DISK, or specify a label for the disk with the command SET VOLUME/LABEL. The default behavior is NOVERIFY_LABEL, which means that the volume label of the copy targets will not be checked. This is the same behavior that occurred before the introduction of this qualifier. The volume label of the copy targets will not be checked.
/SHADOW=(*physical-device-name*[:][, . . .])	Directs the Mount utility to bind the specified physical devices into a shadow set represented by the virtual unit named in the command.

Caution

Do not use the /OVERRIDE=IDENTIFICATION or /NOMOUNT_VERIFICATION qualifiers when mounting shadow sets. Using either of these qualifiers can result in loss of data.

If you mount a shadow set with the /OVERRIDE=IDENTIFICATION qualifier, individual shadow set members start with different volume labels, which can cause a volume to lose data.

If you specify the /NOMOUNT_VERIFICATION qualifier, the shadow set becomes unusable at the first state change of the shadow set.

4.4.2 Additional MOUNT Command Qualifiers Used for Shadowing

The MOUNT command qualifiers described in this section are not specific to shadowing but can be very useful when creating shadow sets. These additional qualifiers are described in Table 4–2 and in the examples that follow.

Table 4–2 Additional MOUNT Command Qualifiers (Not Shadowing Specific)

Qualifier	Function
/NOASSIST	Successfully mounts a shadow set if at least one of the devices included in the MOUNT command is available for mounting. If the command does not include the /NOASSIST qualifier, and a device included in the MOUNT command is not available for mounting, the MOUNT command will mount the shadow set.
/SYSTEM	Makes the volume available to all users on the system. Use this qualifier when you add a disk to an existing shadow set. If the /CLUSTER qualifier was used when the shadow set was created, the use of /SYSTEM will make the new member of the shadow set available to all nodes in the cluster that already have the shadow set mounted.

(continued on next page)

Table 4–2 (Cont.) Additional MOUNT Command Qualifiers (Not Shadowing Specific)

Qualifier	Function
/GROUP	Makes the volume available to all users with the same group number in their UICs as the user entering the MOUNT command. You must have GRPNAM and SYSNAM user privileges to mount group and system volumes.
/CLUSTER	Creates the virtual unit automatically on every node in the cluster on which shadowing is enabled. Use this qualifier if the shadow set is to be accessed across the cluster. You must have the SYSNAM privilege to use this qualifier. Using /CLUSTER automatically includes the /SYSTEM qualifier, making the shadow set available to all users on the system.

4.4.3 Creating a Shadow Set With /NOASSIST

You may occasionally find it useful to specify the /NOASSIST qualifier on the MOUNT command. For example, you can use the MOUNT/NOASSIST command in startup files to avoid failure of a MOUNT command when a device you specify in the command is not available. The /NOASSIST qualifier can be used in startup files because operator intervention is impossible during startup.

The MOUNT/NOASSIST qualifier can successfully mount the shadow set as long as at least one of the devices included in the MOUNT command is available for mounting. Example 4–2 shows an example of the /NOASSIST qualifier and the resulting messages when one of the members included in the command is not available for mounting.

Example 4–2 Using the /NOASSIST Qualifier

```
$ MOUNT/SYS DSA65:/SHADOW=($4$DIA6,$4$DIA5) GALEXY/NOASSIST
%MOUNT-I-MOUNTED, GALEXY mounted on _DSA65:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA6: (READY) is now a valid member of the shadowset
%MOUNT-I-SHDWMEMFAIL, $4$DIA5 failed as a member of the shadow set
-SYSTEM-F-VOLINV, volume is not software enabled
```

Even though device $4$DIA5 is not available for mounting, the MOUNT command continues to create the shadow set with $4$DIA6 as its only member. If the command did not include the /NOASSIST qualifier, the MOUNT command would not mount the shadow set.

4.4.4 Creating a Shadow Set With /SYSTEM and With /CLUSTER

When you create a shadow set, you must specify either the /SYSTEM qualifier or the /CLUSTER qualifier, or both (see Table 4–2) to provide access for all users on a single system or on a cluster.

In Example 4–3, if the shadow set (identified by its virtual unit name DSA2) is not currently mounted, the first command creates a shadow set with one shadow set member; the second command adds two more members to the *same* shadow set. An automatic copy operation causes any data on the second and third volumes to be overwritten as the shadow set members are added.

In the second MOUNT command, you need only specify the /SYSTEM when you add the $6$DIA5 and $6$DIA6 devices to the shadow set. Do not use /CLUSTER. These disks are added with the same status that the shadow set currently has, which in this case is clusterwide access.

Example 4–3 Using the /CLUSTER Qualifier

```
$ MOUNT DSA2: /CLUSTER /SHADOW=$6$DIA4: PEAKSISLAND DISK$PEAKSISLAND

$ MOUNT DSA2: /SYSTEM/SHADOW=($6$DIA5:,$6$DIA6:) PEAKSISLAND DISK$PEAKSISLAND
```

4.5 Adding Shadow Set Members

Once a shadow set is created, you can add and remove individual members by mounting or dismounting physical disk devices. The shadowing software allows you to add and remove shadow set members at any time, transparently to user processes or applications running on the system.

4.5.1 Adding a Disk to an Existing Shadow Set

Example 4–4 shows how to add the disk $4$DUA3 to the DSA23 shadow set.

Example 4–4 Adding a Disk to an Existing Shadow Set

```
$  MOUNT/CONFIRM/SYSTEM DSA23: /SHADOW=($4$DUA9,$4$DUA3) volume-label
```

The command in Example 4–4 specifies both the currently active shadow set member ($4$DUA9) and the new member ($4$DUA3). Although it is not necessary to include them when mounting additional physical devices, you can specify current shadow set members without affecting their membership state.

Note that when you add volumes to an existing shadow set mounted across an OpenVMS Cluster system, the shadowing software automatically adds the new members on each OpenVMS Cluster node.

4.5.2 Creating a Two-Member Shadow Set and Adding a Third Member

Example 4–5 shows two commands. The first command creates the shadow set with two members; the next adds a third member to that shadow set.

Example 4–5 Creating a Shadow Set and Adding Third Member

```
$ MOUNT/SYSTEM DSA4: /SHADOW = ($3$DIA7:, $3$DIA8:)
FORMERSELF❶
%MOUNT-I-MOUNTED, FORMERSELF   mounted on DSA4:
%MOUNT-I-SHDWMEMSUCC, _$3$DIA7: (DISK300) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$3$DIA8: (DISK301) is now a valid member of
                      the shadow set

$ MOUNT/SYSTEM DSA4: /SHADOW = $3$DIA6:  FORMERSELF❷

%MOUNT-I-SHDWMEMCOPY, _$3$DIA6: (DISK302) added to the shadow set
                      with a copy operation
```

❶ A shadow set is created whose virtual unit name is DSA4. The member disks are $3$DIA7 and $3DIA8.

❷ The disk $3$DIA6 is mounted systemwide in the shadow set identified by virtual unit DSA4. The shadow set now includes three shadow set members: $3$DIA6, $3$DIA7, and $3$DIA8. In this example, when you add $3$DIA6 after the shadow set already exists, the added volume becomes the target of a copy operation.

4.5.3 Checking Status of Potential Shadow Set Members With /CONFIRM

When you add a disk to an existing shadow set, a copy operation is necessary. Volume shadowing automatically performs the copy operation, unless you use the /CONFIRM qualifier or the /NOCOPY qualifier. When you specify the /CONFIRM qualifier, as shown in Example 4–6, the MOUNT command displays the targets of copy operations and requests permission before the operations are performed. This precaution prevents the erasing important data. For more information about copy operations, see Chapter 6.

Example 4–6 Using the /CONFIRM Qualifier

```
$ MOUNT/CONFIRM DSA23: /SHADOW=($1$DUA4:,$1$DUA6:) SHADOWVOL ❶

%MOUNT-F-SHDWCOPYREQ, shadow copy required
Virtual Unit - DSA23 Volume Label - SHADOWVOL ❷
     Member                    Volume Label Owner UIC ❸
     $1$DUA6: (LOVE)           SCRATCH      [100,100]
Allow FULL shadow copy on the above member(s)? [N]: NO ❹
$
```

❶ This command instructs MOUNT to build a shadow set with the specified devices and to prompt for permission to perform any copy operations.

❷ Because a copy operation is necessary, the virtual unit name and the volume label are displayed.

❸ The display also includes the physical device name, the volume label, and the volume owner of the potential shadow set member that requires the copy operation.

❹ A response of No causes MOUNT to quit without mounting or copying.

4.5.4 Checking Status of Potential Shadow Set Members With /NOCOPY

When you specify more than one disk, the shadowing software automatically determines the correct copy operation to perform in order to make shadow set members consistent with each other (see Section 6.2 for details). The Mount utility interprets information recorded on each member to determine whether a member requires a copy operation, a merge operation, or no copy operation. If you are not sure which disks might be targets of copy operations, you can specify the /CONFIRM qualifier or the /NOCOPY qualifier as a precaution against overwriting important data when you mount a disk. With the /NOCOPY qualifier, you disable the copy operation.

Example 4–7 shows how to use the /NOCOPY qualifier to check the status of potential shadow set members before any data is erased.

Example 4–7 Using the /NOCOPY Qualifier

```
$ MOUNT/NOCOPY DSA2: /SHADOW=($1$DUA4:,$1$DUA6:,$1$DUA7:) -
_$ SHADOWVOL DISK$SHADOWVOL ❶

%MOUNT-F-SHDWCOPYREQ, shadow copy required
%MOUNT-I-SHDWMEMFAIL, DUA7: failed as a member of the shadow set
%MOUNT-F-SHDWCOPYREQ, shadow copy required ❷
```

(continued on next page)

Example 4–7 (Cont.) Using the /NOCOPY Qualifier

```
$  MOUNT/COPY❸ DSA2: /SHADOW=($1$DUA4:,$1$DUA6:,$1$DUA7:) -
_$ SHADOWVOL DISK$SHADOWVOL

%MOUNT-I-MOUNTED, SHADOWVOL    mounted on _DSA2:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA4: (VOLUME001) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA6: (VOLUME002) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA7: (VOLUME003) added to the shadow set
                      with a copy operation ❹
```

❶ This command instructs MOUNT to build a shadow set, with the specified devices, but only if a copy or merge operation is not required.

❷ MOUNT did not build the shadow set because the specified disk, loaded on device $1$DUA7, required a copy operation. At this point you can verify that the volume in device $1$DUA7 does not contain any useful data.

❸ If the device does not contain valuable data, you can reenter the MOUNT command and include the /COPY qualifier. This command instructs MOUNT to mount a shadow set and to proceed with the necessary copy or merge operation.

❹ The shadow set is successfully mounted. The $1$DUA7 device is currently the target of a copy operation; it will attain full shadow set membership when the copy operation completes.

4.6 Mounting a Shadow Set on Other Nodes in the Cluster

If a shadow set is already mounted on one or more nodes in an OpenVMS Cluster system, the /SHADOW qualifier is not required when you mount the same shadow set on other nodes in the cluster. For example, if DSA42 is already mounted in the cluster when a new node is brought into the cluster, you can use the following command to mount DSA42 on the new node:

```
$ MOUNT/SYS DSA42:  volume-label logical-name
```

Upon receiving this command, the volume shadowing software creates the virtual unit on the new node with the same members that currently exist in the cluster.

4.6.1 Reconstructing a Shadow Set With /INCLUDE

Example 4–8 shows how to reconstruct a shadow set. The volume shadowing software determines which disk volumes are former members of the shadow set.

Example 4–8 Reconstructing Shadow Sets With /INCLUDE

```
$ MOUNT /SYSTEM DSA4/SHAD=($4$DIA1,$4$DIA2,$4$DIA3) NEWDISK❶
%MOUNT-I-MOUNTED, NEWDISK   mounted on _DSA4:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA1: (DISK01) is now a valid member
                          of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$4$DIA2: (DISK02) added to the shadow set
                          with a copy operation
%MOUNT-I-SHDWMEMCOPY, _$4$DIA3: (DISK03) added to the shadow set
                          with a copy operation
$ DISMOUNT DSA4❷
$
$ MOUNT DSA4:/SYSTEM/SHAD=$4$DIA1 NEWDISK/INCLUDE❸
%MOUNT-I-MOUNTED, NEWDISK   mounted on _DSA4:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA1: (DISK01) is now a valid member ❹
                          of the shadow set
%MOUNT-I-AUTOMEMCOPY, _$4$DIA2: (DISK02) automatically added ❹
                          to the shadow set
%MOUNT-I-AUTOMEMCOPY, _$4$DIA3: (DISK03) automatically added ❹
                          to the shadow set
```

❶ This is the original MOUNT command that created the shadow set represented by DSA4. The shadow set consists of three shadow set members: $4$DIA1, $4$DIA2, and $4$DIA3.

❷ After all copy operations have completed, the DISMOUNT command dissolves the shadow set.

❸ The /INCLUDE qualifier triggers the MOUNT command to reconstruct the shadow set back to the way it was before the shadow set was dissolved. The MOUNT command must specify the original virtual unit name (DSA4) and at least one of the original shadow set members ($4$DIA1). The Mount utility reads the membership list on $4$DIA1 (specified in the MOUNT command) to determine that $4$DIA2 and $4$DIA3 are also members of the shadow set.

❹ Because the shadow set was properly dismounted, the shadow set members are in a consistent state. The MOUNT status messages indicate that the shadow set devices are added back into the shadow set without the need for copy operations.

4.6.2 Mounting a Former Shadow Set Member as a Nonshadowed Disk

Occasionally, you will need to mount a physical shadow set member as a nonshadowed disk. By default, when a shadow set member is mounted outside a shadow set, the Mount utility automatically write-locks the disk. This provides a safeguard against accidental modification, thereby allowing the disk to be remounted into a shadow set at a later time.

To override this default behavior, include the /OVERRIDE=SHADOW_MEMBERSHIP qualifier on the MOUNT command as shown in the following example:

```
$ MOUNT/OVERRIDE=SHADOW_MEMBERSHIP $4$DUA20: WORKDISK
```

This command ignores shadow set membership status and mounts a former shadow set member on $4$DUA20 as a nonshadowed disk with write access.

4.7 Specifying Disaster-Tolerant Management Attributes (Alpha Only)

Starting with OpenVMS Alpha Version 7.3, qualifiers to the DCL command SET DEVICE are provided for specifying management attributes for shadow set members located at different sites. By using these qualifiers, system managers can override the default volume shadowing actions that can occur when the systems at one site of a disaster-tolerant OpenVMS Cluster configuration fail. These qualifiers are designed primarily for use in a configuration that uses Fibre Channel for a site-to-site storage interconnect. They can be used in other configurations as well.

Similarly, the DCL command DISMOUNT has been enhanced by the addition of the qualifier /FORCE_REMOVAL *ddcu:*. This qualifier has been added for the same purpose—to give system managers greater control of shadow set members located at different sites. For more information about this qualifier, see Section 4.8.1.

Table 4–3 SET DEVICE Command Qualifiers for Multiple-Site Shadow Set Members

Qualifier	Function
/FORCE_ REMOVAL *ddcu:*	If connectivity to a device has been lost and the shadow set is in mount verification, this qualifier causes the member to be expelled from the shadow set immediately. If the shadow set is not currently in mount verification, no immediate action is taken. If connectivity to a device has been lost but the shadow set is not in mount verification, this qualifier lets you flag the member to be expelled from the shadow set, as soon as it does enter mount verification. The device specified must be a member of a shadow set that is mounted on the node where the command is issued.
/MEMBER_ TIMEOUT = *xxxxxx ddcu:*	Specifies the timeout value to be used for a member of a shadow set. The value supplied by this qualifier overrides the SYSGEN parameter SHADOW_MBR_TMO for this specific device. Each member of a shadow set can be assigned a different MEMBER_TIMEOUT value. The valid range for *xxxxxx* is 1 to 16,777,215 seconds. The device specified must be a member of a shadow set that is mounted on the node where the command is issued. After you have applied this qualifier to a member, the setting remains in effect as long as the member is part of the shadow set. If the member is removed from the shadow set and later returned, this qualifier must be specified again.

(continued on next page)

Table 4–3 (Cont.) SET DEVICE Command Qualifiers for Multiple-Site Shadow Set Members

Qualifier	Function
/MVTIMEOUT = *yyyyyy* DSA*nnnn*:	Specifies the mount verification timeout value to be used for this shadow set, specified by its virtual unit name, DSA*nnnn*. The value supplied by this qualifier overrides the SYSGEN parameter MVTIMEOUT for this specific shadow set. The valid range for *yyyyyy* is 1 to 16,777,215 seconds. The device specified must be a shadow set that is mounted on the node where the command is issued. After you have applied this qualifier, the setting remains in effect as long as the shadow set is mounted. If the shadow set is dismounted and later remounted, this qualifier must be specified again
/READ_COST = *zzz ddcu:*	The valid range for *zzz* is 1 to 65,535 units. The device specified must be a member of a shadow set that is mounted on the node where the command is issued. This qualifier enables you to modify the default “cost” assigned to each member of a shadow set. By modifying the assignments, you can bias the reads in favor of one member of a two-member shadow set, or, in the case of three-member shadow sets, in favor of one or two members of the set over the remaining members. The shadowing driver assigns default READ_COST values to shadow set members when each member is initially mounted. The default value depends on the device type and its configuration relative to the system mounting it. There are default values for a DECRAM device; a directly connected device in the same physical location; a directly connected device in a remote location; a DECram served device; and a default value for other served devices. The value supplied by this qualifier overrides the default assignment. The shadowing driver adds the value of the current queue depth of the shadow set member to the READ_COST value and then reads from the member with the lowest value. After you have applied this qualifier to a member, the setting remains in effect as long as the member is part of the shadow set. If the member is removed from the shadow set and later returned, this qualifier must be specified again. Different systems in the cluster can assign different costs to each shadow set member. If the /SITE command qualifier has been specified, the shadowing driver will take site values into account when it assigns default READ_COST values. Note that in order for the shadowing software to determine whether a device is in the category of “directly connected device in a remote location,” the /SITE command qualifier must have been applied to both the shadow set and the DSA device. Reads requested for a shadow set from a system at site 1 are performed from a shadow set member that is also at site 1. Reads requested for the same shadow set from site 2 can read from the member located at site 2.
/READ_COST = *y* DSA*nnnn*	The valid range for *y* is *any* nonzero number. The value supplied has no inherent meaning. The purpose of this qualifier is to switch the read cost setting for all shadow set members back to the default read cost settings established automatically by the shadowing software. DSA*nnnn* must be a shadow set that is mounted on the node from which this command is issued.

(continued on next page)

Table 4–3 (Cont.) SET DEVICE Command Qualifiers for Multiple-Site Shadow Set Members

Qualifier	Function

/SITE = (*nnn*, *logical_name*) (*ddcu*: DSA*nnnn*:)	This qualifier indicates to the shadowing driver the site location of the shadow set member or of the shadow set (represented by its virtual unit name). Prior to using this qualifier, you can define the site location in the SYLOGICALS.COM command procedure to simplify its use.
	The valid range for *nnn* is 1 through 255.
	After you have applied this qualifier, the setting remains in effect as long as the member is part of the shadow set. If the member is removed from the shadow set and later returned, this qualifier must be specified again
	The following example shows the site locations defined, followed by the use of the /SITE qualifier:
	`$ DEFINE/SYSTEM/EXEC ZKO 1`
	`$ DEFINE/SYSTEM/EXEC LKG 2`
	`$!`
	`$! At the ZKO site ...`
	`$ MOUNT/SYSTEM DSA0/SHAD=($1$DGA0:,$1$DGA1:) TEST`
	`$ SET DEVICE/SITE=ZKO  DSA0:`
	`$!`
	`$! At the LKG site ...`
	`$ MOUNT/SYSTEM DSA0/SHAD=($1$DGA0,$1$DGA1) TEST`
	`$ SET DEVICE/SITE=LKG  DSA0:`
	`$!`
	`$! At both sites, the following would be used:`
	`$ SET DEVICE/SITE=ZKO  $1$DGA0:`
	`$ SET DEVICE/SITE=LKG  $1$DGA1:`

/COPY_SOURCE (*ddcu*:, DSA*nnnn*:)	Controls whether one or both source members of a shadow set are used as the source for read data during full copy operations, when a third member is added to the shadow set. This only affects copy operations that do not use DCD operations. HSG80 controllers have a read-ahead cache, which significantly improves single-disk read performance. Copy operations normally alternate reads between the two source members, which effectively nullifies the benefits of the read-ahead cache. This qualifier lets you force all reads from a single source member for a copy operation. If the shadow set is specified, then all reads for full copy operations will be performed from whichever disk is the current “master” member, regardless of physical location of the disk. If a member of the shadow set is specified, then that member will be used as the source of all copy operations. This allows you to choose a local source member, rather than a remote master member.
/ABORT_VIRTUAL_UNIT DSA*nnnn*:	To use this qualifier, the shadow set must be in mount verification. When you specify this qualifier, the shadow set aborts mount verification immediately on the node from which the qualifier is issued. This qualifier is intended to be used when it is known that the unit cannot be recovered. Note that after this command completes, the shadow set must still be dismounted. Use the following command to dismount the shadow set: `$ DISMOUNT/ABORT   DSAnnnn`

4.8 Removing Members and Dissolving Shadow Sets

You can remove shadow set members and dissolve shadow sets with the DCL command DISMOUNT. You must have GRPNAM and SYSNAM user privileges to dismount group and system volumes. The DISMOUNT command has the following format:

DISMOUNT {device-name[:] virtual-unit-name}

The action taken differs depending on whether you specify an individual shadow set member or the shadow set (by its virtual unit name) on the DISMOUNT command:

- If you specify the device name of a shadow set member, only that member is dismounted, and the remaining shadow set members continue servicing I/O requests.
- If you specify a shadow set virtual unit, all shadow set members are dismounted and the shadow set is dissolved.

To dismount a shadow set that is mounted across an OpenVMS Cluster system, include the /CLUSTER qualifier with the DISMOUNT command. If you dismount a shadow set without including the /CLUSTER qualifier, only the node from which you issued the command dismounts the shadow set. The shadow set remains operational on the other OpenVMS Cluster nodes that have the shadow set mounted.

If the disks on your system are neither SCSI nor Fibre Channel disks, you can use the /NOUNLOAD qualifier on the DISMOUNT command to prevent the disk volume or volumes from spinning down. The devices remain in a ready state. If you specify the /UNLOAD qualifier when dismounting a virtual unit, the disk volumes are physically spun down *after* the shadow set is dissolved. See the *OpenVMS DCL Dictionary* for more information about using the DISMOUNT command and its qualifiers.

4.8.1 Removing Members from Shadow Sets

To remove an individual member from a shadow set, specify the name of the physical device with the DISMOUNT command. For example:

```
$ DISMOUNT $5$DUA7:
```

When you dismount an individual shadow set member, all outstanding I/O operations are completed and the member is removed from the set.

Starting with OpenVMS Alpha Version 7.3, the /FORCE_REMOVAL *ddcu:* qualifier is available. If connectivity to a device has been lost and the shadow set is in mount verification, `/FORCE_REMOVAL` *`ddcu:`* can be used to immediately expel a named shadow set member (*ddcu:*) from the shadow set. If you omit this qualifier, the device is not dismounted until mount verification completes. Note that this qualifier cannot be used in conjunction with the /POLICY=MINICOPY (=OPTIONAL) qualifier.

The device specified must be a member of a shadow set that is mounted on the node where the command is issued.

This qualifier gives system managers greater control of shadow sets whose members are located at different sites in an OpenVMS Cluster configuration. SET DEVICE command qualifiers are also available for specifying disaster-tolerant management attributes for shadow set members, as described in Section 4.7.

