USER GUIDE FOR LINUX

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Fusion ioMemory™ VSL® 3.2.15

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Fusion ioMemory VSL 3.2.15 User Guide for Linux

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Introduction

Overview

Congratulations on your purchase of a SanDisk® solid-state storage device. This guide explains how to install, troubleshoot, and maintain the Fusion ioMemory™ VSL® software for your Fusion ioMemory devices.

NOTE-

Throughout this manual, when you see a reference to any **Fusion ioMemory device**, you may substitute your particular device(s) from the *Supported Devices* list located in the *Fusion ioMemory VSL Release Notes*.

ATTENTION!

Products with Multiple Devices
Some products, such as a Fusion ioMemory ioDrive Duo device, are actually comprised of **multiple Fusion ioMemory devices**. If your product consists of multiple Fusion ioMemory devices, you will manage each Fusion ioMemory device as an independent device.

For example, if you have a Fusion ioMemory ioDrive Duo device, you can independently attach, detach, and/or format each of the two Fusion ioMemory devices. Each of the two devices will be presented as an individual device to your system.

About the ioMemory Platform

The ioMemory platform combines Fusion ioMemory VSL software (VSL stands for Virtual Storage Layer) with ioMemory hardware to take enterprise applications and databases to the next level.

Performance

The ioMemory platform provides consistent microsecond latency access for mixed workloads, multiple gigabytes per second access and hundreds of thousands of IOPS from a single product. The sophisticated ioMemory architecture allows for nearly symmetrical read and write performance with best-in-class low queue depth performance, making the ioMemory platform ideal across a wide variety of real world, high-performance enterprise environments.

The ioMemory platform integrates with host system CPUs as flash memory to give multiple (and mostly idle) processor cores, direct and parallel access to the flash. The platform's cut-through architecture gives systems more work per unit of processing, and continues to deliver performance increases as CPU power increases.

Endurance

The ioMemory platform offers best-in-class endurance in all capacities, which is crucial for caching and write-heavy databases and applications.

Reliability

The ioMemory platform eliminates concerns about reliability like NAND failures and excessive wear. The all-new intelligent, self-healing feature called Adaptive Flashback provides complete, chip-level fault tolerance. Adaptive Flashback technology enables an ioMemory product to repair itself after a single chip or a multi-chip failure without interrupting business continuity.

Fusion ioMemory VSL Software Installation

Before continuing with the installation of this software, please read the following:

1. Ensure that your operating system is included in the list of **supported operating systems** contained in the *Fusion ioMemory VSL Release Notes* for this release.
2. Before installing the Fusion ioMemory VSL software, make sure you have properly installed the Fusion ioMemory device(s). Refer to the *Fusion ioMemory Hardware Installation Guide* for full details and hardware requirements.

ATTENTION!

Every Fusion ioMemory device in a system must be upgraded to the appropriate firmware.

For example, if you have a system running Fusion ioMemory VSL software version 2.3.1 with Fusion ioMemory devices previously installed, and you want to install new Fusion ioMemory ioDrive2 devices (that require the latest version of the firmware), then you will need to upgrade all of the existing devices with firmware that supports this version of the Fusion ioMemory VSL software. Follow the upgrade path in the *Fusion ioMemory VSL Release Notes* to determine the upgrade sequence.

WARNING!

Upgrade Previous Devices First

If you have Fusion ioMemory devices configured for Fusion ioMemory VSL software version 2.x or earlier, you must upgrade their firmware before installing new devices in the system. See Upgrading Devices from VSL 2.x to 3.x on page 76 for the upgrade instructions.

NOTE-

All commands require administrator privileges. Use `sudo` or log in as "root" to run the install.

Installation Overview

1. Download the latest version of the software at https://link.sandisk.com/commercialsupport.

2. If you are installing version 3.2.15 of Fusion ioMemory VSL software on a system with Fusion ioMemory ioDrive devices configured with firmware for Fusion ioMemory VSL software version 2.x, you must carefully follow the instructions in the Upgrading Devices from VSL 2.x to 3.x on page 76. (Follow those instructions instead of the normal installation instructions.)

3. If you have a previous version of the Fusion ioMemory VSL software installed, you will need to uninstall the Fusion ioMemory VSL software and the utilities. See Uninstalling the Software on page 47 for instructions. Once you have uninstalled the packages, return to this page.

   ATTENTION!

   Kernel Upgrades

   If you ever plan to upgrade the kernel when the Fusion ioMemory VSL software is installed, you **must** follow the procedure for Upgrading the Kernel on page 48.

4. Install the latest version of the Fusion ioMemory VSL software. Depending on the format your distribution uses for installation packages, you will need to follow the instructions on Installing RPM Packages on page 10 or Installing DEB Packages on page 15. The installation instructions will help you determine which of these package types is supported by your kernel:

   - A pre-compiled binary package

   - A source-to-build package

5. Install utilities and management software (included in driver installation instructions).

6. Follow the instructions on Loading the ioMemory VSL Driver on page 20 and consider Setting the ioMemory VSL Options on page 26.

7. Determine if you need to upgrade the firmware to the latest version, see Upgrading the Firmware on page 23.

Installing RPM Packages

To install the Linux Fusion ioMemory VSL software and utilities on SUSE, RHEL, Fedora, and CentOS:

1. You will need to install a version of the Fusion ioMemory VSL software that is built for your kernel. To determine what kernel version is running on your system, use the following command at a shell prompt:

```
$ uname -r
```

2. Compare your kernel version with the binary versions of the software available at https://link.sandisk.com/commercialsupport .

   - If there is a binary version of the software that corresponds to your kernel version, download that. **For example**:

   ```
   iomemory-vsl-<kernel-version>-<VSL-version>.x86_64.rpm
   ```

   - If there is no binary version of the software corresponding to your kernel, download the source package. **For example**:

   ```
   iomemory-vsl-<VSL-version>.src.rpm
   ```

   NOTE-

   Exact package names may vary, depending on software and kernel version chosen.

   Use the source package that is made for your distribution. Source packages from other distributions are not guaranteed to work.

   NOTE-

   For Oracle VM (OVM), please use the OEL source package.

3. Download the support RPM packages you need from https://link.sandisk.com/commercialsupport . These packages provide utilities, firmware, and other files.

ATTENTION!

libvsl Packaging Change. The SDK libraries needed for 64-bit management tools (formerly downloaded separately as `libvsl-<version>.x86_64.rpm`), are now packaged in the `iomemory-vsl-<kernel-version>-<VSL-version>.x86_64.rpm` (or in the `iomemory-vsl-<VSL-version>.src.rpm` if you are building the package). However, the SDK libraries needed for working with 32-bit management applications must still be downloaded separately (see table below).

For more information on available management tools, please refer to Monitoring and Managing Devices on page 42 .

ATTENTION!

Unified Utilities. If you plan to run the 4.2.1 (or newer) Unified Utilities on a VSL 3.2.15 server, you will need to download both the VSL 3.2.15 Release utilities package `fio-util-<VSL-version>.x86_64.rpm`, and the VSL 4.2.1 (or newer) Release utilities package `fio-util-<VSL-version>.x86_64.rpm` from https://link.sandisk.com/commercialsupport.

Be aware that only certain operating systems installed with VSL 3.2.15 can use the 4.2.1 (or newer) utilities. For the list of operating systems compatible with Unified Utilities on VSL 3.2.15 systems, refer to the 3.2.15 *Fusion ioMemory VSL Release Notes*.

For Unified Utilities installation, after you install the 3.2.15 Fusion ioMemory VSL and utilities packages and upgrade the firmware, you will then install the 4.2.1 (or newer) `fio-util-<VSL-version>.x86_64.rpm` package on your VSL 3.2.15 server. This installation will replace your VSL 3.2.15 utilities with the VSL 4.2.1 (or newer) Unified Utilities. See the end of this section for more information.

Examples:

Package	What Is Installed
`fio-util-<VSL-version>.x86_64.rpm`	ioMemory VSL utilities – **Strongly Recommended** **NOTE-** If you plan to run the 4.2.1 (or newer) Unified Utilities on a VSL 3.2.15 server, you will need to download both the 3.2.15 `fio-util-<VSL-version>.x86_64.rpm` for the VSL 3.2.15 Release, and the 4.2.1 (or newer) `fio-util-<VSL-version>.x86_64.rpm` for the VSL 4.2.1 (or newer) Release Version (preferably into separate folders or locations).