Note

You cannot dismount a device if it is the only source member in a shadow set. All shadow sets must have at least one valid source member. If you try to dismount the only source member device, the DISMOUNT command fails and returns the message:

```
%DISM-F-SRCMEM, Only source member of shadow set cannot be dismounted
```

The only way to dismount the last source member of a shadow set is to dissolve the shadow set by specifying the virtual unit name on the DISMOUNT command.

4.8.2 Dissolving Shadow Sets

You **dissolve** a shadow set by specifying its virtual unit name with the DISMOUNT command. Specifying the virtual unit name causes all members in the shadow set to be dismounted, thereby dissolving the shadow set on the node that issues the DISMOUNT command. The command in Example 4–9 includes the /CLUSTER qualifier to dissolve the DSA36 shadow set across an OpenVMS Cluster system.

Example 4–9 Dissolving a Shadow Set

```
$ DISMOUNT /CLUSTER DSA36:
```

Dismounting the virtual unit can be done only after all files are closed, thereby ensuring that the dismounted disks are fully consistent from a file system perspective. The dismount operation marks the shadow set members as being properly dismounted so that a rebuild is not required the next time the disks are mounted. However, if a merge operation was either pending or in progress, then the dismount operation marks the shadow set members as being improperly dismounted and requires a merge operation.

Note

If you dismount a virtual unit while a copy operation is in progress for the shadow set, the copy operation aborts and the shadow set is dissolved. You receive OPCOM messages similar to those in the following example:

```
$ DISMOUNT DSA9999:
```

```
%%%%%%%%%%%  OPCOM  24-MAR-1990 20:29:57.52  %%%%%%%%%%%
$7$DUA6:  (WRKDSK) has been removed from shadow set.
%%%%%%%%%%%  OPCOM  24-MAR-1990 20:29:57.68  %%%%%%%%%%%
$7$DUA56: (PLADSK)  has been removed from shadow set.
%%%%%%%%%%%  OPCOM  24-MAR-1990 20:29:57.88  %%%%%%%%%%%
Message from user SYSTEM on SYSTMX
```

4.8.3 Dismounting and Remounting With One Less Member for Backup

As discussed in Section 4.8.2, the virtual unit can be dismounted on the system or across an OpenVMS Cluster system. To ensure that the virtual unit has been dismounted correctly, the following steps are recommended:

1. Issue the MOUNT/NOWRITE command, followed by the SHOW DEVICE command, for example:

   ```
   $ MOUNT/NOWRITE DSA42: /SHADOW=($4$DUA3,$4$DUA4,$4$DUA5) volume-label
   $ SHOW DEVICE DSA42:
   ```

2. Observe that the virtual unit is in a steady state; that is, all members are consistent and no copy or merge operation is in progress. If a copy or merge operation is in progress, you must wait for the operation to complete.
3. When the virtual unit is in a steady state, remove a member from the shadow set with the DISMOUNT command, as shown in the following example:

   ```
   $ DISMOUNT $4$DUA5
   ```

4. Dismount the virtual unit and then remount it with one less member, as shown by the following command:

   ```
   $ MOUNT/SYS DSA42: /SHADOW=($4$DUA3,$4$DUA4) volume-label
   ```

   The shadow set member that was removed can now be used for a backup operation of the virtual unit.

Note

If your application must run continuously (that is, you cannot dismount the virtual unit without disrupting your business), you can still remove a shadow set member that you plan to return later to the shadow set. Your application and recovery procedures must be designed to ensure data consistency, as described in Section 7.12.

4.9 Displaying Information About Shadow Sets

You can use the DCL command SHOW DEVICE or the F$GETDVI lexical function to get information about a shadow set virtual unit and the physical volumes that make up the members. You can also use the System Dump Analyzer (SDA) to get more information about shadow sets.

The following sections describe how to use these tools to examine volume shadowing virtual units and shadow set members. See also the *OpenVMS DCL Dictionary* for a full description of how to use the SHOW DEVICE command and the F$GETDVI lexical function. See the *OpenVMS Alpha System Analysis Tools Manual* and the *OpenVMS VAX System Dump Analyzer Utility Manual* for more information about how to use SDA on OpenVMS Alpha and OpenVMS VAX systems, respectively.

You can use any of the SHOW DEVICE qualifiers when you examine shadow sets (by specifying a shadow set's virtual unit name) or shadow set members.

Note

Because shadow sets are created and maintained individually on each node in the OpenVMS Cluster, the SHOW DEVICE display does not list shadow sets that have been created on only remote nodes.

4.9.1 Listing Shadow Sets

Use SHOW DEVICE in the following format to display information about shadow sets:

SHOW DEVICE [virtual-unit-name[:]]

The variable *virtual-unit-name* replaces *device-name* as the SHOW DEVICE command parameter for shadow sets. Use the virtual unit naming format DSA*n*:.

As with any SHOW DEVICE command, the colon is optional. Note also that you can specify a complete virtual unit name (or a portion of a virtual unit name) just as you can with device names. If you omit the virtual unit number, SHOW DEVICE lists all the shadow set virtual units that represent shadow set member disks of the type specified. If you truncate a device name (for example, if you specify D), SHOW DEVICE lists all the devices and all the virtual units that begin with the letters you entered (in this case, D).

When you specify the virtual unit number, SHOW DEVICE displays the names of the shadow set members it represents. If you use the /FULL qualifier, SHOW DEVICE displays full information about the shadow set and all the associated shadow set members.

Because individual shadow set members that are mounted for systemwide or clusterwide access are not allocated or mounted in the traditional sense, a SHOW DEVICE command with the /ALLOCATED or /MOUNTED qualifiers displays only virtual units.

4.9.2 Listing Shadow Set Members

Use the same format for the SHOW DEVICE command with shadow set members as you use with other physical devices. The command lists all shadow set members of the device name you specify.

Because shadow set members are not mounted in a traditional sense and they all have the same device characteristics, SHOW DEVICE displays most of the relevant data with the associated virtual unit. Listings of shadow set members include information about current membership status.

If a shadow set is undergoing a copy or a merge operation, the display resulting from the SHOW DEVICE command includes the percentage of the disk that has been copied or merged. The SHOW DEVICE information is available on all nodes that have the shadow set mounted.

The SHOW DEVICE display indicates the exact percentage of the disk that has been copied. The node that is managing the copy operation knows precisely how far the copy or merge operation has progressed, and periodically notifies the other nodes in the OpenVMS Cluster of the progress. Thus, the other nodes in the cluster know approximately the percentage copied. When you enter the SHOW DEVICE command from a node other than the one where the copy or merge operation is taking place, the number indicating the percentage copied in the SHOW DEVICE output lags (by a small percentage) the actual percentage copied.

Note that if a copy and a merge operation are occurring at the same time in the same shadow set, the number indicating the percentage merged remains static until the copy completes. Then the merge operation proceeds to completion.

4.9.3 SHOW DEVICE Examples for Shadow Set Information

The following examples of output from the SHOW DEVICE command illustrate the types of shadow set information you can obtain, such as shadow set membership and the status of each shadow set member during copy and merge operations. For examples of output for write bitmaps used with the minicopy operation, see Section 7.10.

Examples

1.
```
$ SHOW DEVICE D

Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA0:                Mounted           0  SHADOWDISK        8694   151   1
DSA9999:             Mounted           0  APPARITION      292971     1   1
$4$DUA0:   (SYSTMX)  Online            0
$4$DUA8:   (HSJ001)  ShadowSetMember   0  (member of DSA0:)
$4$DUA10:  (SYSTMX)  ShadowSetMember   0  (member of DSA9999:)
$4$DUA11:  (SYSTMX)  ShadowSetMember   0  (member of DSA9999:)
$4$DUA12:  (SYSTMX)  ShadowSetMember   0  (member of DSA9999:)
$4$DUA89:  (HSJ002)  ShadowSetMember   0  (member of DSA0:)
```

By truncating the device name, you cause the SHOW DEVICE command to list all the devices and all the virtual units on the local node that begin with the letters you entered (in this case, D). This example shows that two virtual units, DSA0 and DSA9999, are active. Both shadow sets are in a steady state. The device status "ShadowSetMember" indicates that the shadow set is in a steady state—the shadow set members are consistent with each other.

2.
```
$ SHOW DEVICE DSA8

Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA8:                Mounted           0  APPARITION      890937     1   1
$11$DUA8:   (SYSTMX)   ShadowSetMember   0  (member of DSA8:)
$11$DUA89:  (SYSTMY)   ShadowSetMember   0  (member of DSA8:)
```

This example shows the membership and status of the shadow set represented by the DSA8 virtual unit. The SHOW DEVICE display provides information not only about the virtual unit DSA8, but also about the physical devices $11$DUA8 and $11$DUA89 that are members of the shadow set. The device status "ShadowSetMember" indicates that the shadow set is in a steady state—the shadow set members are consistent with each other. The shadow set members are being served by OpenVMS Cluster nodes SYSTMX and SYSTMY.

3.
```
$ SHOW DEVICE DSA

Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA7:                Mounted           0  PHANTOM          27060    35   7
DSA8:                Mounted           0  APPARITION      890937     4   6
```

You might specify DSA on the SHOW DEVICE command to request information about all the shadow sets on the local node. Entering a generic virtual unit name, such as DSA, as a parameter produces a display of all virtual units representing shadow sets mounted on the local system.

This example shows that two shadow sets are mounted on the local node, represented by the virtual units DSA7 and DSA8.

4. `$ SHOW DEVICE $11$DUA8:`

```
Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA8:                Mounted           0  APPARITION      890937     1   1
$11$DUA8:   (HSJ001) ShadowSetMember   0  (member of DSA8:)
$11$DUA89:  (HSJ002) ShadowSetMember   0  (member of DSA8:)
```

Although the SHOW DEVICE command specifies the name of a single device, the resulting display includes information about the membership and status of the shadow set represented by the DSA8 virtual unit to which the $11$DUA8 device belongs. The device status “ShadowSetMember” indicates that the shadow set is in a steady state—the shadow set members are consistent with each other. The shadow set members are accessed through the node named HSJ001.

5. `$ SHOW DEVICE $11$DUA8:`

```
Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA8:                Mounted           0  APPARITION      890937     1   1
$11$DUA8:  (HSJ001)  ShadowSetMember   0  (member of DSA8:)

$11$DUA89: (HSJ002)  ShadowCopying     0  (copy trgt DSA8:  48% copied)
```

The output from this SHOW DEVICE command shows a shadow set that is in a transient state. The device status “ShadowCopying” indicates that the physical device $11$DUA89 is the target of a copy operation, and 48% of the disk has been copied. The device $11$DUA8 is the source member for the copy operation.

6. `$ SHOW DEVICE DSA8`

```
Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA8:                Mounted           0  APPARITION      890937     1  12

$11$DUA8:  (HSJ001)  ShadowCopying     0  (copy trgt DSA8: 5% copied)
$11$DUA89: (HSJ002)  ShadowMergeMbr    0  (merging DSA8:   0% merged)
```

This example shows how the SHOW DEVICE command displays a shadow set during a copy operation after a node in an OpenVMS Cluster system fails. In this example, the shadow set members are located on different nodes in the cluster, and one node on which the shadow set is mounted fails. At the time of the failure, the shadow set was in a transient state, with the $11$DUA8 device undergoing a copy operation. The SHOW DEVICE command shows the state of the shadow set during the copy operation, before the merge operation occurs.

At the same time the $11$DUA89 shadow set member is acting as the source member for the copy operation, $11$DUA89 also accepts and performs I/O requests from applications running on the OpenVMS Cluster system. Once the copy operation completes, a merge operation automatically starts. See Chapter 6 for more information about merge operations.

The next example shows how the SHOW DEVICE command display looks during the merge operation.

7.

```
$ SHOW DEVICE DSA8

Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA8:                Mounted           0  APPARITION      890937     1   1

$11$DUA8:   (HSJ001) ShadowMergeMbr    0  (merging DSA8: 78% merged)
$11$DUA89:  (HSJ002) ShadowMergeMbr    0  (merging DSA8: 78% merged)
```

The SHOW DEVICE command produces a display similar to this example when a shadow set is in a transient state because of a merge operation. The merge operation is 78% complete.

8.

```
$ SHOW DEV D

Device               Device        Error    Volume         Free  Trans Mnt
 Name                Status        Count     Label        Blocks Count Cnt
DSA456:      (FUSS)  Mounted           0  AUDITINGDISK    123189   225  17
$11$DIA1:  (LISBEN)  Online            0
$11$DJA16: (GALEXI)  Online            0
$11$DJA128:(GALEXI)  Mounted wrtlck    0  CORPORATEVOL    164367     1  18
$11$DJA134:(GALEXI)  Mounted           0  WORKVOLUME      250344     1  16
$11$DUA1:    (FUSS)  Mounted           0  MAR24DISKVOL    676890     1  18
$11$DUA2:    (FUSS)  ShadowSetMember   0  (member of DSA456:)
$11$DUA7:   (BLISS)  Online            0  (remote shadow member)
$11$DUA11: (LISBEN)  Mounted           0  RMSFILES        621183     1  18
$11$DUA13:  (BLISS)  Mounted           0  RESIDENTVOL     525375     1  18
```

This example shows how the SHOW DEVICE command displays remote shadow set members. In this display, the device $11$DUA7, whose description is “remote shadow member,” is a member of a shadow set that is not mounted on this system.

9.

```
$ SHOW DEVICE/FULL DSA80

Disk DSA80:, device type MSCP served SCSI disk, is online, mounted, file-
oriented device, shareable, available to cluster, error logging is enabled.

Error count                    0    Operations completed              138
Owner process                 ""    Owner UIC                    [SHADOW]
Owner process ID        00000000    Dev Prot    S:RWED,O:RWED,G:RWED,W:RWED
Reference count                1    Default buffer size               512
Total blocks              891072    Sectors per track                  51
Total cylinders             1248    Tracks per cylinder                14

Volume label         "SHADTEST1"    Relative volume number              0
Cluster size                   3    Transaction count                   1
Free blocks               890937    Maximum files allowed          111384
Extend quantity                5    Mount count                         4
Mount status              System    Cache name         "_DSA2010:XQPCACHE"
Extent cache size             64    Maximum blocks in extent cache   89093
File ID cache size            64    Blocks currently in extent cache     0
Quota cache size               0    Maximum buffers in FCP cache       216

Volume status:  subject to mount verification, file high-water marking,write-
  through caching enabled.
Volume is also mounted on BLASTA, CNASTA, SHASTA.

Disk $255$DUA56:, device type MSCP served SCSI disk, is online, member of
shadow set DSA80:, error logging is enabled.

Error count                    0    Shadow member operation count      301
Host name               "SHASTA"    Host type, avail      VAX 6000-320,yes
Allocation class             255

  Volume status:  volume is a merge member of the shadow set.
```

```
Disk $255$DUA58:, device type MSCP served SCSI disk, is online, member of
shadow set DSA80:, error logging is enabled.

Error count                  0    Shadow member operation count      107
Host name             "SHASTA"    Host type, avail      VAX 6000-320,yes
Allocation class           255

Volume status:  volume is a merge member of the shadow set.
```

This example shows how the SHOW DEVICE/FULL command displays detailed information about the shadow set and its members. Notice that both members, $255$DUA56 and $255$DUA58, are merge members. Section 4.9.4 shows what this shadow set looks like when it is examined using the System Dump Analyzer.

4.9.4 Displaying Shadow Set Information With SDA

The System Dump Analyzer (SDA) is a utility provided with the OpenVMS operating system. Although the main function of SDA is for crash dump analysis, it is also a useful tool for examining a running system, including the shadow sets. You can also use SDA to determine whether or not a third-party SCSI device supports the shadowing data repair (disk bad block errors) capability.An example is included in Section 4.9.4.1.

The SDA command SHOW DEVICE displays information from the system data structures that describe the devices in the system configuration. To examine a shadow set, first enter ANALYZE/SYSTEM at the DCL prompt to invoke the System Dump Analyzer. Then at the SDA> prompt, enter the SHOW DEVICE command followed by the virtual unit name.

The following example shows how to obtain information about the shadow set represented by the virtual unit DSA80. Compare the SDA output in the following example with the DCL SHOW DEVICE output shown in the last example in Section 4.9.3.

```
$ ANALYZE/SYSTEM

VAX/VMS System analyzer

SDA> SHOW DEVICE DSA80

I/O data structures
-------------------
DSA80                                  HSJ00            UCB address:  810B7F50

Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
                 00082021 clu,mscp,loc,vrt

Owner UIC [004000,000015]   Operation count       138   ORB address    810B8080
      PID       00000000   Error count             0   DDB address    813F49F0
Alloc. lock ID  009C2595   Reference count         1   DDT address    810BEBB8
Alloc. class           0   Online count            1   VCB address    810BE3F0
Class/Type         01/15   BOFF                 0000   CRB address    8129EB10
Def. buf. size       512   Byte count           0200   PDT address    810121A0
DEVDEPEND       04E00E33   SVAPTE           81FDE55C   CDDB address   813F4360
DEVDEPND2       00000000   DEVSTS               0004   SHAD address   8111D460
FLCK index            34   RWAITCNT             0000   I/O wait queue    empty
DLCK address    00000000

Shadow Device status:   0004 nocnvrt

  ----- Shadow Descriptor Block (SHAD) 8111D460 -----

Virtual Unit status:             0041 normal,merging
```

```
Members                2    Act user IRPs          0    VU UCB          810B7F50
Devices                2    SCB LBN         0006CC63    Write log addr  00000000
Fcpy Targets           0    Generation Num  28D47C20    Master FL          empty
Mcpy Targets           2                    00935BC7    Restart FL         empty
Last Read Index        1    Virtual Unit Id 00000000
Master Index           0                    12610050

     ----- SHAD Device summary for Virtual Unit  DSA80  -----

Device $255$DUA56
 Index 0 Device Status    A6 merge,cip,src,valid
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN 0004B94D
Device $255$DUA58
 Index 1 Device Status    A6 merge,cip,src,valid
 UCB 81051260     VCB 81439800      Unit Id. 12A1003A 000000FF
 Merge LBN 0004B94D

SDA> exit
```

The SDA utility's SHOW DEVICE command first displays device characteristics of the DSA80 virtual unit and the addresses of data structures. SDA then displays the DSA80 virtual unit status and the status of the individual shadow set members. Notice how the device status for each member reflects that the unit is in a merge state. For example, $255$DUA56 is shown with the following device status:

```
Device $255$DUA56
 Index 0 Device Status    A6 merge ❶, cip ❷, src ❸, valid ❹
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN 0004B94D
```

This information translates to the following:

❶ merge—$255$DUA56 is marked for a merge operation.

❷ cip—Copy in progress. In this example, a merge operation is in progress.

❸ src—$255$DUA56 is considered a source member for the read operations.

❹ valid—The SCB information on $255$DUA56 is considered valid.

Notice also how both devices $255$DUA56 and $255$DUA58 show that, at the time the SDA took this "snapshot" of the shadow set, the merge operation is merging at LBN 0004B94D.

The following example shows an SDA display of the same shadow set when $255$DUA56 is a merge member and $255$DUA58 is the recipient of a copy operation. A shadow set can be in this merge/copy state when a node that has the shadow set mounted crashes while a member in the shadow set is undergoing a copy operation. Volume shadowing automatically marks the member undergoing the copy operation so that it receives a merge operation after the copy operation completes. This ensures consistency across the shadow set.

The example first shows output for one shadow set member, using the DCL command SHOW DEVICE $255$DUA58; then the example shows the output for the entire shadow set, using the SDA command SHOW DEVICE DSA80. (SDA is invoked by the ANALYZE/SYSTEM command.)

```
$ SHOW DEVICE $255$DUA58

Device                  Device           Error    Volume         Free  Trans Mnt
 Name                   Status           Count     Label        Blocks Count Cnt
DSA80:                  Mounted              0  SHADTEST1       890937     1   3
```

```
$255$DUA56:   (SHASTA)  ShadowMergeMbr       0  (merging DSA80:   0% merged)
$255$DUA58:   (SHASTA)  ShadowCopying        0  (copy trgt DSA80: 9% copied )

$ ANALYZE/SYSTEM

VAX/VMS System analyzer

SDA> SHOW DEVICE DSA80

I/O data structures
-------------------
DSA80                                  RA81             UCB address:  810B7F50

Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
                 00082021 clu,mscp,loc,vrt

Owner UIC [004000,000015]   Operation count       130   ORB address    810B8080
      PID       00000000   Error count             0   DDB address    813F49F0
Alloc. lock ID   009C2595   Reference count         1   DDT address    810BEBB8
Alloc. class           0   Online count            1   VCB address    810BE3F0
Class/Type         01/15   BOFF                 0000   CRB address    8129EB10
Def. buf. size       512   Byte count           0000   PDT address    810121A0
DEVDEPEND       04E00E33   SVAPTE           00000000   CDDB address   813F4360
DEVDEPND2       00000000   DEVSTS               0004   SHAD address   8111D460
FLCK index            34   RWAITCNT             0000   I/O wait queue    empty
DLCK address    00000000

Shadow Device status:   0004 nocnvrt

  ----- Shadow Descriptor Block (SHAD) 8111D460 -----

Virtual Unit status:             0061 normal,copying,merging

Members              1    Act user IRPs        0    VU UCB         810B7F50
Devices              2    SCB LBN       0006CC63    Master FL        empty
Fcpy Targets         1    Generation Num  7B7BE060    Restart FL       empty
Mcpy Targets         0                  00935BC4
Last Read Index      0    Virtual Unit Id 00000000
Master Index         0                  12610050

     ----- SHAD Device summary for Virtual Unit  DSA80  -----

Device $255$DUA56
 Index 0 Device Status    A2 merge,src,valid
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN FFFFFFFF
Device $255$DUA58
 Index 1 Device Status    87 fcpy,merge,cip,valid
 UCB 81051260     VCB 81439800      Unit Id. 12A1003A 000000FF
 Copy LBN 00033671
```

In this example, in the SHAD Device summary for Virtual Unit DSA80 display, the device status (fcpy) for $255$DUA58 shows that it is the target of a full copy operation. The source of the operation is $255$DUA56; notice that the Merge LBN line for $255$DUA56 shows a series of Fs (FFFFFFFF). This notation indicates that a merge operation must be done after the copy operation completes. The Copy LBN line for the target disk $255$DUA58 shows that the copy operation is currently copying at LBN 00033671.

4.9.4.1 Using SDA to Obtain Information About Third-Party SCSI Devices

When you mount a SCSI disk, the SCSI disk class driver, DKDRIVER, checks the device-specific parameters to see whether the disk supports READL/WRITEL commands.

If a SCSI disk does not support READL and WRITEL commands, DKDRIVER sets a NOFE (no forced error) bit to indicate that the disk cannot support the shadowing data repair (disk bad block errors) capability. You can use the SDA command SHOW DEVICE to check for the NOFE flag in the Characteristics field of the SDA display.

```
$ ANALYZE/SYSTEM
SDA> SHOW DEVICE DKA300:❶

I/O data structures
-------------------
COLOR$DKA300              Generic_DK        UCB address:  80A665E0

Device status:   00000010 online
Characteristics: 1C454008 dir,fod,shr,avl,elg,idv,odv,rnd
                 05010281 clu,srv,nnm,scsi,nofe❷
    .
    .
    .
```

❶ Enter the SHOW DEVICE command and the physical device name.

❷ Device DKA300 has NOFE set indicating that the device cannot support shadowing data repair.

For SCSI devices that support READL and WRITEL operations, SDA displays a Characteristics field that does not contain the NOFE flag, similar to the following example:

```
SDA> SHOW DEVICE DKA200:
I/O data structures
-------------------
COLOR$DKA200             Generic_DK        UCB address:  806EEAF0

Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
                 01010281 clu,srv,nnm,scsi
```

The Characteristics field does not show a NOFE bit set; therefore, device DKA200 can support shadowing data repair.

4.9.5 Obtaining Shadow Set Information With F$GETDVI

The F$GETDVI lexical function provides another method for obtaining information about devices mounted in shadow sets. Using F$GETDVI, you can obtain general device and volume information and specific information about the shadow set status of the device or volume. For example, you can determine the following types of information:

- Whether a device is a shadow set virtual unit or a shadow set member
- Whether a copy operation is in progress on a device
- What type of copy operation is in progress on a device

- The name of the virtual unit that represents the shadow set of which the particular device is a member
- The entire membership of a shadow set, including the virtual unit and all of the members

You can use the F$GETDVI lexical function interactively at the DCL command level or in a DCL command procedure. You can also use the $GETDVI system service with volume shadowing (see Section 5.6).

The format for the F$GETDVI lexical function is as follows:

```
F$GETDVI (device-name,item)
```

You supply two arguments to the F$GETDVI lexical function: a physical device name and the name of an item that specifies the type of information you want to obtain.

Note

If you use the file-system-related item codes with the $GETDVI system service to obtain meaningful system information (such as FREEBLOCK information) for a shadow set, you should specify the virtual unit name with the $GETDVI service. If you specify the device name of one of the shadow set members, the $GETDVI service returns a value of 0.

The *OpenVMS DCL Dictionary* contains a large list of item codes that you can supply as an argument to F$GETDVI. Table 4–4 lists the items specific to volume shadowing that you can supply as arguments to the F$GETDVI lexical function. The table lists the type of information returned by each item and the data types of the return values.

Table 4–4 F$GETDVI Item Codes for Volume Shadowing

Item	Return Type	Information Returned
SHDW_CATCHUP_ COPYING	String	Returns TRUE or FALSE to indicate whether the device is a member that is the target of a copy operation.
SHDW_MASTER	String	Returns TRUE or FALSE to indicate whether the device is a virtual unit.
SHDW_MASTER_NAME	String	Returns the name of the virtual unit that represents the shadow set of which the specified device is a member. F$GETDVI returns a null string if the specified device is not a member or is, itself, a virtual unit.
SHDW_MEMBER	String	Returns TRUE or FALSE to indicate whether the device is a shadow set member.

(continued on next page)

Table 4–4 (Cont.) F$GETDVI Item Codes for Volume Shadowing

Item	Return Type	Information Returned
SHDW_MERGE_COPYING	String	Returns TRUE or FALSE to indicate whether the device is a member that is a merge member of the shadow set.
SHDW_NEXT_MBR_NAME	String	Returns the device name of the next member in the shadow set. If you specify a virtual unit, F$GETDVI returns the device name of a member of the shadow set. If you specify the name of a shadow set member with the device name and item arguments, F$GETDVI returns the name of the “next” member or a null string if there are no more members. To determine all the members of a shadow set, first specify the virtual unit to F$GETDVI; on subsequent calls, specify the member name returned by the previous F$GETDVI call until it has finished, when it returns a null member name.

Example

To check a device for possible shadow set membership, you could include the following DCL command in a command procedure:

```
$  IF F$GETDVI("WRKD$:","SHDW_MEMBER") THEN GOTO SHADOW_MEMBER
```

If WRKD$ (a logical name for a disk) is a shadow set member, then F$GETDVI returns the string TRUE and directs the procedure to the volume labeled SHADOW_MEMBER.

See the *OpenVMS DCL Dictionary* for additional information about the F$GETDVI lexical function.

5

Creating and Managing Shadow Sets with System Services

This chapter describes how to create, mount, dismount, and dissolve shadow sets using the $MOUNT and $DISMOU system services. It also describes how to use the $GETDVI system service to access current information about the state of shadow sets. For complete information about these OpenVMS system services, see the *OpenVMS System Services Reference Manual*.

5.1 Using $MOUNT to Create and Mount Shadow Sets

You can create and mount shadow sets using the $MOUNT system service in a user-written program. Program calls to $MOUNT that create, mount, or add devices to shadow sets use the same syntax. To direct the system to perform any mount operation, you construct a $MOUNT item list. The item list specifies the virtual unit that represents the shadow set and the members (physical devices) that the shadow set contains.

The call to the $MOUNT system service has the following format:

SYS$MOUNT itmlst

Example 5–1 illustrates MACRO-32 statements that produce a $MOUNT system service item list to create and mount a shadow set.

Example 5–1 Item List to Create and Mount a Shadow Set

```
DSA23:  .ASCID /DSA23:/
MEMBER001:   .ASCID /$4$DUA9:/
MEMBER002:   .ASCID /$4$DUA5:/

VOLUME_LABEL:  .ASCID /MYVOLUME/
VOLUME_LOGNM:  .ASCID /DISK$MYVOLUME/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM

ITMLST: .ITEM   6,  MNT$_SHANAM, DSA23  ❶
        .ITEM   8,  MNT$_SHAMEM, MEMBER001   ❷
        .ITEM   8,  MNT$_SHAMEM, MEMBER002

        .ITEM   8,  MNT$_VOLNAM, VOLUME_LABEL  ❸
        .ITEM   13, MNT$_LOGNAM, VOLUME_LOGNM  ❹
        .LONG   0
```

The following list describes the elements in Example 5–1:

❶ Notice that the virtual unit item descriptor occurs first. This item descriptor specifies DSA23 as the name of the virtual unit. See Section 4.2 for the proper naming syntax for the virtual unit and shadow set members.

❷ The virtual unit item descriptor is followed by two member-unit item descriptors. Because Volume Shadowing for OpenVMS automatically determines the type of operation (copy or merge) necessary before disks can join a shadow set, all of the devices are mounted with MNT$_SHAMEM item descriptors. These item descriptors specify that the physical devices, $4$DUA9 and $4$DUA5, are to join the shadow set represented by DSA23.

❸ The member item descriptors are followed by an item descriptor that specifies MYVOLUME as the volume label for the shadow set.

❹ The last item descriptor specifies DISK$MYVOLUME as the logical name for the shadow set.

Later, if you want to add another device to the shadow set, you make another call to $MOUNT that specifies an item list that contains the name of the virtual unit and the name of the device you want to add to the shadow set. Example 5–2 shows how to add the physical device $4$DUA10: to the shadow set created in Example 5–1.

Example 5–2 Item List to Add a Member to a Shadow Set

```
DSA23:  .ASCID /DSA23:/

MEMBER003:  .ASCID /$4$DUA10:/
VOLUME_LABEL:  .ASCID /MYVOLUME/
VOLUME_LOGNM:  .ASCID /DISK$MYVOLUME/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM

ITMLST: .ITEM   6,  MNT$_SHANAM, DSA23

        .ITEM   9,  MNT$_SHAMEM, MEMBER003
        .ITEM   8,  MNT$_VOLNAM, VOLUME_LABEL
        .ITEM   13, MNT$_LOGNAM, VOLUME_LOGNM
        .LONG   0
```

Section 5.2 briefly describes the $MOUNT shadow set item codes and discusses how to construct a valid $MOUNT item list. For a complete description of the $MOUNT service and all its item codes, refer to the *OpenVMS System Services Reference Manual*.

5.2 $MOUNT Shadow Set Item Codes

This section briefly describes the SYS$MOUNT item codes that are useful for shadow set management. Refer to the *OpenVMS System Services Reference Manual* for complete information about SYS$MOUNT, item codes, and other system services.

Table 5–1 describes the $MOUNT shadow set item codes.

Table 5–1 SYS$MOUNT Item Codes

Item Code	Function
MNT$_FLAGS	Specifies a longword bit vector in which each bit specifies an option for the mount operation. The buffer must contain a longword, which is the bit vector. The $MNTDEF macro defines symbolic names for each option (bit) in the bit vector. You construct the bit vector by specifying the symbolic names for the desired options in a logical OR operation. The following list describes the symbolic names for each shadow set option: • MNT$M_INCLUDE automatically reconstructs a shadow set to the state it was in before the shadow set was dissolved (because of dismounting or system failure). Use this option when mounting a complete shadow set. • MNT$M_NOCOPY disables automatic copy operations on all physical devices being mounted or added to a shadow set. This option prevents accidental loss of data that could occur if an unintended device is added to the shadow set. • MNT$M_MINICOPY_REQUIRED means that $MOUNT fails if minicopy has not been enabled on the disk. • MNT$M_MINICOPY_OPTIONAL means that $MOUNT continues even if minicopy has not been enabled on the disk. • MNT$M_OVR_SHAMEM allows you to mount former shadow set members outside of the shadow set. If you do not specify this option, $MOUNT automatically mounts the volume write-locked to prevent accidental deletion of data. To specify this option, you must either own the volume or have the VOLPRO privilege. When you use this option, the shadow set generation number is erased from the volume. If you then remount the volume in the former shadow set, $MOUNT considers it an unrelated volume and marks it for a copy operation. • MNT$M_REQUIRE_MEMBERS controls whether every physical device specified with the /SHADOW qualifier must be accessible when the MOUNT command is issued in order for the $MOUNT system service to take effect. • MNT$M_VERIFY_LABELS requires that any member to be added to the shadow set have a volume label of SCRATCH_DISK. This helps ensure that the wrong disk is not added to a shadow set. If you plan to use VERIFY_LABELS, you must assign the disk a label first. You can do this either by initializing the disk to be added to the set with the label SCRATCH_DISK or by specifying a label for the disk with the SET VOLUME/LABEL command. The default is NOVERIFY_LABEL, which means that the volume label of the copy targets will not be checked. This default behavior is the same that occurred prior to the introduction of this option.

(continued on next page)

Table 5–1 (Cont.) SYS$MOUNT Item Codes

Item Code	Function
MNT$_SHANAM	Specifies the name of the virtual unit to be mounted. The buffer is a 1- to 64-character string containing the virtual unit name in the format DSA*n*:. This string can also be a logical name; if it is a logical name, it must translate to a virtual unit name. An item list must include at least one MNT$_SHANAM item descriptor. If you are mounting a volume set containing more than one shadow set, you must include one MNT$_SHANAM item descriptor for each virtual unit included in the volume set.
MNT$_SHAMEM	Specifies the name of a physical device to be mounted into a shadow set. The shadowing software adds the device to the shadow set represented by the virtual unit specified in the MNT$_SHANAM item descriptor. The MNT$_SHAMEM descriptor is a 1- to 64-character string containing the device name. The string can be a physical device name or a logical name; if it is a logical name, it must translate to a physical device name. An item list must contain at least one item descriptor specifying a member; this item descriptor must appear after the MNT$_SHANAM item descriptor.

Here are some important things to remember when you construct a $MOUNT item list:

- Every item list that mounts a shadow set must contain at least one item descriptor that specifies the virtual unit and at least one item descriptor that specifies a member.
- The item descriptor that specifies the virtual unit must come before the item descriptors that specify the members contained in the shadow set. Then, you can specify any number of members that are to be represented by that virtual unit by using the MNT$_SHAMEM item code.
- When mounting a volume set, your item list must contain an item descriptor for each virtual unit. The virtual unit item descriptor must be followed by item descriptors specifying the members to be represented by that virtual unit.
- When you mount a shadow set, the system determines whether a device requires a copy or merge operation before it can join the shadow set. Therefore, you can use the MNT$_SHAMEM item code to specify any member, regardless of the operation the device requires.

5.3 Using $MOUNT to Mount Volume Sets

When mounting volume sets, always list the volume with the largest storage capacity first. You should name the largest volume first because the volume set and directory information goes on the first volume listed in a MOUNT command line. A small-capacity disk may not have adequate storage for the volume and directory information.

Example 5–3 shows the MACRO-32 statements required to produce a $MOUNT system service item to mount a volume set that contains two shadow sets.

Example 5–3 Item List to Create and Mount a Volume Set

```
DSA23:  .ASCID /DSA23:/
DSA51:  .ASCID /DSA51:/
MEMBER009:   .ASCID /$4$DUA9:/
MEMBER005:   .ASCID /$4$DUA5:/
MEMBER010:  .ASCID /$4$DUA10:/
MEMBER012:  .ASCID /$4$DUA12:/
MEMBER003:   .ASCID /$4$DUA3:/
MEMBER034:  .ASCID /$4$DUA34:/
VOLUME_WORK1:  .ASCID /WORK1/
VOLUME_WORK2:  .ASCID /WORK2/
VOLUME_LOGNM:  .ASCID /WRKD$/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM

ITMLST: .ITEM   6, MNT$_SHANAM, DSA23  ❶
        .ITEM   8, MNT$_SHAMEM, MEMBER009   ❷
        .ITEM   8, MNT$_SHAMEM, MEMBER005
        .ITEM   9, MNT$_SHAMEM, MEMBER010
        .ITEM   5, MNT$_VOLNAM, VOLUME_WORK1  ❸
        .ITEM   6, MNT$_SHANAM, DSA51  ❹
        .ITEM   9, MNT$_SHAMEM, MEMBER012  ❹
        .ITEM   8, MNT$_SHAMEM, MEMBER003
        .ITEM   9, MNT$_SHAMEM, MEMBER034
        .ITEM   5, MNT$_VOLNAM, VOLUME_WORK2   ❹
        .ITEM   5, MNT$_LOGNAM, VOLUME_LOGNM   ❺
        .LONG   0
```

The following list describes the elements in Example 5–3:

❶ Notice that the virtual unit item descriptor for the first volume in the volume set occurs first. This item descriptor specifies DSA23 as the name of the first virtual unit in the volume set.

❷ The virtual unit item descriptor is followed by item descriptors for each of the devices or members that are to be represented by the first virtual unit: $4$DUA9, $4$DUA5, and $4$DUA10.

❸ The member item descriptors are followed by an item descriptor that specifies the volume label for the first shadow set in the volume set as WORK1.

❹ Following the descriptors for the first shadow set in the volume set are similar item descriptors for the second shadow set in the volume set. These item descriptors specify the second virtual unit as DSA51; the devices as $4$DUA12, $4$DUA3, and $4$DUA34; and the volume label as WORK2.

❺ The last item descriptor specifies the logical name for the entire volume set as WRKD$.

5.4 Using $DISMOU to Dismount Shadow Sets

You can use the $DISMOU system service to perform the following three shadow set operations:

- Remove a member from a shadow set
- Remove a member from a shadow set for a minicopy operation (as described in Section 7.12)

- Dismount a shadow set across a cluster from a single node
- Dismount and dissolve a shadow set

The call to the $DISMOU system service has the following format:

SYS$DISMOU devnam, flags

The action that $DISMOU takes depends in part on whether you specify a shadow set virtual unit or a shadow set member in the **devnam** argument.

For a complete description of the $DISMOU service and its arguments, see the *OpenVMS System Services Reference Manual*.

5.4.1 Removing Members from Shadow Sets

If you want to remove a single member from a shadow set, you must make a call to $DISMOU. In the **devnam** argument, you should specify the name of the shadow set member you want to remove. The specified member is spun down unless you specify the DMT$M_NOUNLOAD option in the **flags** argument.

The MACRO-32 code in Example 5–4 demonstrates a call to $DISMOU that removes the member $2$DUA9 from a shadow set.

Example 5–4 Removing a Member from a Shadow Set

```
$DMTDEF
FLAGS:  .LONG DMT$M_NOUNLOAD
MEMBER001: .ASCID /$2$DUA9:/
 .
 .
 .
$DISMOU_S -
 devnam = MEMBER001, -
 flags = FLAGS
 .
 .
 .
.END
```

5.4.2 Dismounting and Dissolving Shadow Sets

If you want to dismount a shadow set on a single node, you must make a call to $DISMOU. In the **devnam** argument, you should specify the name of the virtual unit that represents the shadow set you want to dismount. If you want to dismount the shadow set clusterwide, specify the DMT$M_CLUSTER option in the **flags** argument of the call.

When you dismount a shadow set on a single node in an OpenVMS Cluster system, and other nodes in the OpenVMS Cluster still have the shadow set mounted, none of the shadow set members contained in the shadow set are spun down, even if you have not specified the DMT$M_NOUNLOAD flag. After this call completes, the shadow set is unavailable on the node from which the call was made. The shadow set is still available to other nodes in the cluster that have the shadow set mounted.

If the node on which the shadow set is being dismounted is the only node that has the shadow set mounted, the shadow set dissolves. The shadow set member devices are spun down unless you specify the DMT$M_NOUNLOAD flag.

The MACRO-32 code in Example 5–5 demonstrates how to use the $DISMOU system service to dismount the shadow set represented by the virtual unit DSA23.

Example 5–5 Dismounting and Dissolving a Shadow Set Locally

```
$DMTDEF
FLAGS:    .LONG 0
DSA23:  .ASCID /DSA23:/
 .
 .
 .
$DISMOU_S -
 devnam = DSA23, -
 flags = FLAGS
 .
 .
 .
.END
```

When a shadow set is dissolved:

- Each of the former shadow set members can be mounted as a single disk for other purposes.

  Each volume, however, continues to be marked as having been part of a shadow set. After you dissolve a shadow set, each volume retains the volume shadowing generation number that identifies it as being a former shadow set member (unless you remount the volume outside of the shadow set). Volumes marked as having been part of a shadow set are automatically software write-locked to prevent accidental deletion of data. You cannot mount these volumes for writing outside of a shadow set unless you use the MNT$M_OVR_SHAMEM option with the system service MNT$_FLAGS item code.
- The virtual unit changes to an offline state.

The MACRO-32 code in Example 5–6 demonstrates a call to the $DISMOU system service to perform a dismount across the cluster. When the shadow set is dismounted from the last node, the shadow set is dissolved.

Example 5–6 Dismounting and Dissolving a Shadow Set Across the Cluster

```
$DMTDEF
FLAGS:   .LONG  DMT$M_CLUSTER
DSA23:  .ASCID /DSA23:/
 .
 .
 .
$DISMOU_S -
 devnam = DSA23, -
 flags = FLAGS
 .
 .
 .
.END
```

You must specify the DMT$M_CLUSTER option with the **flags** argument if you want the shadow set dismounted from every node in the cluster. When each node in the cluster has dismounted the shadow set (the number of hosts having the shadow set mounted reaches zero), the volume shadowing software dissolves the shadow set.

5.4.3 Setting $DISMOU Flags for Shadow Set Operations

Table 5–2 lists the options for the $DISMOU **flags** argument and describes the shadow set operations that use these options. For a full description of each of these flag options, see the description of the $DISMOU service in the *OpenVMS System Services Reference Manual*.

Table 5–2 $DISMOU Flag Options

Option	Description
DMT$M_MINICOPY_ REQUIRED	$DISMOU fails if minicopy has not been enabled on the disk.
DMT$M_MINICOPY_ OPTIONAL	$DISMOU takes place, regardless of whether minicopy is enabled on the disk.
DMT$M_FORCE	If connectivity to a device has been lost and the shadow set is in mount verification, this flag causes a named shadow set member to be immediately expelled from the shadow set.
DMT$M_UNLOAD	Valid for all shadowing-related requests.
DMT$M_CLUSTER	Valid for all shadowing-related requests.
DMT$M_ABORT	Honored for virtual units, ignored for members.
DMT$M_UNIT	Ignored for virtual units and their members.

5.5 Evaluating Condition Values Returned by $DISMOU and $MOUNT

This section discusses the condition values returned by the $DISMOU and $MOUNT system services that pertain to mounting and using shadow sets. For a complete list of the condition values returned by these services, see the *OpenVMS System Services Reference Manual*.

If $MOUNT returns the condition value SS$_BADPARAM, your item list probably contains one of the following errors:

- The virtual unit specified in one of your MNT$_SHANAM item descriptors contains a name other than DSA*n*:.
- A MNT$_SHAMEM item descriptor appears in the item list before any MNT$_SHANAM item descriptor.
- Your item list contains a MNT$_SHANAM item descriptor, but it is not followed by the item descriptor MNT$_SHAMEM.
- A MNT$_DEVNAM item descriptor appears in the item list in the middle of a series of item descriptors that specify a single shadow set. You can construct a volume set that contains one or more nonshadowed disks, as well as one or more shadow sets. However, when you use the MNT$_DEVNAM item descriptor to specify the nonshadowed disk, it must not appear between the MNT$_SHANAM item descriptor that specifies a virtual unit and the item descriptors that specify the members of the shadow set that the virtual unit represents.

- The following list contains possible status messages that $MOUNT can return when mounting and using shadow sets:
  - SS$_VOLINV (label mismatched)
  - SS$_SHACHASTA (shadow state change occurred during a mount operation)
  - SS$_MEDOFL (physical unit not accessible)
  - SS$_INCSHAMEM (physical disk incompatible for shadow set)

See also Appendix A for shadowing-related status messages.

5.6 Using $GETDVI to Obtain Information About Shadow Sets

The $GETDVI system service is useful for obtaining information about the shadow set devices on your system. Through the use of the shadow set item codes, you can determine the following types of information:

- Whether a device is a shadow set virtual unit or a shadow set member
- Whether a device is the target of a copy or merge operation
- The name of the virtual unit that represents the shadow set of which the particular device is a member
- The entire membership of a shadow set, including the virtual unit and all of the members
- Whether or not a member has been removed from the shadow set

The call to $GETDVI has the following format:

```
SYS$GETDVI [efn],[chan],[devnam],itmlst,[iosb],[astadr],[astprm],[nullarg]
```

For a complete description of the $GETDVI and $GETDVIW services and their arguments, see the *OpenVMS System Services Reference Manual*.

> **Note**
>
> If you use the file-system-related item codes with the $GETDVI system service to obtain meaningful system information (such as FREEBLOCK information) for a shadow set, you should specify the virtual unit name with the $GETDVI service. If you specify the device name of one of the shadow set members, the $GETDVI service returns a value of 0.

5.6.1 $GETDVI Shadow Set Item Codes

Table 5–3 lists the information returned by the $GETDVI shadow set item codes.

Table 5–3 SYS$GETDVI Item Codes

Item Code	Function
DVI$_SHDW_CATCHUP_COPYING	Returns a Boolean longword. The value 1 indicates that the device is the target of a copy operation.
DVI$_SHDW_MASTER	Returns a Boolean longword. The value 1 indicates that the device is a virtual unit.
DVI$_SHDW_MASTER_NAME[1]	When the specified device is a shadow set member, $GETDVI returns the virtual unit name for the shadow set of which it is a member. If you specify a virtual unit or a device that is not a shadow set member, $GETDVI returns a null string.
DVI$_SHDW_MEMBER	Returns a Boolean longword. The value 1 indicates that the device is a shadow set member.
DVI$_SHDW_MERGE_COPYING	Returns a Boolean longword. The value 1 indicates that the device is a merge member of the shadow set.
DVI$_SHDW_NEXT_MBR_NAME[1]	Returns the device name of the next member in the shadow set. If you specify a virtual unit, $GETDVI returns the member device names in the shadow set. If you specify the name of a device that is neither a virtual unit nor a shadow set member, $GETDVI returns a null string.

[1] Because shadow set device names can include up to 64 characters, the buffer length field of this item descriptor should specify 64 (bytes).

5.6.2 Obtaining the Device Names of Shadow Set Members

To obtain the device names of all members of a shadow set, you must make a series of calls to $GETDVI. In your first call to $GETDVI, you can specify either the virtual unit that represents the shadow set or the device name of a member of the shadow set.