Package	What Is Installed
`fio-preinstall-<VSL-version>.x86_64.rpm`	This package installs the `fio-firmware` utility, which reports the version and revision of the firmware on all Fusion ioMemory devices without requiring you to load the ioMemory VSL software driver. – **Optional** For `fio-firmware` usage information, please refer to fio-firmware on page 58.
`fio-firmware-<version>.<date>-1.0.noarch.rpm`	Firmware archive package, installs the firmware archive file in a specific location (`/usr/share/fio/firmware`) – **Optional**
`fusion_<version>.<date>.fff`	Firmware archive file (not an installer package) used to upgrade the firmware, make note of where you store this file – **Optional**
`lib32vsl-<version>.i386.rpm`	SDK libraries needed for working with 32-bit management applications – **Optional** and only available for certain distributions. **ATTENTION!** You must have a full set of 32-bit system libraries installed (32-bit compatibility layer installed on your 64-bit system) before you can install this package.
`fio-common-<VSL-version>.x86_64.rpm`	Files required for the init script – **Strongly Recommended**
`fio-sysinit-<VSL-version>.x86_64.rpm`	Init script – **Strongly Recommended**, see Loading the ioMemory VSL Driver on page 20 for more information.

4. Change to the directory where you downloaded the installation packages.
5. If needed, build the Fusion ioMemory VSL software from source:
    - **If you downloaded a binary version of the software**: skip the **Building the Software from Source** instructions below and continue to the next step.
    - **If you downloaded the software source package**: follow these **Building the Software from Source** instructions:

Building the Software from Source
You only need to follow these additional instructions if you downloaded the source package. a. Install the prerequisite files for your kernel version. **NOTE-** Some of the prerequisite packages may already be in the default OS installation. If your system is not configured to get packages over the network, then you may need to mount

your install CD/DVD.

- On RHEL/CentOS/OEL 5/6/7, you need `kernel-devel`, `rpm-build`, GCC4, `make`, and `rsync`.

```
$ yum install rsync tar gcc make kernel-devel-`uname -r`
rpm-build
```

This command will force `yum` to download the exact versions for your kernel. If the exact versions are no longer available in the repository, then you will have to manually search for them on the Internet.

ATTENTION!

If you are using the UEK kernel on OEL, replace `kernel-devel` with: `kernel-uek-devel`

- On SLES 10/11/12 you need `kernel-syms, make, rpm, rpm-build`, GCC4, `rsync`, and `kernel-source`.

```
$ zypper install kernel-syms make rpm rpm-build gcc rsync
kernel-source
```

b. To build an RPM installation package for the current kernel, navigate to the directory with the downloaded source RPM file and run this command:

```
$ rpmbuild --rebuild iomemory-vsl-<VSL-version>.src.rpm
```

ATTENTION!

If your kernel is an Unbreakable Enterprise Kernel (UEK), you may also need to use the ––`nodeps` option.

When using a .rpm source package for a non-running kernel, run this command:

```
$ rpmbuild --rebuild --define 'rpm_kernel_version <kernel-
version>'  iomemory-vsl-<VSL-version>.src.rpm
```

c. The new RPM package is located in a directory that is indicated in the output from the `rpmbuild` command. To find it, look for the `Wrote` line. In the following example, the RPM packages are located in the `/usr/src/redhat/RPMS/x86_64/` directory.

```
...
Processing files: iomemory-vsl-source-<version>-1.0.x86_64.rpm
Requires(rpmlib): rpmlib(PayloadFilesHavePrefix) <= 4.0-1 rpmlib
```

```
(CompressedFileNames) <= 3.0.4-1
Obsoletes: iodrive-driver-source
Checking for unpackaged file(s): /usr/lib/rpm/check-files
/var/tmp/iomemory-vsl-<version>-root
Wrote: /usr/src/redhat/RPMS/x86_64/iomemory-vsl-2.6.18-128.el5-
<version>-1.0.x86_64.rpm
Wrote: /usr/src/redhat/RPMS/x86_64/iomemory-vsl-source-<version>-
1.0.x86_64.rpm
```

In this example, `iomemory-vsl-2.6.18-128.el5-<version>-1.0.x86_64.rpm` is the package you will use.

d. Copy your custom-built software installation RPM package into the directory where you downloaded the installation packages and navigate to that directory.

e. Continue to the next step.