5.6.2.1 Virtual Unit Names

If your first call specifies the name of the virtual unit, the item list should contain a DVI$_SHDW_NEXT_MBR_NAME item descriptor into which $GETDVI returns the name of the lowest-numbered member of the shadow set. The **devnam** argument of the next call to $GETDVI should specify the device name returned in the previous call's DVI$_SHDW_NEXT_MBR_NAME item descriptor. This second call's item list should contain a DVI$_SHDW_NEXT_MBR_NAME item descriptor to receive the name of the next-highest-numbered unit in the shadow set. You should repeat these calls to $GETDVI until $GETDVI returns a null string, which means that there are no more members in the shadow set.

5.6.2.2 Shadow Set Member Names

If your first call specifies the device name of a shadow set member, you must determine the name of the virtual unit that represents the shadow set before you can obtain the device names of all members contained in the shadow set. Therefore, if your first call specifies a member, it should also specify an item list that contains a DVI$_SHDW_MASTER_NAME item descriptor. $GETDVI returns to this descriptor the name of the virtual unit that represents the shadow set. You can now make the series of calls to $GETDVI described in Section 5.6.2.1. The **devnam** argument of each call specifies the name of the device returned in the previous call's DVI$_SHDW_NEXT_MBR_NAME item descriptor. You repeat these calls until $GETDVI returns a null string, indicating that there are no more members in the shadow set.

6
Ensuring Shadow Set Consistency

Volume shadowing performs four basic functions. The two most important, as with any disk I/O subsystem, are to satisfy read and write requests. The other two functions, copy and merge, are required for shadow set maintenance.

Copy and merge operations are the cornerstone of achieving data availability. Under certain circumstances, Volume Shadowing for OpenVMS must perform a copy or a merge operation to ensure that corresponding LBNs on all shadow set members contain the same information. Although volume shadowing automatically performs these operations, this chapter provides an overview of their operation.

Copy and merge operations occur at the same time that applications and user processes read and write to active shadow set members, thereby having a minimal effect on current application processing.

6.1 Shadow Set Consistency

During the life of a shadow set, the state of any shadow set member relative to the rest of the members of the shadow set can vary. The shadow set is considered to be in a steady state when all of its members are known to contain identical data. Changes in the composition of the shadow set are inevitable because:

- Disk drives occasionally need corrective maintenance.
- New disks are added to replace other disks.
- System failures occur, requiring merge operations to take place within the shadow set.
- Controllers fail, requiring maintenance.
- System management functions, such as backup, are required.

For example, suppose an operator dismounts a member of a shadow set and then remounts the member back into the shadow set. During the member's absence, the remaining members of the shadow set may have experienced write operations. Thus, the information on the member being remounted into the shadow set will differ from the information on the rest of the shadow set. Therefore, a copy (or minicopy) operation is required.

As another example, consider a situation where a shadow set is mounted by several systems in an OpenVMS Cluster configuration. If one of those systems fails, the data on the members of the shadow set may differ because of outstanding or incomplete write operations issued by the failed system. The shadowing software resolves this situation by performing a merge operation.

In any event, copy and merge operations allow volume shadowing to preserve the consistency of the data written to the shadow set. A shadow set is considered to be in a **transient state** when one or more of its members are undergoing a copy or a merge operation.

Additionally, volume shadowing maintains shadow set consistency by:

- Maintaining consistent data on shadow set members by automatically detecting and replacing bad blocks on one shadow set member and rewriting those bad blocks with good data from another shadow set member.
- Notifying all nodes when a member is added or removed from a shadow set, and ensuring the shadow set membership is consistent clusterwide.

Volume shadowing uses two internal mechanisms to coordinate shadow set consistency:

- Storage control blocks (SCBs)

  Volume shadowing uses a storage control block (SCB) as a primary method for controlling shadow set membership. Each physical disk contains an SCB in which the shadowing software records the names of all the current members of the shadow set. Each time the composition of the shadow set changes, the SCB on all members is updated. This feature simplifies clusterwide membership coordination and is also used by the MOUNT qualifier /INCLUDE to reconstruct a shadow set.
- Shadow set generation number

  Volume shadowing uses a shadow set generation number as a primary method of determining shadow set member validity and status. A shadow set generation number is an incrementing value that is stored on every member of a shadow set. Each time a membership change occurs to the shadow set (members are mounted, dismounted, or fail), the generation number on the remaining members is incremented. Thus, if a shadow set's generation number is 100 and a member is dismounted from the set, the generation numbers on the remaining members are incremented to 101. The removed member's generation number remains at 100. When mounting shadow sets, the shadowing software uses the generation numbers, found in the SCB on the physical units, to determine the need for and direction of copy operations.

Table 6–1 lists some of the information contained in the SCB.

Table 6–1 Information in the Storage Control Block (SCB)

SCB Information	Function
Volume label	Identifies a unique name for the volume. Every member of a shadow set must use the same volume label.
BACKUP revision number	A BACKUP/IMAGE restoration rearranges the location of data on a volume and sets a revision number to record this change. The Mount utility (MOUNT) checks the revision number of the proposed shadow set member against the numbers on current or other proposed shadow set members. If the revision number differs, the shadowing software determines whether a copy or merge operation is required to bring the data on the less current members up to date.
Volume shadowing generation number	When a member joins a shadow set, it is marked with a volume shadowing generation number. You can zero the generation number by using the /OVERRIDE=SHADOW_MEMBERSHIP qualifier with the MOUNT command.

(continued on next page)

Table 6–1 (Cont.) Information in the Storage Control Block (SCB)

SCB Information	Function
Mount and dismount status	The SCB mount status field is used as a flag that is set when a volume is mounted and cleared when it is dismounted. There is also a count of the number of nodes that have mounted the shadow set write-enabled. The MOUNT command checks this field when a disk is mounted. If the flag is set, this indicates that the disk volume was incorrectly dismounted. This will occur in the event of system failure. When mounting shadow sets that were incorrectly dismounted, or where the write count field is not correct, the shadowing software automatically initiates merge operations.

Upon receiving a command to mount a shadow set, the volume shadowing software immediately determines whether a copy or a merge operation is required; if either is required, the software automatically performs the operation to reconcile data differences. If you are not sure which disks might be targets of copy operations, you can specify the /CONFIRM or /NOCOPY qualifiers when you use the MOUNT command. To disable performing any copy operations, use the /NOCOPY qualifier. If you mount a shadow set interactively, use the /CONFIRM qualifier to instruct MOUNT to display the targets of copy operations and request permission before the operations are performed.

When you dismount an individual shadow set member, you produce a situation similar to a hardware disk failure. Because files remain open on the virtual unit, the removed physical unit is marked as *not* being properly dismounted.

After one of the devices is removed from a shadow set, the remaining shadow set members have their generation number incremented, identifying them as being more current than the former shadow set member. This generation number aids in determining the correct copy operation if you remount the member into a shadow set.

6.2 Copy Operations

The purpose of a copy operation is to duplicate data on a source disk to a target disk. At the end of a copy operation, both disks contain identical information, and the target disk becomes a complete member of the shadow set. Read and write access to the shadow set continues while a disk or disks are undergoing a copy operation.

The DCL command MOUNT initiates a copy operation when a disk is added to an existing shadow set. A copy operation is simple in nature: A source disk is read and the data is written to the target disk. This is usually done in multiple block increments referred to as LBN ranges. In an OpenVMS Cluster environment, all systems that have the shadow set mounted know about the target disk and include it as part of the shadow set. However, only one of the OpenVMS systems actually manages the copy operation.

Two complexities characterize the copy operation:

- Handling user I/O requests while the copy operation is in progress
- Dealing with writes to the area that is currently being copied without losing the new write data

Volume Shadowing for OpenVMS handles these situations differently depending on the operating system version number and the hardware configuration. For systems running software earlier than OpenVMS Version 5.5–2, the copy operation is performed by an OpenVMS node and is known as an **unassisted** copy operation (see Section 6.2.1).

With Version 5.5–2 and later, the copy operation includes enhancements for shadow set members that are configured on controllers that implement new copy capabilities. These enhancements enable the *controllers* to perform the copy operation and are referred to as **assisted** copies (see Section 6.2.2).

Volume Shadowing for OpenVMS supports both assisted and unassisted shadow sets in the same cluster. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the shadowing software reevaluate's each device in the changed configuration to determine whether the device is capable of supporting the copy assist.

6.2.1 Unassisted Copy Operations

Unassisted copy operations are performed by an OpenVMS system. The actual transfer of data from the source member to the target is done through host node memory. Although unassisted copy operations are not CPU intensive, they are I/O intensive and consume a small amount of CPU bandwidth on the node that is managing the copy. An unassisted copy operation also consumes interconnect bandwidth.

On the system that manages the copy operation, user and copy I/Os compete evenly for the available I/O bandwidth. For other nodes in the cluster, user I/Os proceed normally and contend for resources in the controller with all the other nodes. Note that the copy operation may take longer as the user I/O load increases.

The volume shadowing software performs an unassisted copy operation when it is not possible to use the assisted copy feature (see Section 6.2.2). The most common cause of an unassisted copy operation is when the source and target disk or disks are not on line to the same controller subsystem. For unassisted copy operations, two disks can be active targets of an unassisted copy operation simultaneously, if the members are added to the shadow set on the same command line. Disks participating in an unassisted copy operation may be on line to any controller anywhere in a cluster.

During any copy operation, a logical barrier is created that moves across the disk, separating the copied and uncopied LBN areas. This barrier is known as a **copy fence**. The node that is managing the copy operation knows the precise location of the fence and periodically notifies the other nodes in the cluster of the fence location. Thus, if the node performing the copy operation shuts down, another node can continue the operation without restarting at the beginning.

Read I/O requests to either side of the copy fence are serviced only from a source shadow set member.

Write I/O requests before or at the fence are issued in parallel to all members of the shadow set.

Write I/O requests, after the fence, are completed first to source members, then to copy target members.

The time and amount of I/O required to complete an unassisted copy operation depends heavily on the similarities of the data on the source and target disks. It can take at least two and a half times longer to copy a member containing dissimilar data than it does to complete a copy operation on a member containing similar data.

6.2.2 Assisted Copy Operations

Unlike an unassisted copy, an assisted copy does not transfer data through the host node memory. The actual transfer of data is performed within the controller, by direct disk-to-disk data transfers, without having the data pass through host node memory. Thus, the assisted copy decreases the impact on the system, the I/O bandwidth consumption, and the time required for copy operations.

Shadow set members must be accessed from the same controller in order to take advantage of the assisted copy. The shadowing software controls the copy operation by using special MSCP copy commands, called disk copy data (DCD) commands, to instruct the controller to copy specific ranges of LBNs. For an assisted copy, only one disk can be an active target for a copy at a time.

For OpenVMS Cluster configurations, the node that is managing the copy operation issues an MSCP DCD command to the controller for each LBN range. The controller then performs the disk-to-disk copy, thus avoiding consumption of interconnect bandwidth.

By default, the Volume Shadowing for OpenVMS software (beginning with OpenVMS Version 5.5–2) and the controller automatically enable the copy assist if the source and target disks are accessed through the same HSC or HSJ controller.

Shadowing automatically disables the copy assist if:

- The source and target disks are not accessed using the same controller.

  In the case of dual-ported disks, you can use the $QIO SET PREFERRED PATH feature to force both disks to be accessed via the same controller. See the PREFER program in SYS$EXAMPLES and refer to the *OpenVMS I/O User's Reference Manual* for more information about setting a preferred path.

- The shadow set is mounted on a controller that does not support the copy assist.

- The shadow set member is mounted on an HSC controller with the copy assist disabled. (HSC controllers are the only controllers on which you can disable copy assists.)

- The number of assisted copies specified by the DCD connection limit, only on HSC controllers, has been reached, at which point additional copies will be performed unassisted.

See Section 6.4 for information about disabling and reenabling the assisted copy capability.

6.3 Merge Operations

The purpose of a merge operation is to compare data on shadow set members and to ensure that inconsistencies are resolved. A merge operation is initiated if either of the following events occurs:

- A system failure results in the possibility of incomplete writes.

For example, if a write request is made to a shadow set but the system fails before a completion status is returned from all the shadow set members, it is possible that:

- All members might contain the new data.
- All members might contain the old data.
- Some members might contain new data and others might contain old data.

The exact timing of the failure during the original write request defines which of these three scenarios results. When the system recovers, however, it is essential that corresponding LBNs on each shadow set member contain the *same* data (old or new). Thus, the issue here is not one of data availability, but rather of reconciling potential differences among shadow set members. Once the data on *all* disks is made identical, application data can be reconciled, if necessary, either by the user reentering the data or by database recovery and application journaling techniques.

- If a shadow set enters mount verification with outstanding write I/O in the internal queue, and the problem is not corrected before mount verification times out, the systems on which the timeout occurred cause the shadow set to require a merge operation.

  For example, if the shadow set were mounted on eight nodes and mount verification timed out on two of them, those two nodes would each cause the shadow set to require a merge operation.

The merge operation is managed by one of the OpenVMS systems that has the shadow set mounted. The members of a shadow set are physically compared to each other to ensure that they contain the same data. This is done by performing a block-by-block comparison of the entire volume. As the merge proceeds, any blocks that are different are made the same –either both old or new—by means of a copy operation. Because the shadowing software does not know which member contains newer data, any full member can be the **source** member of the merge operation.

The shadowing software always selects one member as a **logical master** for any merge operation, across the OpenVMS Cluster. Any difference in data is resolved by a propagation of the information from the merge master to *all* the other members.

The system responsible for doing the merge operation on a given shadow set, updates the **merge fence** for this shadow set after a range of LBNs is reconciled. This fence "proceeds" across the disk and separates the merged and unmerged portions of the shadow set.

Application read I/O requests to the merged side of the fence can be satisfied by any source member of the shadow set. Application read I/O requests to the unmerged side of the fence are also satisfied by any source member of the shadow set; however, any potential data differences—discovered by doing a data compare operation—are corrected on all members of the shadow set *before* returning the data to the user or application that requested it.

This method of dynamic correction of data inconsistencies during read requests allows a shadow set member to fail at any point during the merge operation without impacting data availability.

Volume Shadowing for OpenVMS supports both assisted and unassisted merge operations in the same cluster. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the shadowing software reevaluates each device in the changed configuration to determine whether it is capable of supporting the merge assist.

6.3.1 Unassisted Merge Operations

For systems running software earlier than OpenVMS Version 5.5–2, the merge operation is performed by the system and is known as an **unassisted** merge operation.

To ensure minimal impact on user I/O requests, volume shadowing implements a mechanism that causes the merge operation to give priority to user and application I/O requests.

The shadow server process performs merge operations as a background process, ensuring that when failures occur, they minimally impact user I/O. A side effect of this is that unassisted merge operations can often take an extended period of time to complete, depending on user I/O rates. Also, if another node fails before a merge completes, the current merge is abandoned and a new one is initiated from the beginning.

Note that data availability and integrity are fully preserved during merge operations regardless of their duration. All shadow set members contain equally valid data.

6.3.2 Assisted Merge Operations

Starting with OpenVMS Version 5.5–2, the merge operation includes enhancements for shadow set members that are configured on controllers that implement **assisted** merge capabilities. The assisted merge operation is also referred to as a **minimerge**. The minimerge feature significantly reduces the amount of time needed to perform merge operations. Usually, the minimerge completes in a few minutes.

By using information about write operations that were logged in controller memory, the minimerge is able to merge only those areas of the shadow set where write activity was known to have been in progress. This avoids the need for the total read and compare scans required by unassisted merge operations, thus reducing consumption of system I/O resources.

Controller-based write logs contain information about exactly which LBNs in the shadow set had write I/O requests outstanding (from a failed node). The node that performs the assisted merge operation uses the write logs to merge those LBNs that may be inconsistent across the shadow set. No controller-based write logs are maintained for a one member shadow set. No controller-based write logs are maintained if only one OpenVMS system has the shadow set mounted.

Note

The shadowing software does not automatically enable a minimerge on a system disk because of the requirement to consolidate crash dump files on a nonsystem disk. Dump off system disk (DOSD) is supported on both OpenVMS VAX and OpenVMS Alpha, starting with OpenVMS VAX Version 6.2 and OpenVMS Alpha Version 7.1. If DOSD is enabled, the system disk can be minimerged.

The minimerge operation is enabled on nodes running OpenVMS Version 5.5–2 or later. Volume shadowing automatically enables the minimerge if the controllers involved in accessing the physical members of the shadow set support it. See the Volume Shadowing for OpenVMS *Software Product Description* (SPD 27.29.*xx*) for a list of supported controllers. Note that minimerge operations are possible even when shadow set members are connected to different controllers. This is because write log entries are maintained on a per controller basis for each shadow set member.

Volume Shadowing for OpenVMS automatically disables minimerges if:

- The shadow set is mounted on a cluster node that is running an OpenVMS release earlier than Version 5.5–2.
- A shadow set member is mounted on a controller running a version of firmware that does not support minimerge.
- A shadow set member is mounted on a controller that has performance assists disabled.
- If any node in the cluster, with a shadow set mounted, is running a version of Volume Shadowing that has minimerge disabled.
- The shadow set is mounted on a standalone system. (Minimerge operations are not enabled on standalone systems.)
- The shadow set is mounted on only one node in the OpenVMS Cluster.

The following transient conditions can also cause a minimerge operation to be disabled:

- If an unassisted merge operation is already in progress when a node fails.

  In this situation, the shadowing software cannot interrupt the unassisted merge operation with a minimerge.
- When not enough write log entries are available in the controllers.

  The number of write log entries available is determined by controller capacity. The shadowing software dynamically determines when there are enough entries to maintain write I/O information successfully. If the number of available write log entries is too low, shadowing temporarily disables logging for that shadow set, and it returns existing available entries on this and every node in the cluster. After some time has passed, shadowing will attempt to reenable write logging on this shadow set.

  A controller retains a write log entry for each write I/O request until that entry is deleted by shadowing, or the controller is restarted.

  A multiple-unit controller shares its write log entries among multiple disks. This pool of write log entries is managed by the shadowing software. If a controller runs out of write log entries, shadowing disables minimerges and will perform an unassisted merge operation, should a node leave the cluster without first dismounting the shadow set. Note that write log exhaustion does not typically occur with disks on which the write logs are not shared.
- When the controller write logs become inaccessible for one of the following reasons, a minimerge operation is not possible.
  - Controller failure causes write logs to be lost or deleted.

– A device that is dual ported to multiple controllers fails over to its secondary controller. (If the secondary controller is capable of maintaining write logs, the minimerge operations are reestablished quickly.)

6.4 Controlling HSC Assisted Copy and Minimerge Operations

This section describes how to control assisted copy and minimerge operations on an HSC controller. It is not possible to control these operations on an HSJ controller.

To disable both the merge and copy performance assists on the HSC controller, follow these steps on each HSC controller for which you want to disable the assists:

1. Press Ctrl/C to get to the HSC prompt.
2. When the HSC> prompt appears on the terminal screen, enter the following commands:

```
HSC> RUN SETSHO
SETSHO> SET SERVER DISK/NOHOST_BASED_SHADOWING
SETSHO-I Your settings require an IMMEDIATE reboot on exit.
SETSHO> EXIT
SETSHO-Q Rebooting HSC.  Press RETURN to continue, CTRL/Y to abort:
```

After you issue these commands, the HSC controller automatically reboots:

```
INIPIO-I Booting...
```

To reenable the assists, follow the same procedure on your HSC controller, but use the /HOST_BASED_SHADOWING qualifier on the SET SERVER DISK command.

Use the HSC command SHOW ALL to see whether the assists are enabled or disabled. The following example shows a portion of the SHOW ALL display that indicates the shadowing assists status:

```
HSC> SHOW ALL

   .
   .
   .
      5-Jun-1997 16:42:51.40 Boot:  21-Feb-1997 13:07:19.47   Up: 2490:26
Version: V860          System ID: %X000011708247      Name: HSJNOT
Front Panel:  Secure                                  HSC Type: HSC90
 .
 .
 .
Disk Server Options:
        Disk Caching: Disabled
        Host Based Shadowing Assists: Enabled
        Variant Protocol: Enabled
        Disk Drive Controller Timeout: 2 seconds
        Maximum Sectors per Track: 74 sectors
        Disk Copy Data connection limit: 4      Active: 0
   .
   .
   .
```

6.5 What Happens to a Shadow Set When a System Fails?

When a system, controller, or disk failure occurs, the shadowing software maintains data availability by performing the appropriate copy, merge, or minimerge operation. The following subsections describe the courses of action taken when failures occur. The course of action taken depends on the event and whether the shadow set is in a steady state or a transient state.

Transitions from Steady State

When a shadow set is in a steady state, the following transitions can occur:

- If you mount a new disk into a steady state shadow set, the shadowing software performs a copy operation to make the new disk a full shadow set source member.
- If a failure occurs on a standalone system (the system crashes), on a steady state shadow set, the shadow set SCB reflects that the shadow set has been incorrectly dismounted. When the system is rebooted and the set is remounted, a copy operation is not necessary, but a merge operation is necessary and initiated.
- If a failure occurs in a cluster, the shadow set is merged by a remaining node that has the shadow set mounted:
  - If performance assists are enabled, and the controller-based write logs are available, the shadowing software performs a minimerge.
  - If performance assists are not enabled, the shadowing software performs a merge operation.

Once the transition completes, the disks contain identical information and the shadow set returns to a steady state.

Transitions During Copy Operations

The following list describes the transitions that can occur to a shadow set that is undergoing a copy operation:

- If you mount an additional disk into the shadow set that is already undergoing a copy operation, the shadowing software finishes the original copy operation before it begins another copy operation on the newly mounted disk.
- When a shadow set on a standalone system is undergoing a copy operation and the system fails, the copy operation aborts and the shadow set is left with the original members. For a standalone system, there is no recourse except to reboot the system and reinitiate the shadow set copy operation with a MOUNT command.
- If a shadow set is mounted on more than one node in the cluster and is undergoing a copy operation, should the node performing the copy operation dismount the virtual unit, another node in the cluster that has that shadow set mounted will continue the copy operation automatically.
- If a shadow set is mounted on more than one node in the cluster and is undergoing a copy operation, should the node performing the copy operation fail, another node in the cluster that has that shadow set mounted will continue the copy operation automatically.

When a node failure occurs during a shadow set copy operation, merge behavior depends on whether or not the shadowing performance assists are enabled.

- If minimerge is enabled and can be performed, the shadowing software interrupts the copy operation to perform a minimerge and then resumes the copy operation.
- If the minimerge is not enabled, the shadowing software marks the set as needing a merge operation and finishes the copy operation before beginning the merge operation.

Transitions During Minimerge Operations

When a shadow set is undergoing a minimerge operation, the following transitions can occur:

- If a new member is mounted into a shadow set when a minimerge operation is in progress, the minimerge is completed before the copy operation is started.
- If another system failure occurs before a pending minimerge has completed, the action taken depends on whether or not the shadowing performance assists are enabled and if the controller-based write logs are available.
  - If performance assists are enabled and if the controller-based write logs are available for the last node failure, the shadowing software restarts the minimerge from the beginning and adds new LBNs to the write log file based on the entries taken from the nodes that failed.
  - If performance assists are disabled, the shadowing software reverts to a merge operation. The performance assists might be disabled if the controller runs out of write logs or if a failover occurs from a controller with write logs to one that does not.

Transitions During Merge Operations

The following list describes the transitions that can occur to the shadow set that is undergoing a merge operation when performance assists are not available:

- If you add a new disk to a shadow set that is undergoing a merge operation, the shadowing software interrupts the merge operation to perform a copy operation. The merge operation resumes when the copy operation is completed.
- If a node failure occurs when the shadow set is performing a merge operation, the shadowing software abandons the current merge operation and starts a new merge operation.

6.6 Examples of Copy and Merge Operations

Example 6–1 shows what happens when you create a shadow set by mounting two disk volumes that have never been a part of a shadow set. Because neither disk volume has been a part of a shadow set, the Mount utility (MOUNT) assumes that the first disk named in the MOUNT command is the source member. When the Mount utility checks the volume labels on the disks, it discovers that they are different from each other, and the utility automatically performs a copy operation.

In this example, DSA0 is the virtual unit name, $1$DUA8 and $1$DUA89 are the names of the disk volumes, and SHADOWDISK is the volume label.

Example 6–1 Copy Operation: Creating a New Shadow Set

```
$ MOUNT DSA0: /SHADOW=($1$DUA8:,$1$DUA89:) SHADOWDISK
%MOUNT-I-MOUNTED, SHADOWDISK    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA8: (FUSS) is now a valid member
                      of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA89: (FUSS) added to the shadow
                      set with a copy operation

$ SHOW DEVICE DSA0:

Device                  Device           Error    Volume         Free  Trans Mnt
 Name                   Status           Count     Label       Blocks Count Cnt
DSA0:                   Mounted              0  SHADOWDISK      890937     1   1
$1$DUA8:        (FUSS)  ShadowSetMember      0  (member of DSA0:)

$1$DUA89:       (FUSS)  ShadowCopying        0  (copy trgt DSA0:  1% copied)
```

The SHOW DEVICE display in Example 6–1 shows the shadow set during the copy operation (transient state). Because the SCB information on $1$DUA8 and $1$DUA89 indicates that these devices have never been part of a shadow set, the shadowing software uses the first device named in the command line ($1$DUA8) as the source of the copy operation. The device status “ShadowSetMember” indicates that the $1$DUA8 device is a source shadow set member, and “ShadowCopying” indicates that the physical device $11$DUA89 is the target of a copy operation.

Suppose you want to add a new member to an existing shadow set, and the device you add is a previous member of this same shadow set. In this case, the volume label of the new member matches that of the current shadow set members, but the new member’s MOUNT generation number is out of date compared with those of the current members. Thus, the Mount utility automatically performs a copy operation on that member.

Example 6–2 shows the format of the MOUNT command and MOUNT status messages returned when you add the $3$DIA12 device to the shadow set represented by the DSA9999 virtual unit. Notice that you do not need to list the member units currently in the shadow set on the MOUNT command line.

Example 6–2 Copy Operation: Adding a Member to an Existing Shadow Set

```
$ MOUNT /SYSTEM DSA9999: /SHADOW=$3$DIA12: AXP_SYS_071
%MOUNT-I-MOUNTED, AXP_SYS_071 mounted on _DSA9999:
%MOUNT-I-SHDWMEMCOPY, _$3$DIA12: (SHAD03) added to the shadow
                      set with a copy operation

$ SHOW DEVICE DSA9999:

Device                  Device           Error    Volume         Free  Trans Mnt
 Name                   Status           Count     Label       Blocks Count Cnt
DSA9999:                Mounted              0  AXP_SYS_071     70610     1   1
$3$DIA7:      (BGFUSS)  ShadowSetMember      0  (member of DSA9999:)
$3$DIA5:      (SHAD03)  ShadowSetMember      0  (member of DSA9999:)

$3$DIA12:     (SHAD03)  ShadowCopying        0  (copy trgt DSA9999:  0% copied)
```

Example 6–3 shows what happens when a three-member shadow set is dissolved on one node and then is immediately remounted on another node. When the Mount utility checks the volume information on each member, it finds that the volume information is consistent across the shadow set. Thus, a copy operation is not necessary when the shadow set is mounted.

In Example 6–3, DSA10 is the virtual unit and $3$DUA10, $3$DUA11, and $3$DUA12 are the member volumes. The first part of the example displays the output from a SHOW DEVICE command, which shows that the shadow set is mounted and in a steady state. Then the user dismounts the DSA10 shadow set and immediately remounts it.

Example 6–3 No Copy Operation: Rebuilding a Shadow Set

```
$ SHOW DEVICE D

Device                  Device           Error    Volume         Free  Trans Mnt
 Name                   Status           Count     Label        Blocks Count Cnt
DSA10:                 Mounted              0  VAX_SYS_071      292971     1   1
$3$DUA10:    (MYNODE)  ShadowSetMember      0  (member of DSA10:)
$3$DUA11:    (MYNODE)  ShadowSetMember      0  (member of DSA10:)
$3$DUA12:    (MYNODE)  ShadowSetMember      0  (member of DSA10:)

$ DISMOUNT /NOUNLOAD DSA10:
%%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.40  %%%%%%%%%%%
$3$DUA10: (MYNODE) has been removed from shadow set.
%%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%%
$3$DUA11: (MYNODE) has been removed from shadow set.
%%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%%
$3$DUA12: (MYNODE) has been removed from shadow set.
%%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%%

$ MOUNT /SYSTEM DSA10: /SHADOW=($3$DUA10:, $3$DUA11:, $3$DUA12:) VAX_SYS_071
%MOUNT-I-MOUNTED, VAX_SYS_071 mounted on _DSA10:
%MOUNT-I-SHDWMEMSUCC, _$3$DUA10: (MYNODE) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$3$DUA11: (MYNODE) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$3$DUA12: (MYNODE) is now a valid member of
                      the shadow set
$
```

Example 6–4 shows the output from the SHOW DEVICE command at the time of the merge operation.

When a system fails, the volume information is left in a state that shows that each shadow set member was not properly dismounted. If you issue the MOUNT command again after the node reboots, the shadowing software automatically performs a merge operation on the shadow set.

Example 6–4 Merge Operation: Rebuilding a Shadow Set

```
$ SHOW DEVICE DSA42:
Device                  Device           Error    Volume         Free  Trans Mnt
 Name                   Status           Count     Label        Blocks Count Cnt
DSA42:                  Mounted              0    ATHRUZ        565997     1   1

$4$DUA2:     (MYNODE)   ShadowMergeMbr       0  (merging DSA42: 0% merged)
$4$DUA42:    (YRNODE)   ShadowMergeMbr       0  (merging DSA42: 0% merged)
```

7
Using Minicopy for Backing Up Data (Alpha)

This chapter describes the minicopy feature of Compaq Volume Shadowing for OpenVMS introduced in OpenVMS Version 7.3. Minicopy and its enabling technology, write bitmaps, are fully implemented on OpenVMS Alpha systems. OpenVMS VAX nodes can write to shadow sets that use this feature but they can neither create master write bitmaps nor manage them with DCL commands. In a mixed-architecture OpenVMS Cluster system, only one Alpha system is required in order to use minicopy.

The primary purpose of minicopy is to shorten the time it takes to return a shadow set member to the shadow set. The shadow set member is typically removed for the purpose of backing up the data and is then returned to membership in the shadow set.

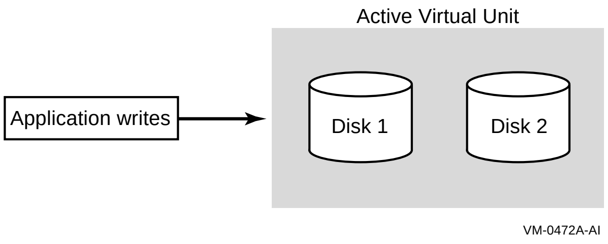
7.1 What Is Minicopy?

A minicopy operation is a streamlined copy operation. Minicopy ensures that the data on a shadow set member, when returned to the shadow set, is identical to the data in the shadow set.

A write bitmap tracks writes to a shadow set and is used to direct a minicopy operation when a shadow set member is returned to the shadow set.

Prior to the removal of a shadow set member, application writes are sent directly to the shadow set (also known as the virtual unit), as shown in Figure 7–1.

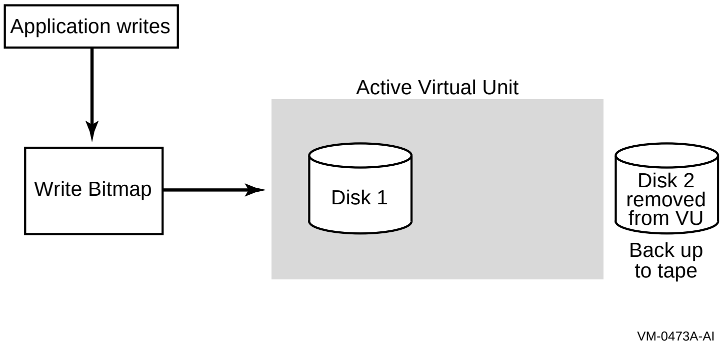
Figure 7–1 Application Writes to a Shadow Set



If you specify the minicopy qualifier (/POLICY=MINICOPY[=OPTIONAL]) when you dismount a shadow set member, a write bitmap is created. Subsequent writes to the shadow set are recorded by the write bitmap. Note that the write bitmap records only the logical block numbers (LBNs) of the associated writes, not the contents. The address is noted by setting one or more bits in a write bitmap; each bit corresponds to a range of 127 disk blocks.

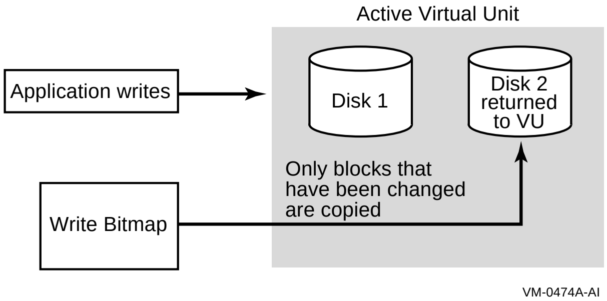
When data is written to any block in the range of 127 blocks, the bit in the write bitmap that corresponds to that range is set. After the bit or bits are set, the data is written to the shadow set, as shown in Figure 7–2.

Figure 7–2 Application Writes to a Write Bitmap



When the member is returned to the shadow set, the write bitmap is used to direct the minicopy operation, as shown in Figure 7–3. While the minicopy operation is taking place, the application continues to read and write to the shadow set.

Figure 7–3 Member Returned to the Shadow Set (Virtual Unit)



With the minicopy function, a full copy is no longer required when a member is returned to its shadow set, provided that the system managers follow the guidelines provided in Section 7.12. Note that, in this chapter, copy and full copy mean the same thing.

Several DCL commands can be used to manage write bitmaps. System parameters are provided for managing the write bitmap updates in an OpenVMS Cluster system and for setting an upper limit on shadow sets per node.

7.2 Different Uses for Copy and Minicopy

Prior to the introduction of minicopy, the copy operation was used for two purposes: to add members to a virtual unit, and to restore a member to the shadow set from which it was removed. In order for a member to rejoin the shadow set, its data must be made to match the data on the shadow set.

The copy operation remains the only method for creating a multiple member shadow set. The minicopy operation is now the preferred method for returning a member to a shadow set.

Typically, the reason for removing a shadow set member is to back up the data onto tape or disk.

To use a shadow set member to perform a backup operation, a system manager must perform the following steps:

- Using the SHOW DEVICE command, verify that the virtual unit is not marked for a merge operation.
- Stop the application I/O

  The method for doing this is specific to the application and the computing environment.
- Remove a shadow set member
- Reactivate the application
- Back up the data of the shadow set member to disk or tape

  While the backup is progressing, the application is writing data to the remaining members of the shadow set.
- Return the shadow set member to the shadow set when the backup is complete.

Note

For detailed information about the conditions under which this form of backup is supported, see Section 7.12.

7.3 Why Use Minicopy?

The minicopy operation can be used at the discretion of the system manager and at a time chosen by the system manager.

Because minicopy can significantly reduce the time it takes to return a member to a shadow set, it gives system managers greater flexibility in scheduling the removal and return of a shadow set member, and it improves availability.

The time needed to perform a minicopy is proportional to the amount of change that occurred to a shadow set in the disk's absence. A shorter copy time gives sites more flexibility in managing backups.

Table 7–1 shows the results from one series of tests, comparing full copy and minicopy times for shadow sets over a spectrum of write activity. The results presented in Table 7–1 and Table 7–2 should be used only as an indication of the performance gain you may experience using minicopy.

Table 7–1 Comparison of Minicopy and Full Copy Performance

Percentage of Bits Set	Time for Full Copy (seconds)	Time for Minicopy (seconds)	Minicopy Time as Percentage of Full Copy Time
100%	4196.09	3540.21	84.4%
90%	3881.95	3175.92	81.8%
80%	3480.50	2830.47	81.3%
75%	3290.67	2614.87	79.5%
70%	3194.05	2414.03	75.6%
60%	2809.06	2196.60	78.2%
50%	2448.39	1759.67	71.9%
40%	2076.52	1443.44	69.5%
30%	1691.51	1039.90	61.5%
25%	1545.94	775.35	50.2%
20%	1401.21	682.67	48.7%
15%	1198.80	554.06	46.2%
10%	1044.33	345.78	33.1%
5%	905.88	196.32	21.7%
2%	712.77	82.79	11.6%
1%	695.83	44.90	6.5%

Table 7–2 shows the results from another series of tests, comparing performance times of a hardware assisted copy (using MSCP disk copy data (DCD) commands on an HSJ controller) with a minicopy over a spectrum of write activity.

Table 7–2 Comparison of Minicopy and Hardware-Assist (DCD) Copy Performance

Percentage of Bits Set	DCD Copy Time (seconds)	Minicopy Time (seconds)	Minicopy Time as Percentage of DCD Copy Time
100%	1192.18	1181.61	99.1%
90%	1192.18	1097.03	92.0%
80%	1192.18	979.06	82.1%
70%	1192.18	862.66	72.4%
60%	1192.18	724.61	60.8%
50%	1192.18	627.24	52.6%
40%	1192.18	490.70	41.2%
30%	1192.18	384.45	32.3%
20%	1192.18	251.53	21.1%
10%	1192.18	128.11	10.7%
5%	1192.18	71.00	6.0%
0%	1192.18	8.32	0.7%

7.4 Procedure for Using Minicopy

To use the minicopy operation:

1. Start a write bitmap.

   A write bitmap is started by specifying the new qualifier /POLICY=MINICOPY[=OPTIONAL] to the DISMOUNT command when removing a member from a shadow set. You can also start a write bitmap with the MOUNT command when mounting a shadow set less one or two members, as described in Section 7.6.2.

2. Use the write bitmap for a minicopy operation when you return the shadow set member to the shadow set.

   If a write bitmap exists for the shadow set, a minicopy operation is invoked by default by the following MOUNT command:

   ```
   $ MOUNT DSA42/SHAD=$4$DUA42 volume-label
   ```

   To guarantee that only a minicopy takes place, use the /POLICY=MINICOPY qualifier, as shown in the following example:

   ```
   $ MOUNT DSA42/SHAD=$4$DUA42 volume-label/POLICY=MINICOPY
   ```

   If a write bitmap does not exist for a minicopy, the mount fails.

   When a minicopy operation is completed, the write bitmap associated with the disk is deleted.

For a detailed description of how to use /POLICY=MINICOPY[=OPTIONAL] with the MOUNT and DISMOUNT commands, see Section 7.6 and Section 7.7.

7.5 Minicopy Restrictions

The following restrictions apply to the use of minicopy:

- Minicopy can be used in an OpenVMS Cluster only when all nodes in the cluster are running OpenVMS Version 7.3 (or later). The exception to this rule is for nodes running OpenVMS Version 7.2-*xx* for which an upgrade will be made available soon after the release of OpenVMS Version 7.3. The upgrade will contain support for minicopy.

- The write bitmap can be used only once.

  For example, if you dismount a three-member shadow set consisting of D1, D2, and D3, and you then mount only D1 with the /POLICY=MINICOPY[=OPTIONAL] qualifier, a write bitmap is created. When you mount either D2 or D3 back into the shadow set, a minicopy is performed. When you mount the remaining member into the shadow set, a full copy is performed.

  To avoid the requirement of a full copy on the second member, dismount shadow set members one at a time, using /POLICY=MINICOPY for each. In that way, you will have a write bitmap for each shadow set member. When you return each disk to the shadow set, you will be able to do a minicopy for each.

- You cannot prioritize which member is updated by a minicopy operation if you specify two members in the same MOUNT command.

  To ensure that the minicopy occurs immediately, specify only one shadow set member in each MOUNT command. Wait for the minicopy to start, then add the next member with another MOUNT command.

- If a shadow set is already marked by the volume shadowing software for a merge operation, the merge operation occurs, and a write bitmap is not created.
- Unused write bitmaps for a virtual unit remain in memory when the virtual unit is dismounted. When the virtual unit is mounted again, they are automatically deleted.

  You can delete excess write bitmaps with the DELETE command, as described in Section 7.10.4.
- Misleading error message

  When you attempt to start a write bitmap and dismount a shadow set member (with DISMOUNT/POLICY=MINICOPY[=OPTIONAL]), the following error message is displayed if the shadow set member is in a merge operation or is a copy target:

  ```
  %DISM-F-SRCMEM, only source member of shadow set cannot be dismounted
  ```

  A more meaningful error message is planned for a future version of minicopy.
- If a node with one or more master bitmaps shuts down or crashes, the bitmaps on the node are deleted. Therefore, the shadow sets whose master bitmaps were deleted will not be able to use a minicopy operation. Instead, a full copy will be performed.
- If a shadow set member leaves the set because of an error or timeout, a write bitmap will not be available. A write bitmap is only available for a minicopy when a shadow set member is explicitly dismounted.
- If you intend to use the minicopy feature in a mixed-architecture OpenVMS Cluster system, Compaq advises you to set the SHADOW_MAX_COPY system parameter to zero on all VAX systems. This setting prevents a copy from being performed on a VAX when the intent was to perform a minicopy on an Alpha. In a mixed-architecture cluster, it is possible, although highly unlikely, that a VAX system could be assigned the task of adding a member to a shadow set. Because a VAX system cannot perform a minicopy, it would perform a full copy instead. Fo information about SHADOW_MAX_COPY, see Section 3.2.
- Additional steps are required to access the dump file from a system disk shadow set in which a minicopy operation was used to return a member to the shadow set. For more information, see Section 1.4.2.1.

7.6 Creating Write Bitmaps

The DCL commands DISMOUNT and MOUNT are used for creating write bitmaps. The MOUNT command is used for starting a minicopy operation using a write bitmap (see Section 7.7).

7.6.1 Creating a Write Bitmap With DISMOUNT

To create a write bitmap, you must specify the /POLICY=MINICOPY[=OPTIONAL] qualifier with the DISMOUNT command. If you specify /POLICY=MINICOPY=OPTIONAL, a write bitmap is created if there is sufficient memory. The disk is dismounted, regardless of whether a write bitmap is created.

The following example shows the use of the POLICY=MINICOPY=OPTIONAL qualifier with the DISMOUNT command:

```
$ DISMOUNT $4$DUA1 /POLICY=MINICOPY=OPTIONAL
```

This command removes $4$DUA1 from the shadow set and starts logging writes to a write bitmap, if possible.

If you specify /POLICY=MINICOPY only (that is, if you omit =OPTIONAL) and there is not enough memory on the node to create a write bitmap, the dismount fails.

7.6.2 Creating a Write Bitmap With MOUNT

You can create a write bitmap with the MOUNT command under the following conditions:

- The shadow set that was previously mounted was correctly dismounted.

  A multiple member shadow set must have been mounted before on the same node, on another node in the same cluster, or on another node outside the cluster.
- The shadow set is not currently mounted on any other node in the cluster (if the node on which you are mounting the shadow set is in a cluster).
- When you mount the shadow set, you mount it minus one member.
- You specify the /POLICY=MINICOPY[=OPTIONAL] qualifier to the MOUNT command.

The write bitmap created with this command is used for a minicopy operation when you later mount one of the former members of the shadow set into the set.

If you specify the /POLICY=MINICOPY=OPTIONAL qualifier and the shadow set is already mounted on another node in the cluster, the MOUNT command succeeds but a write bitmap is not created.

7.7 Starting a Minicopy Operation

If a write bitmap exists for a shadow set member, a minicopy operation starts by default when you specify the MOUNT command to return a shadow set member to the shadow set. This is equivalent to using the /POLICY=MINICOPY=OPTIONAL qualifier to the MOUNT command. If a write bitmap is not available, a full copy occurs.

An example of using the /POLICY=MINICOPY=OPTIONAL qualifier with the MOUNT command follows:

```
$ MOUNT DSA5/SHAD=$4$DUA0/POLICY=MINICOPY=OPTIONAL volume_label
```

If the shadow set (DSA5) is already mounted and a write bitmap exists for this shadow set member ($4$DUA0), the command adds the device $4$DUA0 to the shadow set with a minicopy operation. If a write bitmap is not available, this command adds $4$DUA0 with a full copy.

To ensure that a MOUNT command succeeds only if a minicopy can take place, specify /POLICY=MINICOPY only (that is, omit =OPTIONAL). If a write bitmap is not available, the mount will fail.

7.8 Master and Local Write Bitmaps

In an OpenVMS Cluster system, a **master write bitmap** is created on the node that issues the DISMOUNT or MOUNT command that creates the write bitmap. When a master write bitmap is created, a **local write bitmap** is automatically created on all other nodes in the cluster on which the shadow set is mounted, provided the nodes have sufficient memory.

A master write bitmap contains a record of all the writes to the shadow set from every node in the cluster that has the shadow set mounted. A local write bitmap tracks all the writes that the local node issues to a shadow set.

Note that if a node with a local bitmap writes to the same logical block number (LBN) of a shadow set more than once, only the LBN of the first write is sent to the master write bitmap. The minicopy operation uses the LBN for the update, not the number of changes to the same LBN.

When there is not enough memory on a node to create a local write bitmap, the node sends a message for each write directly to the master write bitmap. This will degrade application write performance.

7.9 System Parameters for Managing Write Bitmap Messages and Shadow Set Limit

System parameters are available for managing the update traffic between a master write bitmap and its corresponding local write bitmaps in an OpenVMS Cluster system. Another new system parameter controls whether write bitmap system messages are sent to the operator console and if they are to be sent, the volume of messages. These system parameters are dynamic, that is, they can be changed on a running system. They are shown in Table 3–3.

In addition, a new volume shadowing system parameter, SHADOW_MAX_UNIT, is provided for specifying the maximum number of shadow sets that can exist on a node. This parameter is described in Table 3–1.

The system parameters for managing write bitmap message traffic control whether the messages are buffered and then packaged in a single SCS message to update the master write bitmap or whether each one is sent immediately. The system parameters are used to set the upper and lower threshholds of message traffic and a time interval during which the traffic is measured.

The writes issued by each remote node are, by default, sent one by one in individual SCS messages to the node with the master write bitmap. This is known as **single-message mode**.

If the writes sent by a remote node reach an upper threshhold of messages during a specified interval, single-message mode switches to **buffered-message mode**. In buffered-message mode, the messages (up to nine) are collected for a specified interval and then sent in one SCS message. During periods of increased message traffic, grouping multiple messages to send in one SCS message to the master write bitmap is generally more efficient than sending each message separately.

7.10 Managing Write Bitmaps With DCL Commands

The SHOW DEVICE, SHOW CLUSTER, and DELETE commands have been extended for managing write bitmaps.

7.10.1 Determining Write Bitmap Support and Activity

You can find out whether a write bitmap exists for a shadow set by using the DCL command SHOW DEVICE/FULL *device-name*. If a shadow set supports write bitmaps, **device supports bitmaps** is displayed along with either **bitmaps active** or **no bitmaps active**. If the device does not support write bitmaps, no message pertaining to write bitmaps is displayed.

The following command example shows that no write bitmap is active:

```
$ SHOW DEVICE/FULL DSA0

Disk DSA0:, device type RAM Disk, is online, mounted, file-oriented device,
    shareable, available to cluster, error logging is enabled, device supports
    bitmaps (no bitmaps active).

    Error count                    0    Operations completed                 47
    Owner process                 ""    Owner UIC                      [SYSTEM]
    Owner process ID        00000000    Dev Prot            S:RWPL,O:RWPL,G:R,W
    Reference count                2    Default buffer size                 512
    Total blocks                1000    Sectors per track                    64
    Total cylinders                1    Tracks per cylinder                  32
  Volume label              "TST0"    Relative volume number                0
    Cluster size                   1    Transaction count                     1
    Free blocks                  969    Maximum files allowed               250
    Extend quantity                5    Mount count                           1
    Mount status              System    Cache name      "_$252$DUA721:XQPCACHE"
    Extent cache size             64    Maximum blocks in extent cache       96
    File ID cache size            64    Blocks currently in extent cache      0
    Quota cache size               0    Maximum buffers in FCP cache        404
    Volume owner UIC        [SYSTEM]    Vol Prot    S:RWCD,O:RWCD,G:RWCD,W:RWCD

  Volume Status:  ODS-2, subject to mount verification, file high-water marking,
      write-back caching enabled.

Disk $252$MDA0:, device type RAM Disk, is online, member of shadow set DSA0:.

    Error count                    0    Shadow member operation count       128
    Allocation class             252


Disk $252$MDA1:, device type RAM Disk, is online, member of shadow set DSA0:.

    Error count                    0    Shadow member operation count       157
    Allocation class             252
```

7.10.2 Displaying Write Bitmap IDs

You can find out the ID of each write bitmap on a node with the DCL command SHOW DEVICE/BITMAP *device-name*. The /BITMAP qualifier cannot be combined with other SHOW DEVICE qualifiers except /FULL. The SHOW DEVICE/BITMAP display can be brief or full; brief is the default.

If no bitmap is active, no bitmap ID is displayed. The phrase **no bitmaps active** is displayed.

The following example shows a SHOW DEVICE/BITMAP display:

```
$ SHOW DEVICE/BITMAP DSA1
Device         BitMap        Size        Percent of
Name           ID            (Bytes)     Full Copy
DSA1:          00010001      652         11%
```

The following example shows a SHOW DEVICE/BITMAP/FULL display:

```
$ SHOW DEVICE DSA12/BITMAP/FULL
Device  Bitmap  Size   Percent of  Active Creation            Master  Cluster Local Delete  Bitmap
Name    ID     (bytes) Full Copy          Date/Time           Node    Size    Set   Pending Name

DSA12: 00010001  652    11%        Yes  5-MAY-2000 13:30:25:30 300F2   127     2%    No      SHAD$TEST
```

7.10.3 Displaying Write Bitmap Status of Cluster Members

You can specify bitmap information in the SHOW CLUSTER display by issuing the ADD BITMAPS command, as shown in the following example:

```
$ SHOW CLUSTER/CONTINUOUS

Command > ADD BITMAPS
Command > ADD CSIO

View of Cluster from system ID 57348  node: WPCM1         14-FEB-2000 13:38:53

      SYSTEMS              MEMBERS
  NODE   SOFTWARE    CSID   STATUS    BITMAPS

 CSGF1   VMS X6TF    300F2   MEMBER    MINICOPY

 HSD30Y  HSD YA01    300E6

 HS1CP2  HSD V31D    300F4

 CSGF2   VMS X6TF    300D0  MEMBER    MINICOPY
```

In this example, MINICOPY means that nodes CSGF1 and CSGF2 are capable of supporting minicopy operations. If a cluster node does not support minicopy, the term UNSUPPORTED replaces MINICOPY in the display, and the minicopy function is disabled in the cluster.

7.10.4 Deleting Write Bitmaps

After a minicopy operation is completed, the corresponding write bitmap is automatically deleted.

There may be times when you would like to delete one or more bitmaps. Reasons for deleting bitmaps include the following:

- To recover the memory consumed by a write bitmap
- To stop the recording of the write bitmap

You can delete write bitmaps with the DCL command DELETE with the /BITMAP qualifer. You use the bitmap qualifer to specify the ID of the bitmap you want to delete. For example:

```
$ DELETE/BITMAP/LOG 00010001

%DELETE-I-DELETED, 00010001 deleted
```

7.11 Performance Implications of Write Bitmaps

There are two aspects of write bitmaps that affect performance; the message traffic that occurs between local and master write bitmaps and the size requirements of each bitmap.

The message traffic can be adjusted by changing the message mode. Single message mode is the default. Buffered message mode can improve overall system performance, but the time to record each process's write in the master write bitmap usually takes longer. These modes are described in detail in Section 7.9.

Additional memory is required to support write bitmaps, as described in Section 1.3.1. Depending on the memory usage of your system, it may require additional memory.

7.12 Guidelines for Using a Shadow Set Member for Backup

Volume Shadowing for OpenVMS can be used as an online backup mechanism. With proper application design and proper operating procedures, shadow set members removed from mounted shadow sets constitute a valid backup.

To obtain a copy of a file system or application database for backup purposes using Volume Shadowing for OpenVMS, the standard recommendation has been to determine that the virtual unit is not in a merge state, to dismount the virtual unit, then to remount the virtual unit minus one member. Prior to OpenVMS Version 7.3, there was a documented general restriction on dismounting an individual shadow set member for backup purposes from a virtual unit that is mounted and in active use. This restriction relates to data consistency of the file system, application data, or database located on that virtual unit, at the time the member is removed.

However, Compaq recognizes that this restriction is unacceptable when true 24x7 application availability is a requirement, and that it is unnecessary if appropriate data-consistency measures can be ensured through a combination of application software and system management practice.

7.12.1 Removing a Shadow Set Member for Backup

With currently supported OpenVMS releases, DISMOUNT can be used to remove members from shadow sets for the purpose of backing up data, provided that the following requirements are met:

- The shadow sets *must not be in a merge state.* Compaq also recommends that there not be any shadow copy operations in progress.
- Adequate redundancy must be maintained after member removal. Compaq recommends that the active shadow set never be reduced to less than two members; alternatively, the shadow sets should employ controller mirroring or RAID 5.

Follow these steps to remove the member:

1. Establish data consistency over the virtual units through system management procedures or application software, or both. This is a complex topic and is the subject of most of the rest of this chapter.
2. Ensure that the requirements regarding merge state and adequate redundancy are met.
3. Remove the members to be backed up from the virtual units.

4. Terminate the data consistency measures taken in step 1.

7.12.2 Data Consistency Requirements

Removal of a shadow set member results in what is called a **crash-consistent copy.** That is, the copy of the data on the removed member is of the same level of consistency as what would result if the system had failed at that instant. The ability to recover from a crash-consistent copy is ensured by a combination of application design, system and database design, and operational procedures. The procedures to ensure recoverability depend on application and system design and will be different for each site.

The conditions that might exist at the time of a system failure range from no data having been written, to writes that occurred but were not yet written to disk, to all data having been written. The following sections describe components and actions of the operating system that may be involved if a failure occurs and there are outstanding writes, that is, writes that occurred but were not written to disk. You must consider these issues when establishing procedures to ensure data consistency in your environment.

7.12.3 Application Activity

To achieve data consistency, application activity should be suspended and no operations should be in progress. Operations in progress can result in inconsistencies in the backed-up application data. While many interactive applications tend to become quiet if there is no user activity, the reliable suspension of application activity requires cooperation in the application itself. Journaling and transaction techniques can be used to address in-progress inconsistencies but must be used with extreme care. In addition to specific applications, miscellaneous interactive use of the system that might affect the data to be backed up must also be suspended.

7.12.4 RMS Considerations

Applications that use RMS file access must be aware of the following issues.

7.12.4.1 Caching and Deferred Writes

RMS can, at the application's option, defer disk writes to some time after it has reported completion of an update to the application. The data on disk will be updated in response to other demands on the RMS buffer cache and to references to the same or nearby data by cooperating processes in a shared file environment.

Writes to sequential files are always buffered in memory and are not written to disk until the buffer is full.

7.12.4.2 End of File

The end-of-file pointer of a sequential file is normally updated only when the file is closed.

7.12.4.3 Index Updates

The update of a single record in an indexed file may result in multiple index updates. Any of these updates can be cached at the application's option. Splitting a shadow set with an incomplete index update will result in inconsistencies between the indexes and data records. If deferred writes are disabled, RMS orders writes so that an incomplete index update may result in a missing update but never in a corrupt index. However, if deferred writes are enabled, the order in which index updates are written is unpredictable.

7.12.4.4 Run-Time Libraries

The I/O libraries of various languages use a variety of RMS buffering and deferred write options. Some languages allow application control over the RMS options.

7.12.4.5 $FLUSH

Applications can use the $FLUSH service to guarantee data consistency. The $FLUSH service guarantees that all updates completed by the application (including end of file for sequential files) have been recorded on the disk.

7.12.4.6 Journaling and Transactions

RMS provides optional roll-forward, roll-back, and recovery unit journals, and supports transaction recovery using the OpenVMS transaction services. These features can be used to back out in-progress updates from a removed shadow set member. Using such techniques requires careful data and application design. It is critical that virtual units containing journals be backed up along with the base data files.

7.12.5 Mapped Files

OpenVMS allows access to files as backing store for virtual memory through the process and global section services. In this mode of access, the virtual address space of the process acts as a cache on the file data. OpenVMS provides the $UPDSEC service to force updates to the backing file.

7.12.6 Database Systems

Database management systems, such as those from Oracle, are well suited to backup by splitting shadow sets, since they have full journaling and transaction recovery built in. Before dismounting shadow set members, an Oracle database should be put into “backup mode” using SQL commands of the following form:

```
ALTER TABLESPACE tablespace-name BEGIN BACKUP;
```

This command establishes a recovery point for each component file of the tablespace. The recovery point ensures that the backup copy of the database can subsequently be recovered to a consistent state. Backup mode is terminated with commands of the following form:

```
ALTER TABLESPACE tablespace-name END BACKUP;
```

It is critical to back up the database logs and control files as well as the database data files.

7.12.7 Base File System

The base OpenVMS file system caches free space. However, all file metadata operations (such as create and delete) are made with a “careful write-through” strategy so that the results are stable on disk before completion is reported to the application. Some free space may be lost, which can be recovered with an ordinary disk rebuild. If file operations are in progress at the instant the shadow member is dismounted, minor inconsistencies may result that can be repaired with ANALYZE/DISK. The careful write ordering ensures that any inconsistencies do not jeopardize file integrity before the disk is repaired.

7.12.8 $QIO File Access and VIOC

OpenVMS maintains a virtual I/O cache (VIOC) to cache file data. However, this cache is write through. OpenVMS Version 7.3 introduces extended file cache (XFC), which is also write through.

File writes using the $QIO service are completed to disk before completion is reported to the caller.

7.12.9 Multiple Shadow Sets

Multiple shadow sets present the biggest challenge to splitting shadow sets for backup. While the removal of a single shadow set member is instantaneous, there is no way to remove members of multiple shadow sets simultaneously. If the data that must be backed up consistently spans multiple shadow sets, application activity must be suspended while all shadow set members are being dismounted. Otherwise, the data will not be crash consistent across the multiple volumes. Command procedures or other automated techniques are recommended to speed the dismount of related shadow sets. If multiple shadow sets contain portions of an Oracle database, putting the database into backup mode ensures recoverability of the database.

7.12.10 Host-Based RAID

The OpenVMS software RAID driver presents a special case for multiple shadow sets. A software RAID set may be constructed of multiple shadow sets, each consisting of multiple members. With the management functions of the software RAID driver, it is possible to dismount one member of each of the constituent shadow sets in an atomic operation. Management of shadow sets used under the RAID software must always be done using the RAID management commands to ensure consistency.

7.12.11 OpenVMS Cluster Operation

All management operations used to attain data consistency must be performed for all members of an OpenVMS Cluster system on which the affected applications are running.

7.12.12 Testing

Testing alone cannot guarantee the correctness of a backup procedure. However, testing is a critical component of designing any backup and recovery process.

7.12.13 Restoring Data

Too often, organizations concentrate on the backup process with little thought to how their data will be restored. Remember that the ultimate goal of any backup strategy is to recover data in the event of a disaster. Restore and recovery procedures must be designed and tested as carefully as the backup procedures.

7.12.14 Revalidation of Data Consistency Methods

The discussion in this section is based on features and behavior of OpenVMS Version 7.3 and applies to prior versions as well. Future versions of OpenVMS may have additional features or different behavior that affect the procedures necessary for data consistency. Sites that upgrade to future versions of OpenVMS must reevaluate their procedures and be prepared to make changes or to employ nonstandard settings in OpenVMS to ensure that their backups remain consistent.

8

Performing System Management Tasks on Shadowed Systems

This chapter explains how to accomplish system maintenance tasks on a standalone system or an OpenVMS Cluster system that uses volume shadowing. Refer to Chapter 3 for information about setting up and booting a system to use volume shadowing.

8.1 Upgrading the Operating System on a System Disk Shadow Set

It is important to upgrade the operating system at a time when your system can afford to have its shadowing support disabled. This is because you *cannot* upgrade to new versions of the OpenVMS operating system on a shadowed system disk. If you attempt to upgrade a system disk while it is an active member of a shadow set, the upgrade procedure will fail.

Procedure for Upgrading Your Operating System

This procedure is divided into four parts. Part 1 describes how to prepare a shadowed system disk for the upgrade. Part 2 describes how to perform the upgrade. Part 3 describes how to enable volume shadowing on the upgraded system. Part 4 shows how to boot other nodes in an OpenVMS Cluster system with and without volume shadowing.

Part 1: Preparing a Shadowed System Disk

1. On OpenVMS Cluster systems, choose the node on which you want to perform the upgrade.
2. Create a nonshadowed system disk to do the upgrade using either of these methods:
    - Prepare a copy of the current system disk to use as the target of the upgrade procedure. See Section 8.3.2.
    - Use BACKUP to create a compressed copy of the shadow set on a single scratch disk (a disk with no useful data). See in Section 8.3.4 for an example.
3. Enter the MOUNT/OVERRIDE=SHADOW_MEMBERSHIP command on the upgrade disk to zero the shadowing-specific information on the storage control block (SCB) of the disk. Do not mount the disk for systemwide or clusterwide access; omit the /SYSTEM and /CLUSTER qualifiers on the MOUNT command line.
4. Use the DCL command SET VOLUME/LABEL=*volume-label device-spec[:]* to change the label on the upgrade disk. (The SET VOLUME/LABEL command requires write access [W] to the index file on the volume. If you are not the volume owner, you must have either a system UIC or the SYSPRV privilege.) For OpenVMS Cluster systems, ensure that the volume label is a unique name across the cluster.

Note

If you need to change the volume label of a disk that is mounted across the cluster, be sure you change the label on all nodes in the OpenVMS Cluster system. For example, you could propagate the volume label change to all nodes in the cluster with one SYSMAN utility command, after you define the environment as the cluster:

```
SYSMAN> SET ENVIRONMENT/CLUSTER
SYSMAN> DO SET VOLUME/LABEL=new-label disk-device-name:
```

5. Ensure that the boot command line or file boots from the upgrade disk. The manner in which you store the boot command information depends on the processor on which you are working. For more information about storing boot commands, see the instructions in your hardware installation guide, the upgrade and installation supplement for your VAX computer, or the upgrade and installation manual for your Alpha computer.

   If volume shadowing is enabled on the node, disable it according to the instructions in step 6. Otherwise, continue with Part 2 to upgrade the system.

6. Prepare to perform the upgrade procedure by disabling system disk shadowing (if it is enabled) on the node to be upgraded.

   Note

   You cannot perform an upgrade on a shadowed system disk. If your system is set up to boot from a shadow set, you must disable shadowing the system disk before performing the upgrade. This requires changing SYSGEN parameter values interactively using the SYSGEN utility.

   Invoke SYSGEN by entering the following command:

   ```
   $ RUN SYS$SYSTEM:SYSGEN
   ```

   On OpenVMS Alpha systems, enter the following:

   ```
   SYSGEN> USE upgrade-disk:[SYSn.SYSEXE]ALPHAVMSSYS.PAR
   SYSGEN>
   ```

   On OpenVMS VAX systems, enter the following:

   ```
   SYSGEN> USE upgrade-disk:[SYSn.SYSEXE]VAXVMSSYS.PAR
   SYSGEN>
   ```

   The USE command defines the system parameter file from which data is to be retrieved. You should replace the variable *upgrade-disk* with the name of the disk to be upgraded. For the variable *n* in [SYS*n*.SYSEXE], use the system root directory you want to boot from (this is generally the same root you booted from before you started the upgrade procedure).

   Disable shadowing of the system disk by setting the SYSGEN parameter SHADOW_SYS_DISK to 0, as follows:

   ```
   SYSGEN> SET SHADOW_SYS_DISK 0
   ```

On OpenVMS Alpha systems, enter:

```
SYSGEN> WRITE upgrade-disk:[SYSn.SYSEXE]ALPHAVMSSYS.PAR
```

On OpenVMS VAX systems, enter:

```
SYSGEN> WRITE upgrade-disk:[SYSn.SYSEXE]VAXVMSSYS.PAR
```

Type EXIT or press Ctrl/Z to exit the SYSGEN utility and return to the DCL command level.

You must also change parameters in the MODPARAMS.DAT file *before* shutting down the system. Changing parameters before shutdown ensures that the new system parameter values take effect when AUTOGEN reads the MODPARAMS.DAT file and reboots the nodes. Edit *upgrade-disk*:[SYS*n*:SYSEXE]MODPARAMS.DAT and set SHADOWING and SHADOW_SYS_DISK to 0.

Even if you plan to use the upgraded system disk to upgrade the operating system on other OpenVMS Cluster nodes, you should complete the upgrade on one node before altering parameters for other nodes. Proceed to Part 2.

Part 2: Performing the Upgrade

1. Boot from and perform the upgrade on the single, nonshadowed disk. Follow the upgrade procedure described in the OpenVMS upgrade and installation manual.
2. If you are upgrading a system that already has the volume shadowing software installed and licensed, then skip to Part 3.

   Otherwise, you must register the Volume Shadowing for OpenVMS Product Authorization Key (PAK) or keys. PAK registration is described in the release notes and cover letter supplied with your installation kit.

Part 3: Enabling Volume Shadowing on the Upgraded System

Once the upgrade is complete and the upgraded node has finished running AUTOGEN, you can enable shadowing for the upgraded node using the following steps.

1. Invoke the System Generation utility (SYSGEN) by entering the following command:

   ```
   $ RUN SYS$SYSTEM:SYSGEN
   SYSGEN> USE CURRENT
   SYSGEN>
   ```

   The USE CURRENT command initializes the SYSGEN work area with the source information from the current system parameter file on disk. (To find out the current value of system parameters, use the SHOW command [for example, SHOW SHADOWING] to see the current system parameter values as well as the minimum, maximum, and default values of the parameters.)

   To enable shadowing, set the system parameter SHADOWING to 2. If the system disk is to be a shadow set, set the system parameter SHADOW_SYS_DISK to 1, and set the SHADOW_SYS_UNIT parameter to the unit number of the virtual unit, as follows (assume the system disk virtual unit is DSA54):

   ```
   SYSGEN> SET SHADOWING 2
   SYSGEN> SET SHADOW_SYS_DISK 1
   SYSGEN> SET SHADOW_SYS_UNIT 54
   SYSGEN> WRITE CURRENT
   ```

Type EXIT or press Ctrl/Z to exit the SYSGEN utility and return to the DCL command level.

2. To ensure that volume shadowing is enabled each time AUTOGEN executes, edit the SYS$SYSTEM:MODPARAMS.DAT file to set the shadowing parameters. For OpenVMS Cluster systems, set system parameters in MODPARAMS.DAT on each node that uses volume shadowing. See Chapter 3 for more information about editing the MODPARAMS.DAT file.

3. Shut down the system on which you performed the upgrade, and reboot.

Part 4: Booting Other Nodes in the OpenVMS Cluster from the Upgraded Disk

If other nodes boot from the upgraded disk, the OpenVMS upgrade procedure automatically upgrades and runs AUTOGEN on each node when it is booted. The procedure for booting other nodes from the upgraded disk differs based on whether the upgraded disk has been made a shadow set.

1. If the upgraded disk is not yet a shadow set:

   a. Disable shadowing (if it is enabled) for the system disk on the nodes to be upgraded.

   b. Alter the boot files for those nodes so they boot from the upgraded disk.

   c. Make sure the system parameters in the node-specific SYS$SYSTEM:MODPARAMS.DAT files are correct (as described in Section 3.3.1). When the OpenVMS upgrade procedure invokes AUTOGEN, it will use these parameter settings.

   d. Boot the nodes from the upgraded disk.

2. If the upgraded disk is already a shadow set member, additional steps are required:

   a. For each node to be booted from the upgraded disk, edit VAXVMSSYS.PAR for VAX systems and ALPHAVMSSYS.PAR for Alpha systems, and MODPARAMS.DAT to enable system disk shadowing. Set SHADOWING to 2, SHADOW_SYS_DISK to 1, and SHADOW_SYS_UNIT to the number of the system disk's virtual unit name. Remember to modify the files on the upgraded disk, not on the system disk, prior to upgrade.

   b. Modify the computer console so that the system boots from the upgraded disk.

      On VAX computers, depending on which model you have, you can alter the boot file on the console media or use a console command to change nonvolatile RAM.

      On Alpha computers, you can use the SET BOOTDEF_DEV console command. For more information, see the hardware information or the upgrade and installation manual for your system.

   c. Boot each node. With shadowing enabled in each node's ALPHAVMSSYS.PAR or VAXVMSSYS.PAR on the upgraded disk, the node will be able to boot from the shadowed (upgraded) system disk.

Once you have successfully upgraded the system or systems and you have completed other postupgrade work (such as layered product installations), perform the following steps:

1. Mount additional shadow set members into the shadow set, if necessary. Do not use a command procedure to add members to a system disk shadow set. For more information, see Section 3.4.
2. Back up your new system disk shadow set. If you usually use online BACKUP for this task, you can use one of the procedures described in Section 8.3. If you usually use standalone BACKUP at this point, refer to Section 8.3.1.

8.2 Modifying Data on Individual Shadow Set Members

Generally, users and applications access a shadow set through the virtual unit. Occasionally, you may want to change the data on an individual shadow set member and then pass the changed data to other shadow set members.

The following series of commands demonstrates how you can dissolve and recreate the shadow set to perform specialized processes on one shadow set member and transfer the change to the other shadow set members.

The following command mounts a shadow set with three shadow set members:

```
$ MOUNT DSA9:/SHADOW=($45$DUA2:,$45$DUA4:,$45$DUA8:) LURK1
```

The following command dissolves the shadow set mounted in the previous command and makes the individual shadow set members available:

```
$ DISMOUNT DSA9:
```

The following command mounts one former shadow set member as a disk volume outside of the shadow set:

```
$ MOUNT/OVERRIDE=SHADOW_MEMBERSHIP $45$DUA2: LURK1
```

In this command, in order to have write access, you must use the /OVERRIDE=SHADOW_MEMBERSHIP qualifier to zero the shadow set generation number. At this point, the disk is mounted as a nonshadowed volume and can be modified as required.

Before creating a new shadow set, dismount the $45$DUA2 physical disk, as follows:

```
$ DISMOUNT/NOUNLOAD $45$DUA2
$ MOUNT DSA9:/SHADOW=$45$DUA2: LURK1
```

The second command recreates the shadow set with $45$DUA2 as the only member.

Note that mounting $45$DUA2 with the /OVERRIDE=SHADOW_MEMBERSHIP qualifier automatically zeroed the volume shadowing generation number. If you were to specify *all* the former members of the shadow set in the same command line, the MOUNT command would consider $45$DUA2 an unrelated volume and would determine that it requires a copy operation. This would overwrite the earlier modifications.

To save the current contents of $45$DUA2, add the other two former shadow set members to the new shadow set with a subsequent MOUNT command:

```
$ MOUNT DSA9:/SHADOW=($45$DUA4:,$45$DUA8:) LURK1
```

In this command, $45$DUA4 and $45$DUA8 are added to the shadow set DSA9. This recreates the original shadow set, except that each shadow set member now has the benefit of the changed data that was done to the single shadow set member.

8.3 Performing Backup Operations on a Shadow Set

You should think of a shadow set as a single, highly available disk. As such, backup techniques for nonshadowed disks apply to shadow set virtual units. However, to preserve the consistency and integrity of the shadow set, avoid removing a physical member of the shadow set without dismounting the virtual unit unless you have scrupulously followed the guidelines in Section 7.12. If you leave some disk members of a shadow set active during the backup operation, data integrity is compromised because some disks in the shadow set may have files open. Refer to Section 4.8.3 for information about obtaining a member of a shadow set for the source of a backup operation.

The following list describes options that are available when backing up shadow sets that are not available with nonshadowed disks.

- To obtain a defragmented backup of a shadowed disk, begin by closing files and stopping application access to the disks. Dismount the virtual unit to dissolve the shadow set. Use the /NOUNLOAD qualifier to avoid spinning down the members of the shadow set. Remount the virtual unit as a private device, and use BACKUP/IMAGE (see Section 8.3.4) with the virtual unit as the source of the backup operation. This is the recommended method of backing up shadow sets.
- To minimize the amount of time that data is unavailable to applications, consider remounting the shadow set with one less member (see Section 4.8.3). Then back up the dismounted member. This technique keeps the shadow set in service at the same time that you perform a backup operation. Once the backup is complete, remount the member into the shadow set. The shadowing software performs a copy, or minicopy, operation to make that member consistent with the other members of the shadow set.

  If a spare disk of the type present in the shadow set is available, consider mounting the spare disk into the shadow set to minimize the time that the shadow set runs with reduced membership. Then, the member that served as the source of the backup can become a spare disk.
- To ensure complete integrity of the backup of the system disk, you must shut down the systems that boot from it. For system disk shadow sets, you should also dismount the virtual unit by any other systems that have it mounted. Then remount the virtual unit as a private device on one of the systems that was not shut down, and use it as the source for a BACKUP/IMAGE operations (see Section 8.3.4).

  In addition, to provide system disk shadowing quickly as you perform a backup operation, remount the shadow set minus one member. Back up that member and either remount it into the shadow set or mount a spare disk. You can use standalone BACKUP (VAX) or the menu-driven BACKUP procedure (Alpha) on one of the systems that is down while the other systems are rebooted.
- To do an incremental backup, use the virtual unit, not a single member of the shadow set. This is because incremental backups alter information in file headers. If you perform an incremental backup on a removed member of a shadow set, that member needs to be the target of a copy operation.

HSC BACKUP and RESTORE techniques are not recommended for saving and restoring the contents of a shadow set member. These HSC utilities are applicable to the disk geometry only, not to the OpenVMS file system. Although HSC BACKUP and RESTORE techniques save and restore the contents of an entire disk volume (including blocks that may not be in use by the file system on that volume), they do not save and restore specific files, groups of files, directories, or subdirectories. In addition, these utilities do not defragment a disk. Moreover, the utilities cannot restore the context of a shadow set virtual unit.

The following sections describe several approaches to shadow set backup operations.

8.3.1 Restrictions on BACKUP Procedures

On VAX systems, accessing shadow sets from standalone BACKUP is not supported. The command procedures supplied with OpenVMS for building standalone BACKUP kits are designed to prevent standalone BACKUP from using volume shadowing improperly. However, these checks can easily be overridden by a well-informed and sufficiently privileged user.

Note the following restrictions for standalone BACKUP on VAX systems that use volume shadowing:

- Do not boot standalone BACKUP from an alternative root on a shadowed system disk while other nodes are booting from the same shadowed system disk. If you do this, the boot attempt will fail.
- Standalone BACKUP does not mount virtual units. This makes access to virtual units impossible from standalone BACKUP.
- Do not assume that standalone BACKUP prevents you from accessing a shadow set member unit. You must prevent standalone BACKUP from sending output to a disk mounted on any other OpenVMS Cluster member, either as a directly accessible disk or as the member of a shadow set.

On Alpha computers, the same restrictions apply. You cannot use the standalone, menu-driven procedure included on the OpenVMS Alpha operating system distribution compact disc to perform BACKUP operations on shadow sets.

8.3.2 Using Copy Operations to Create a Backup

This example shows how to use volume shadowing copy operations to create an offline identical disk volume that you can then use as a backup of your shadow set. The following command creates a shadow set with one shadow set member:

```
$ MOUNT DSA0:/SHADOW=$1$DUA10: SHADOWFACTS
%MOUNT-I-MOUNTED, SHADOWFACTS  mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a
                      valid member of the shadow set
```

The following command adds a second member, $1$DUA11, to the shadow set:

```
$ MOUNT DSA0:/SHADOW=$1$DUA11: SHADOWFACTS
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK02) added to the shadow
                      set with a copy operation
```

At this point you must wait for the copy operation to complete before dismounting the shadow set. When the copy operation is complete, messages are sent to the system console and to any operators enabled to receive them.

The following command dismounts the shadow set, leaving $1$DUA10 and $1$DUA11 with logically identical volumes:

```
$ DISMOUNT DSA0:
```

At this point you can re-create the shadow set with one of the volumes and keep the other as a backup, or use it as a source for the backup operation.

8.3.3 Using the OpenVMS Backup Utility

Generally you can use the OpenVMS Backup utility (BACKUP) with shadow sets as you do with regular volumes. (See the *OpenVMS System Manager's Manual, Volume 1: Essentials* for a description of how to back up volumes.) You can create BACKUP save sets or copies from shadow sets by using the shadow set virtual unit name instead of a physical device name as the input specifier. However, you cannot always restore to a shadow set by listing the virtual unit name as an output specifier. The main restriction to any backup restoration is that you cannot mount the target volume with the /FOREIGN qualifier. The proper procedure for a BACKUP/IMAGE restoration is described in Section 8.3.4.

The format for a BACKUP command is as follows:

BACKUP input-specifier output-specifier

The format is the same as for any BACKUP operation. The following command, for example, designates a virtual unit for the input specifier:

```
$ BACKUP/RECORD  DSA2:[* . . .  ]/SINCE=BACKUP   MTA0:23DEC.BCK
```

```
$ BACKUP/RECORD  DSA2:[* . . .  ]/SINCE=BACKUP   MTA0:23DEC.BCK
```

This command saves all files on the shadow set DSA2 that have been created or modified since the last backup and records the current time as their new backup date.

8.3.4 Using BACKUP/IMAGE on a Shadow Set

You must take special precautions when you restore a shadow set from a BACKUP/IMAGE save set. (See the *OpenVMS System Manager's Manual, Volume 1: Essentials* and *OpenVMS System Management Utilities Reference Manual: A–L* for a description of BACKUP/IMAGE operations with physical volumes.) A BACKUP/IMAGE operation marks the target volume as more current than the other shadow set members. This designates it as the source of copy operations if you re-create the shadow set with it.

Although you can create BACKUP save sets or copies from shadow set virtual units, you cannot mount your shadow set with the /FOREIGN qualifier to allow a BACKUP/IMAGE restoration.

You should either restore to a physical disk and then re-create the shadow set with the restored disk as a shadow set member (Example 2) or, if the save operation was a copy to a compatible disk, re-create the shadow set with that disk as a member (Example 3). The target of the BACKUP/IMAGE operation becomes the source of copy operations if you re-create the shadow set with it.

Example 1

This example shows how to perform a backup on a former shadow set member after you rebuild the shadow set.

```
$ MOUNT DSA0:/SHADOW=($1$DUA10:, $1$DUA11:)  GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA11: (DISK02) is now a valid
                      member of the shadow set
```

The previous command mounts the shadow set DSA0. Make sure all copy operations are finished before you dismount the shadow set by using the following command:

```
$ DISMOUNT DSA0:
```

This command dismounts the shadow set.

```
$ MOUNT/SYSTEM DSA0/SHADOW=$1$DUA10: GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid
                      member of the shadow set
```

This command puts the shadow set back on line without $1$DUA11. You can now perform the backup to tape while the shadow set is on line.

```
$ MOUNT $1$DUA11: GHOSTVOL
%MOUNT-W-VOLSHDWMEM, mounting a shadow set member volume
                     volume write locked
%MOUNT-I-MOUNTED, GHOSTVOL mounted on _$1$DUA11:

$ MOUNT/FOREIGN  MTA0:
%MOUNT-I-MOUNTED, . . .
```

These two commands mount the former shadow set member and a magnetic tape in preparation for a BACKUP command.

```
$ BACKUP/IMAGE $1$DUA11: MTA0:SAVESET.BCK
```

This command produces a BACKUP/IMAGE save set from $1$DUA11 while the shadow set is on line with $1$DUA10.

Example 2

This example shows how to restore a shadow set from an image save set. Restoring an image save set *directly* to a shadow set is not supported because the BACKUP output medium (the shadow set) must be mounted as a foreign volume.

```
$ DISMOUNT DSA0:
$ MOUNT/FOREIGN MTA0:
%MOUNT-I-MOUNTED, . . .

$ MOUNT/FOREIGN/OVERRIDE=SHADOW_MEMBERSHIP $1$DUA10:
%MOUNT-I-MOUNTED, . . .
```

These two commands mount the save-set magnetic tape as the input specifier and the former shadow set member as the output specifier for the restore operation.

```
$ BACKUP/IMAGE MTA0:SAVESET.BCK $1$DUA10:
```

This command restores $1$DUA10 from the save set.

```
$ DISMOUNT/NOUNLOAD $1$DUA10:
```

This command dismounts the restored volume in preparation for mounting into a shadow set.

Note

Do not attempt to add the restored volume to an existing shadow set without first dissolving the original shadow set. Mounting a restored volume into an existing shadow set will result in a copy operation erasing the restored disk.

```
$ MOUNT/SYSTEM DSA0/SHADOW=($1$DUA10:, $1$DUA11:) GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK02) added to the shadow set
                      with a copy operation
```

This command mounts the shadow set with the restored shadow set member. The output of the image backup operation has a newer generation number than other previous members of the shadow set. Therefore, $1$DUA10 (the restored volume) is the source of a copy operation when you form the shadow set.

Example 3

This example illustrates a BACKUP/IMAGE copy operation on a shadow set. The image backup operation stores output files contiguously, eliminating disk fragmentation. Because you must mount the output device of such operations with the /FOREIGN qualifier, you must take special steps as shown with the following commands:

```
$ MOUNT DSA0:/SHADOW=($1$DUA10:,$1$DUA11:)  MEANDMY
%MOUNT-I-MOUNTED, MEANDMY     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK03) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA11: (DISK04) is now a valid
                      member of the shadow set
$ MOUNT/FOREIGN $1$DUA20:
%MOUNT-I-MOUNTED,  . . .
```

The first command mounts the shadow set DSA0. The second command mounts, on $1$DUA20, the volume to be the output of the BACKUP/IMAGE operation. The /FOREIGN qualifier is required.

```
$ BACKUP/IMAGE/IGNORE=INTERLOCK  DSA0: $1$DUA20:
```

This command performs the image backup using the virtual unit name as the input specifier. The image backup copy of a shadow set has a newer backup revision number than the existing members in the shadow set.

Note

If any writes occur between the start of the backup operation and the dismount of both the volume containing the image backup copy and the shadow set, the backup image will not contain all the data on the shadow set. You can prevent any writes from occurring during this period by mounting the shadow set with the /NOWRITE qualifier prior to mounting the volume that will serve as the backup volume.

```
$ DISMOUNT $1$DUA20:
$ DISMOUNT DSA0:
```

These commands dismount the target of the image backup and the shadow set, in preparation for re-creating the shadow set.

```
$ MOUNT/SYSTEM DSA0/SHADOW=($1$DUA10:,$1$DUA11:,$1$DUA20:) MEANDMY
%MOUNT-I-MOUNTED, MEANDMY     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA20: (DISK05) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA10: (DISK03) added to the shadow
                      set with a copy operation
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK04) added to the shadow
                      set with a copy operation
```

This command rebuilds the shadow set with the image backup disk as one of the shadow set members. The other former shadow set members receive copy operations.

8.4 Crash Dumping to a Shadowed Disk

If a multiple-member system disk shadow set is mounted and the system fails, the resulting crash dump information is initially written to the dump file on only one of the shadow set members. Once the dump operation has successfully completed, the unit number of the member with the written dump file is printed on the console device. Error messages display if the dump cannot be written (for example, because the path to the dump unit is unavailable or is unsuitable).

Note

The crash dump file is normally written to the original boot device, provided that it is available and on line. If that device has been removed from the shadow set, the dump file is written to the current master member of the shadow set, provided that it is available and on line.

You can enable a minimerge on shadowed system disks and write a dump to a nonshadowed, nonsystem disk of your choice by doing the following:

- Set the SHADOW_SYS_DISK system parameter to 4097
- Set the DUMPSTYLE system parameter to the appropriate setting for your system for a nonshadowed, nonsystem disk of your choice.
- Configure a disk for dump off system disk (DOSD), as described in the *System Manager's Manual: Tuning, Monitoring, and Complex Systems* manual

If you accidentally enable a minimerge to a system disk that receives a crash dump and you have not set up DOSD, you may be able to recover if you know which disk contains the valid dump. Remove that member, remount it, and remove the dump from that member.

Once the system is rebooted, the shadowing software automatically begins a merge operation. This merge operation automatically propagates the dump file to all of the other members and also corrects any other inconsistencies caused by the system failure.

You can reboot the system from either the original boot device or the current master member device. At boot time, if the paths to all of the members of the shadow set are on the same type of adapter, the shadowing software correctly designates the current master and dump device on all of the booting nodes. At boot time, several OPCOM messages display information about the status of the dump device and the reboot condition of the system.

You cannot reboot the system unless the boot device is a current member of the shadow set. When a multiple member system disk shadow set loses its boot device, a warning is printed on the console device, and an OPCOM message is displayed.

Caution

Do not add shadow set members to an existing system disk shadow set in any startup command procedure. Upon system reboot, all of the data, including the dump file, can be overwritten and therefore lost if volume shadowing automatically performs a copy operation. For more information, see the **Caution** in Section 3.4.

On some systems, you can stipulate that multiple devices be members of the same system disk shadow set. Please refer to the system-specific manual for further details.

If you use the System Dump Analyzer (SDA) to access the dump file on the virtual unit during the merge operation, you can enter the SDA command ANALYZE/CRASH to examine the dump while the shadow set is undergoing a merge operation. If SDA accesses portions of the dump file that have not yet been merged, shadowing resolves inconsistent data across the shadow set before the read is returned to SDA.

You can also use the Crash Log Utility Extractor (CLUE) commands to access the dump file on the virtual unit during a merge operation. CLUE commands can automatically create a footprint of the crash to a .LIS file and store it for future reference.

Note

Accessing the dump file with the SDA command COPY or the SDA command ANALYZE/CRASH on a merging system disk will significantly degrade I/O performance on the volume. Accessing the dump file with the DCL command COPY on a merging system disk will have the same effect.

9 Performance Information for Volume Shadowing

Volume Shadowing for OpenVMS is designed primarily to be a data availability product and not a performance product. Recognizing that the topics of performance and data availability cannot be completely separated from each other, this chapter discusses the performance effects that can result on systems using Volume Shadowing for OpenVMS. Several factors affect the performance of a shadow set, including the following:

- I/O access path (local versus remote)
- Size of I/O requests
- Data access patterns (random or sequential)
- Read-to-write ratio
- Shadow set configuration
- State of a shadow set (steady or transient)
- Whether or not you use the shadowing copy and merge performance assists (see Section 9.2.2)
- Whether or not you use the minicopy operation (see Chapter 7)
- Other work load on the system utilizing common resources (CPUs, disks, controllers, interconnects)
- Striping (RAID) implementation

The following sections examine how the state of a shadow set and its configuration can affect resource utilization and performance. Some guidelines for controlling the use of system resources are also provided in Section 9.3. Because there is no significant difference in the performance of a nonshadowed disk and a one-member shadow set, all discussions that follow apply to multiple-member shadow sets.

9.1 Performance During Steady State

A shadow set is in a steady state when all of its members are consistent and no copy operation or merge operation is in progress. Overall, the performance of a shadow set in a steady state compares favorably with that of a nonshadowed disk. Read and write I/O requests processed by a shadow set utilize a very small amount of extra CPU processing time as compared with a nonshadowed disk. A shadow set often can process read requests more efficiently than can a nonshadowed disk because it can use the additional devices to respond to multiple read requests simultaneously.

For a shadow set in a steady state, the shadowing software handles read and write operations in the following manner:

- Write I/O requests are issued concurrently to all members of the shadow set. Because each member must be updated before the I/O request is considered complete, the overall completion time for a write operation is determined by the member unit with the longest access time from the node issuing the write request. Depending on how the shadow set is configured and the access paths to the individual member units, you might observe a slight increase in the time it takes to complete write I/O requests. The steady state performance is generally better to a member that is locally connected because the access path is shorter and more direct than the access path to a served member. For example, you might notice degraded write performance on shadow sets that include some members that are accessed through an MSCP server across a network link, where each member is locally connected to a separate node.
- Read I/O requests are issued to only one member unit. Volume Shadowing for OpenVMS attempts to access the member unit that can provide the best completion time. In terms of I/O throughput, a two-member shadow set can satisfy nearly twice as many read requests as a nonshadowed disk (and even more throughput is possible with a three-member shadow set). The shadow set can use the additional disk read heads to respond to multiple read requests at the same time. Thus, a steady-state shadow set can provide better performance when an application or user reads data from the disk. However, the performance gains occur mainly when the read requests queued to the shadow set come in batches such that there are as many read requests as there are member units.

Even though the read performance of a shadow set in steady-state has the potential for better performance, the primary purpose of volume shadowing is to provide data availability. It is not appropriate to use volume shadowing as a means to increase the read I/O throughput of your applications (by explicitly increasing the I/O work load). This is because the same level of performance cannot be expected during situations when copy or merge operations must take place to add new members or preserve data consistency, or when members are removed from the shadow set. Section 9.2 discusses performance considerations when the shadow set is in a transient state.

9.2 Performance During Copy and Merge Operations

A shadow set is in a transient state when some or all of its members are undergoing a copy or merge operation. During merge operations, Volume Shadowing for OpenVMS ensures consistency by reading the data from one member and making sure it is the same as the data contained in the same LBNs on the other members of the shadow set. If the data is different, the shadowing software updates the LBN on all members before returning the I/O request. For copy operations, the shadowing software reads data from a source member and writes the data to the same LBN on target members.

At the same time it performs a merge or copy operation, the shadowing software continues to process application and user I/O requests. The I/O processing necessitated by a copy operation can result in decreased performance as compared with the possible performance of the same shadow set under steady-state conditions. However, if your shadow set members are configured on controllers that support the shadowing assisted copy and assisted merge operations, you can significantly improve the speed with which a shadow set performs a copy or merge operation. Volume Shadowing for OpenVMS supports both assisted and unassisted merge and copy operations.

The following list describes how the performance of a shadow set might be affected while an unassisted merge or copy operation is in progress. See Chapter 6 for a description of assisted copy and merge operations.

- Copy operations

  A copy operation is started on a two- or three-member shadow set either when you mount the shadow set to create it or to add a new member to an existing shadow set. During a copy operation, members that are targets of the operation cannot provide data availability until the operation completes. Therefore, the shadowing software performs the copy operation as quickly as possible to make the shadow set fully available.

  During a copy operation, the shadowing software gives equal priority to user and application I/O requests and to I/O requests necessary to complete the copy operation. The performance of a shadow set during a copy operation is reduced because:

  - The shadowing software must follow special protocols for user read and write I/O requests during a copy operation.
  - Copy operation I/O requests are large in size and have the same priority as user and application I/O requests.

  In addition, other system resources are utilized during a copy operation. Depending on the access path to the individual shadow set members, these resources could include the disk controller, interconnects, interconnect adapters, and systems.

  Because you explicitly start copy operations when you mount a new shadow set or add members to an existing set, you can control when the shadowing software performs a copy operation. Therefore, you can minimize the effect on users and applications in the system by limiting the number of copy operations that occur at the same time. For example, when you create new sets or add new members, try to add the sets or members during periods of low system activity, and do not mount several sets at the same time.

  You can further minimize the effect on users and applications in the system by using the minicopy operation, introduced with OpenVMS Version 7.3. The minicopy operation can significantly reduce the time it takes to return a shadow set member to shadow set. By the use of write bitmap technology, the minicopy operation copies only the data that was changed while the member was dismounted. For more information, see Chapter 7.

- Merge operations

  In contrast to copy operations, merge operations are not under the control of a user or program. The shadowing software automatically initiates a merge operation on a shadow set as a result of the failure of a node on which the shadow set is mounted.

  As in the case of a copy operation, the volume shadowing software ensures that all I/O requests to the shadow set follow appropriate protocols to ensure data consistency. However, when a shadow set is undergoing a merge operation, full data availability exists in the sense that individual members of the set are valid data sources and are accessible by applications and users on the system. Therefore, it is not urgent for the shadowing software to finish the merge operation, especially when the system is being heavily used. Because of this major distinction from a copy operation, the shadowing software implicitly places a higher priority on user activity to the shadow set. Volume Shadowing for OpenVMS does this by detecting and evaluating system load, and then dynamically controlling or **throttling** the merge operation so that other I/O activity can proceed without interference.

Because the merge throttle slows merge operations when there is heavy application and user I/O activity on the system, the merge operation can take longer than copy operations. The merge throttle allows application and user activity to continue unimpeded by the merge operation when heavy work loads are detected.

On the other hand, the read performance of a shadow set during a merge operation is reduced because the shadowing software must perform data integrity checks on all members for every read request. The volume shadowing software reads the data from the same LBN on all members of the shadow set, compares the data, and repairs any inconsistencies before returning the read data to the user.

9.2.1 Improving Performance for Unassisted Merge Operations

Because read performance during a shadow set unassisted merge operation is reduced, a mechanism is provided to control the throttle on the merge I/O rate. Two logical names are available to vary the unassisted merge multiplication factor used for a virtual unit on a per-node and per-virtual unit basis.

These logicals must be defined in the system table and should be defined on each node in the cluster. The valid range for the multiplication factor is 100 to 100,000. Any value outside of this range causes the factor to default to 200. This value of 200 is displayed at the start of a shadow set merge, in the `%SHADOW_SERVER-I-SSRVINIMRG` message, following the word `Factor`.

The two logical names are:

- SHAD$MERGE_DELAY_FACTOR_DSA*nnnn*

  This logical is specific to a virtual unit, where *nnnn* represents the virtual unit number. If any important virtual units need to be merged without regard to the impact on application I/O, values as high as 100,000 can be defined.

- SHAD$MERGE_DELAY_FACTOR

  This logical applies to all shadow sets that do not have a virtual unit specific logical defined.

Note

Increasing the values excessively may cause application performance problems when merges are occurring. When setting values, system managers must balance the site specific application needs with their merge requirements.

These two logical names are evaluated again after 100,000 merge I/Os have completed. Therefore, the factor can be adjusted while a merge is in progress.

9.2.2 Improving Performance for Merge and Copy Operations

There are two types of performance assists: the merge assist and the copy assist. The merge assist improves performance by using information that is maintained in controller-based write logs to merge only the data that is inconsistent across a shadow set. When a merge operation is assisted by the write logs, it is referred to as a **minimerge.** The copy assist reduces system resource usage and copy times by enabling a direct disk-to-disk transfer of data without going through host node memory.

Assisted merge operations are usually too short to be noticeable. Improved performance is also possible during the assisted copy operation because it consumes less CPU and interconnect resources. Although the primary purpose of the performance assists is to reduce the system resources required to perform a copy or merge operation, in some circumstances you may also observe improved read and write I/O performance.

Volume Shadowing for OpenVMS supports both assisted and unassisted shadow sets in the same OpenVMS Cluster configuration. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the shadowing software reevaluates each device in the changed configuration to determine whether it is capable of supporting either the copy assist or the minimerge. Enhanced performance is possible only as long as all shadow set members are configured on controllers that support performance assist capabilities. If any shadow set member is connected to a controller without these capabilities, the shadowing software disables the performance assist for the shadow set.

When the correct revision levels of software are installed, the copy assist and minimerge are enabled by default, and are fully managed by the shadowing software.

9.2.3 Effects on Performance

The copy assist and minimerge are designed to reduce the time needed to do copy and merge operations. In fact, you may notice significant time reductions on systems that have little or no user I/O occurring during the assisted copy or merge operation. Data availability is also improved because copy operations quickly make data consistent across the shadow set.

Minimerge Performance Improvements

The minimerge feature provides a significant reduction in the time needed to perform merge operations. By using controller-based write logs, it is possible to avoid the total volume scan required by earlier merge algorithms and to merge only those areas of the shadow set where write activity was known to be in progress at the time the node or nodes failed.

Unassisted merge operations often take several hours, depending on user I/O rates. Minimerge operations typically complete in a few minutes and are usually undetectable by users.

The exact time taken to complete a minimerge depends on the amount of outstanding write activity to the shadow set when the merge process is initiated, and on the number of shadow set members undergoing a minimerge simultaneously. Even under the heaviest write activity, a minimerge will complete within several minutes. Additionally, minimerge operations consume minimal compute and I/O bandwidth.

Copy Assist Performance Improvements

Copy times vary according to each configuration and generally take longer on systems supporting user I/O. Performance benefits are achieved when the source and target disks are on different HSJ internal buses.

9.3 Guidelines for Managing Shadow Set Performance

Sections 9.1 and 9.2 describe the performance impacts on a shadow set in steady state and while a copy or merge operation is in progress. In general, performance during steady state compares with that of a nonshadowed disk. Performance is affected when a copy or a merge operation is in progress to a shadow set. In the case of copy operations, you control when the operations are performed.

However, merge operations are not started because of user or program actions. They are started automatically when a system fails, or when a shadow set on a system with outstanding application write I/O enters mount verification and times out. In this case, the shadowing software reduces the utilization of system resources and the effects on user activity by throttling itself dynamically. Minimerge operations consume few resources and complete rapidly with little or no effect on user activity.

The actual resources that are utilized during a copy or merge operation depend on the access path to the member units of a shadow set, which in turn depends on the way the shadow set is configured. By far, the resources that are consumed most during both operations are the adapter and interconnect I/O bandwidths.

You can control resource utilization by setting the SHADOW_MAX_COPY system parameter to an appropriate value on a system based on the type of system and the adapters on the machine. SHADOW_MAX_COPY is a dynamic system parameter that controls the number of concurrent copy or merge threads that can be active on a single system. If the number of copy threads that start up on a particular system is more than the value of the SHADOW_MAX_COPY parameter on that system, only the number of threads specified by SHADOW_MAX_COPY will be allowed to proceed. The other copy threads are stalled until one of the active copy threads completes.

For example, assume that the SHADOW_MAX_COPY parameter is set to 3. If you mount four shadow sets that all need a copy operation, only three of the copy operations can proceed; the fourth copy operation must wait until one of the first three operations completes. Because copy operations use I/O bandwidth, this parameter provides a way to limit the number of concurrent copy operations and avoid saturating interconnects or adapters in the system. The value of SHADOW_MAX_COPY can range from 0 to 200. The default value is OpenVMS version specific.

Chapter 3 explains how to set the SHADOW_MAX_COPY parameter. Keep in mind that, once you arrive at a good value for the parameter on a node, you should also reflect this change by editing the MODPARAMS.DAT file so that when invoking AUTOGEN, the changed value takes effect.

In addition to setting the SHADOW_MAX_COPY parameter, the following list provides some general guidelines to control resource utilization and the effects on system performance when shadow sets are in transient states.

- Create or add members to shadow sets when your system is lightly loaded.

- The amount of data that a system can transfer during copy operations varies depending on the type of disks, interconnect, controller, the number of units in the shadow set, and the shadow set configuration on the system. For example, approximately 5% to 15% of the Ethernet or CI bandwidth might be consumed for each copy operation (for disks typically configured in CI or Ethernet environments).
- When you create unassisted, three-member shadow sets consisting of one source member and two target devices, add both target devices at the same time in a single mount command rather than in two separate mount commands. Adding all members at once optimizes the copy operations by starting a single copy thread that reads from the source member once, and performs write I/O requests to the target members in parallel.
- For satellite nodes in a mixed-interconnect or local area OpenVMS Cluster system, set the system parameter SHADOW_MAX_COPY to a value of 0 for nodes that do not have local disks as shadow set members.
- Do not use the MOUNT/CLUSTER command to mount *every* shadow set across the cluster unless all nodes must access the set. Instead, use the MOUNT/SYSTEM command to mount the shadow sets on only those nodes that need to access a particular set. This reduces the chances of a shadow set going into a merge state. Because a shadow set goes into a merge state only when a node that has the set mounted fails, you can reduce the chances of this happening by limiting the number of nodes that mount a shadow set, especially when there is no need for a node to access the shadow sets.
- Because a copy operation can occur only on nodes that have the shadow set mounted, create and mount shadow sets on the nodes that are local (have direct access) to the shadow set members. This allows the copy threads to run on these nodes, resulting in faster copy operations with fewer resources utilized.
- If you have shadow sets configured across nodes that are accessed through the MSCP server, you might need to increase the value of the MSCP_BUFFER system parameter in order to avoid fragmentation of application I/O. Be aware that *each* shadow set copy or merge operation normally consumes 127 buffers.
- Dual-pathed and dual-ported shadowed disks in a OpenVMS Cluster system can provide additional coverage against the failure of nodes that are directly connected to shadowed disks. This type of configuration provides higher data availability with reasonable performance characteristics.
- Use the preferred path option to ensure dual-ported drives are accessed via the same controller so that the shadowing software will perform assisted copy operations.

9.4 Striping (RAID) Implementation

Compaq's StorageWorks RAID Software for OpenVMS provides ways to configure and use disk drives so that they achieve improved I/O performance. RAID (redundant arrays of independent disks) uses striping technology to chunk data and distribute it across multiple drives. RAID software is available in various levels, one of which is volume shadowing. Table 9–1 describes RAID levels.

Table 9–1 RAID Levels

RAID Level	Description
Level 0	Striping with no redundancy.
Level 1	Shadowing.
Levels 0 + 1	Striping and shadowing together.
Level 3	Striped data with dedicated parity drive. Drives are rotationally synchronized.
Level 5	Striped data and parity.
Level 6	Striped data and parity with two parity drives.

Shadowing striped drives can increase both performance and availability, because you can achieve faster response time with striping and data redundancy with shadowing. In addition to shadowing striped sets, you can also stripe shadow sets. Each strategy offers different advantages and tradeoffs in terms of availability, performance, and cost.

For more information about RAID 0, see the POLYCENTER product documentation set. For more information about RAID 5, see the *StorageWorks RAID 5 Software for OpenVMS User's Guide*.

A
Messages

This appendix lists volume shadowing status messages that are displayed on the console device. For other system messages that are related to volume shadowing, use the Help Message utility. For information about the HELP/MESSAGE command and qualifiers, see DCL help (type HELP HELP/MESSAGE at the DCL prompt). Messages that can occur before a system is fully functional are also included in *OpenVMS System Messages: Companion Guide for Help Message Users*.

A.1 Mount Verification Messages

The following mount verification messages have approximately the same meaning for shadow sets as they do for regular disks. They are sent to the system console (OPA0) and to any operator terminals that are enabled to receive disk operator messages.

- *virtual-unit*: is off line. Mount verification in progress.
- *virtual-unit*: has completed mount verification.
- *virtual-unit*: has aborted mount verification.

A.2 OPCOM Message

The following OPCOM message is returned in response to shadow set operations. This message results when the shadowing code detects that the boot device is no longer in the system disk shadow set. If the boot device is not added back into the system disk shadow set, the system may not reboot, and the dump may be lost if the system crashes.

virtual-unit: does not contain the member named to VMB. System may not reboot.

Explanation: This message can occur for the following reasons:

- The boot device is dismounted or failed out of the system disk shadow set.
- Shadowing finds the boot device missing from the system disk shadow set membership during any dismount operations on the system disk.

User Action: Do one of the following:

- Mount the boot device back into the shadow set as soon as possible.
- If you cannot mount the boot device back into the shadow set, change the device name in VMB (primary bootstrap) so the system can reboot when necessary.

A.3 Shadow Server Messages

Shadow server operations can display the following status messages on the system console (OPA0) and on terminals enabled to receive operator messages.

Shadow server messages are always informational messages and include the prefix %SHADOW_SERVER-I-SSRV*message-abbreviation*. The following example includes the OPCOM banner and the shadow server message to illustrate what the messages look like when they are output to the console:

```
%%%%%%%%%%%   OPCOM 24-MAR-1990 15:01:30.99   %%%%%%%%%%%
 (from node SYSTMX at 24-MAR-1990 15:01:31.36)
Message from user SYSTEM on SYSTMX
%SHADOW_SERVER-I-SSRVINICOMP, shadow server has completed initialization.
```

The following messages are returned by the shadow server in response to shadow set operations. Several of the messages refer to a **copy thread number**; this is a unique identifier denoting a copy or merge operation. The messages in this section are listed in alphabetical order by message abbreviation. For simplicity, the messages shown here do not include the SHADOW_SERVER-I- prefix.

SSRVCMPFCPY, completing copy operation on device _*virtual-unit*: at LBN: *LBN-location*, ID number: *copy-thread-number*

Explanation: The copy operation has completed.

User Action: None.

SSRVCMPMRG, completing merge operation on device _*virtual-unit*: at LBN: *LBN-location*, ID number: *copy-thread-number*

Explanation: The merge operation has completed.

User Action: None.

SSRVCOMPLYFAIL, still out of compliance for per-disk license units, new shadow members may be immediately removed

Explanation: The number of shadow set members on the node has exceeded the number of VOLSHAD-DISK license units for more than 60 minutes. Attempts to bring the node into compliance by removing unlicensed members from their shadow sets have failed. If any new members are mounted, they might be removed immediately.

User Action: Ensure that the number of VOLSHAD-DISK license units on each node is equal to the number of shadow set members mounted on that node. If necessary, dismount shadow set members until the number of mounted members equals the number of VOLSHAD-DISK license units loaded on the node. If you need more VOLSHAD-DISK license PAKs, contact a Digital support representative.

SSRVINICOMP, shadow server has completed initialization

Explanation: The shadow server has been initialized at boot time.

User Action: None.

SSRVINICPY, initiating copy operation on device _*virtual-unit*: at LBN: *LBN-location*, I/O Size: *number-of-blocks* blocks, ID number: *copy-thread-number*

Explanation: A copy operation is beginning on the shadow set whose virtual unit number is listed in the message.

User Action: None.

SSRVINIMRG, initiating merge operation on device _*virtual-unit*: at LBN *logical-block-number*, I/O Size: *number-of-blocks* blocks, ID number: *copy-thread-number*

Explanation: A merge operation is beginning on the shadow set. The merge can occur after a copy operation has completed.

User Action: None.

SSRVINIMMRG, initiating minimerge operation on device _*virtual-unit*: at LBN *LBN-location*, I/O size: *number-of-blocks* blocks, ID number: *copy-thread-number*

Explanation: A shadowing minimerge is beginning on the device indicated. The message identifies the minimerge with the name of the shadow set virtual unit, and the LBN location of the minimerge, the size of the I/O request (in blocks), and the ID number of the copy thread. For example:

```
%SHADOW_SERVER-I-SSRVINIMMRG, initiating minimerge  operation on
device _DSA2: at LBN 0, I/O size: 105 blocks, ID number: 33555161
```

User Action: None.

SSRVINSUFPDL, insufficient per-disk license units loaded, shadow set member(s) will be removed in *number* minutes

Explanation: The number of shadow set members mounted exceeds the number of VOLSHAD-DISK license units loaded on the node. If this condition is not corrected before the number of minutes displayed in this message has elapsed, Volume Shadowing will remove unlicensed members from shadow sets in an attempt to make the node compliant with the number of loaded VOLSHAD-DISK license units.

User Action: Dismount shadow set members until the number of mounted members is equal to the number of VOLSHAD-DISK license units on the node.

SSRVNORMAL, successful completion of operation on device _*virtual-unit*: at LBN *LBN-location*, ID number: *copy-thread-number*

Explanation: The copy or merge operation has completed.

User Action: None.

SSRVRESCPY, resuming copy operation on device _*virtual-unit*: at LBN: *logical-block-number* I/O size: *number-of-blocks* blocks, ID number: *copy-thread-number*

Explanation: A copy operation is resuming. The message identifies the copy with a unique sequence number, the name of the shadow set virtual unit, the LBN location of the copy, and the size of the I/O request (in blocks). For example:

```
%SHADOW_SERVER-I-SSRVRESFCPY, resuming Full-Copy copy sequence number
16777837 on device _DSA101:, at LBN 208314  I/O size: 71 blocks
```

User Action: None.

SSRVSPNDCPY, suspending operation on device *_virtual-unit*: at LBN: *logical-block-number*, ID number: *copy-thread-number*

Explanation: A copy operation is being interrupted before it completes. (If a crash occurs during a copy operation, a minimerge assist can interrupt the copy operation to resolve inconsistencies. The shadowing software can resume the copy operation when the minimerge completes.) The following message identifies the copy operation with the name of the shadow set virtual unit, the LBN location of the copy, and a unique ID number.

```
%SHADOW_SERVER-I-SSRVSPNDCPY, suspending operation on
device _DSA101:. at LBN: 208314, ID number: 16777837
```

User Action: None.

SSRVSPNDMMRG, suspending minimerge operation on device *_virtual-unit*: at LBN: *logical-block-number* ID number: *copy-thread-number*

Explanation: A minimerge is interrupted before it completes. The message identifies the minimerge with the name of the shadow set virtual unit, the LBN location of the minimerge, and a unique ID number. For example:

```
%SHADOW_SERVER-I-SSRVSPNDMMRG, suspending minimerge operation
on device _DSA101:. at LBN: 3907911, ID number: 16777837
```

User Action: None.

SSRVSPNDMRG, suspending merge operation on device *_virtual-unit*: at LBN: *LBN-location*, ID number: *copy-thread-number*

Explanation: A merge operation has been suspended while the shadow set undergoes a copy operation.

User Action: None.

SSRVTRMSTS, reason for termination of operation on device: *_virtual-unit*:, abort status

Explanation: This message always accompanies the SSRVTERM message to provide further information about the copy termination.

User Action: Possible actions vary depending on the reason for the error. You might need to check and repair hardware or restart the copy operation.

SSRVTERMCPY, terminating operation on device: *_virtual-unit*:, ID number: *copy-thread-number*

Explanation: The copy thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

SSRVTERMMRG, terminating operation on device: *_virtual-unit*:, ID number: *copy-thread-number*

Explanation: The merge thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

SSRVTERMMMRG, terminating operation on device: *_virtual-unit*:, ID number: *copy-thread-number*

Explanation: The minimerge thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

A.4 VOLPROC Messages

Shadowing operations can display the following status messages on the system console (OPA0) and on terminals enabled to receive disk operator messages.

Shadowing messages always include the prefix %SHADOW-I-VOLPROC and can sometimes be followed by “Volume Processing in Progress.” The messages are displayed in the following format:

%SHADOW-I-VOLPROC, *message-text*

- The %SHADOW prefix indicates that the shadowing software is the facility that produced the error.
- I is a one-letter code indicating the status or the severity of the error. The VOLPROC messages are always informational (I) errors.
- VOLPROC is an abbreviation for the volume-processing facility.
- The variable *message-text* is the description of the status message. For most volume-processing errors, the text includes the virtual unit number or member unit number of the disk or device causing the error.

The following example shows a complete volume-processing status message:

```
%SHADOW-I-VOLPROC, DSA13: shadow set has changed state. Volume processing
                          in progress.
```

The following messages are returned by the VOLPROC in response to shadow set operations. The messages in this section are listed in alphabetical order beginning with the first word after the shadow set member name or the virtual unit name. For simplicity, the messages do not include the %SHADOW-I-VOLPROC prefix.

shadow-set-member: contains the wrong volume.

Explanation: The shadowing software discovered a volume label mismatch after failover.

User Action: Check the disk drives and unit numbers.

shadow-set-member: has aborted volume processing.

Explanation: The shadow set is dissolved. A shadow set member was not restored to operational status before the MVTIMEOUT system parameter setting expires; thus, the mount operation aborts for the shadow set.

User Action: Check error logs and the shadow set membership; the disk or controller might need repair.

shadow-set-member: has been write-locked.

Explanation: The data on the disk is protected against write I/O operations.

User Action: Remove the write lock on the volume.

shadow-set-member: has completed volume processing.

Explanation: The shadow set state change is complete.

User Action: Check the shadow set membership; the disk or controller might need repair.

shadow-set-member: is offline.

Explanation: A shadow set member is off line. The shadowing software attempts to fail over.

User Action: None.

shadow-set-member: shadow copy has been completed.

Explanation: A shadow copy operation has completed.

User Action: None.

shadow-set-member: shadow set has been reduced.

Explanation: The specified shadow set member has been removed.

User Action: If the member failed out of the set (not dismounted), look for the cause of the failure and repair it.

virtual-unit: all shadow set copy operations are completed.

Explanation: All pending shadow set copy operations have completed. The same logical block on any shadow set member contains the same data.

User Action: None.

virtual-unit: shadow copy has been started.

Explanation: Indicates the start of a shadow copy operation.

User Action: None.

virtual-unit: shadow master has changed. Dump file will be written if system crashes. Volume Processing in progress.

Explanation: The shadowing software has determined a new master disk for the system disk shadow set. You can write a dump file for this system only if the master is the same disk as the one the system booted from. This is because the boot drivers are not connected with the shadow driver, and different boot drivers from the ones that interact with the booted system disk might be needed to interact with the new master disk. For example, a system disk could be served and also locally connected, causing the served path to use different drivers from the local path.

User Action: None.

virtual-unit: shadow master has changed. Dump file will not be written if the system crashes. Volume processing in progress.

Explanation: Indicates that the disk from which you booted is no longer in the shadow set. If a system failure occurs, a dump file cannot be written to the removed disk.

User Action: Return the disk to the shadow set.

virtual-unit: shadow set has changed state. Volume processing in progress.

Explanation: The state of the shadow set is in transition. The membership of the shadow set is changing because of either the addition or removal of members from the shadow set, or failover to another device after a hardware error. Further messages give details if a change occurs.

User Action: None.

Glossary

An alphabetical list of terms used in *Volume Shadowing for OpenVMS* and their definitions follow.

assisted copy

An assisted copy is a copy operation performed within an HS*x* controller in the configuration. The assisted copy does not transfer data through the host node memory. Because the data transfer is from disk to disk, the assisted copy decreases the impact on the system, the I/O bandwidth consumption, and the time required for copy operations. The shadowing software controls the copy operation by using special MSCP copy commands called disk copy data (DCD) commands to instruct the controller to copy specific ranges of logical blocks. For an assisted copy, only one disk can be an active target for a copy at a time.

copy

A copy operation, in the context of Volume Shadowing for OpenVMS, is the process of duplicating the contents of one device onto a second device.

copy fence

A copy fence is a logical boundary between the blocks that have been copied and those that remain to be copied. A copy fence advances with the completion of each copy operation.

DCD

DCD is the acronym for disk copy data, the name of some specialized MSCP commands. The DCD commands are invoked by shadowing software to control assisted copy operations between disks connected to an HSJ controller.

device

Hardware that allows access to storage media; also called **drive**.

device driver

A software component of the operating system that allows the host computer to communicate with the controller of a device. A device driver exists on the host computer for every peripheral device to which it is attached.

disk

Physical media on which files reside.

dissolve

The act of removing a shadow set from a configuration by removing the virtual unit.

drive

Hardware that allows access to storage media; also called **device**.

generation number

A generation number is the time stamp assigned to all members of a shadow set by the shadowing software, which the shadowing software uses to track changes in the composition of the shadow set. If a member is removed from a shadow set, the shadowing software updates the generation number of the remaining members.

local write bitmap

A local write bitmap is a bitmap that is created when you mount or dismount a minicopy-enabled shadow set. A local write bitmap communicates with the master write bitmap to ensure that the master write bitmap has a record of all changed blocks. See also write bitmap and master write bitmap.

logical block

Organizational unit of volume space.

logical block number (LBN)

A number that identifies a block on a volume. Logical block numbering begins with the first byte in the volume space and continues in a sequentially ascending order through the remainder of the volume space.

master write bitmap

A master write bitmap is created on the first OpenVMS Alpha system that mounts the shadow set. It contains a record of all blocks that have been changed on a shadow set. See also local write bitmap and write bitmap.

merge

A merge operation is an operation to resolve any data inconsistencies between members of a shadow set that could occur when a system fails. A merge operation is declared by the shadowing software for all shadow sets that were mounted on a system that failed.

merge fence

A merge fence is a logical boundary between the blocks that have been compared and those that remain to be compared. A merge fence advances with the completion of each comparison.

minicopy

A minicopy operation is similar to a copy operation, as defined in the context of Volume Shadowing for OpenVMS, except that it copies only the changed blocks. Therefore, the time to perform a minicopy is proportional to the amount of changed blocks on the device. A minicopy operation relies on the existence of a write bitmap for the shadow set.

minimerge

A minimerge operation is similar to a merge operation but faster and requires an HS*x* controller in the configuration. The shadowing software uses a controller-based write log, provided by the HS*x* controller, which shows exactly which blocks had write I/O requests and data security erases (DSEs) outstanding. Only these blocks are made identical.

shadow set

A shadow set consists of up to three devices that are logically bound together by Volume Shadowing for OpenVMS software. The shadow set members are assigned the same virtual unit number, which is stored in the device's storage control block (SCB).

shadow set member

A shadow set member is a device that has been logically bound with other devices into a shadow set.

source device

The device whose contents are copied to a target device.

System Communications Services (SCS)

In an OpenVMS Cluster environment, software that implements intercomputer communication, according to the System Communications Architecture (SCA).

target

The device to which the contents of a shadow set member is being copied. When the copy is complete, the target is a member of the shadow set.

virtual unit

A shadow set is represented as a single virtual device, called a virtual unit. A virtual unit is identified by its name DSA*n*, where *n* can be any number between 0 and 9999.

volume

Disk or tape media that has been prepared for use by creating a new file structure on it and mounting it on a device.

volume set

A collection of disk volumes bound into a single entity by the DCL command MOUNT/BIND. To users, a volume set looks like a single, large volume.

Also, the volumes on which a set of multivolume files is recorded.

write bitmap

A write bitmap is a data structure in memory that tracks the addresses of all write operations and all data security erase (DSE) operations. See also master write bitmap and local write bitmap.

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