6. Enter the following command to install the custom-built software package. Use the package name that you just copied/downloaded into that directory.

```
$ rpm -Uvh iomemory-vsl-<kernel-version>-<VSL-version>.x86_64.rpm
```

7. Enter the following commands to install the support files:

ATTENTION!

Ensure that the 3.2.15 `fio-util-<VSL-version>.x86_64.rpm` package (and not the 4.2.1 (or newer) `fio-util-<VSL-version>.x86_64.rpm` package) is located in the directory where you will be executing the commands below.

```
$ rpm -Uvh lib*.rpm
rpm -Uvh fio*.rpm
```

NOTE-

If the installation of the 3.2.15 `fio-util-<VSL-version>.x86_64.rpm` package fails due to missing dependencies, you will need to install the missing packages before you run the install command again, for example:

```
$ yum install lsof pciutils
```

The Fusion ioMemory VSL software and utilities are installed to the following locations:

Package Type	Installation Location
Fusion ioMemory VSL software	`/lib/modules/<kernel-version>/extra/fio/iomemory-vsl.ko`
Utilities	`/usr/bin`

NOTE-

You may also install the Fusion ioSphere software (optional GUI management software). Fusion ioSphere software and documentation are available as a separate download in the ioSphere download folder.

Once the packages are installed, continue to Loading the ioMemory VSL Driver on page 20.

ATTENTION!

Unified Utilities. After you install 3.2.15 Fusion ioMemory VSL and 3.2.15 utilities, and upgrade the firmware, you can install the 4.2.1 (or newer) Unified Utilities if so desired.

To install the Unified Utilities, you will install the 4.2.1 (or newer) `fio-util-<VSL-version>.x86_64.rpm` for VSL 4.2.1 (or newer) Release Version on your VSL 3.2.15 server using the following command:

```
$ rpm -Uvh fio-util-4.2.x.<buildversion>.x86_64.rpm
```

This command will replace your VSL 3.2.15 utilities with the VSL 4.2.1 (or newer) Unified Utilities. No reboot is required.

> **ATTENTION!**
>
> If the installation of the 4.2.1 (or newer) `fio-util-<VSL-version>.x86_64.rpm` package fails due to missing dependencies, you will need to install the missing packages before you run the install command again, for example:
>
> ```
> $ yum install lsof pciutils
> ```

For information on using the Unified Utilities on VSL 3.2.15 systems, including command differences between 3.2.15 and 4.2.1 (or newer) utilities, refer to the 3.2.15 *Fusion ioMemory VSL Release Notes*.

Installing DEB Packages

To install the Linux Fusion ioMemory VSL software and utilities on Debian/Ubuntu

1. You will need to install a version of the Fusion ioMemory VSL software that is built for your kernel. To determine what kernel version is running on your system, use the following command at a shell prompt:

   ```
   $ uname -r
   ```

2. Compare your kernel version with the binary versions of the software available at https://link.sandisk.com/commercialsupport .
   - If there is a binary version of the software that corresponds to your kernel version, download that. **For example**:

     ```
     iomemory-vsl-<kernel-version>-<VSL-version>_amd64.deb
     ```

   - If there is no binary version of the software corresponding to your kernel, download the source package. **For**

example:

```
iomemory-vsl_<VSL-version>.tar.gz
```

NOTE-

Exact package names may vary, depending on software and kernel version chosen.

Use the source package that is made for your distribution. Source packages from other distributions are not guaranteed to work.

3. Download the support Debian packages you need from https://link.sandisk.com/commercialsupport . These packages provide utilities, firmware, and other files.

ATTENTION!

The SDK libraries needed for management tools (formerly downloaded separately as `libvsl_<version>_amd64.deb`), are now packaged in the `iomemory-vsl-<kernel-version>-<VSL-version>_amd64.deb` and the `iomemory-vsl-<VSL-version>.tar.gz`. For more information on available management tools, please refer to Monitoring and Managing Devices on page 42 .

ATTENTION!

Unified Utilities. If you plan to run the 4.2.1 (or newer) Unified Utilities on a VSL 3.2.15 server, you will need to download both the VSL 3.2.15 Release utilities package `fio-util_<version>_amd64.deb` and the VSL 4.2.1 (or newer) Release utilities package `fio-util_<version>_amd64.deb` from https://link.sandisk.com/commercialsupport.

Be aware that only certain operating systems installed with VSL 3.2.15 can use the 4.2.1 (or newer) utilities. For the list of operating systems compatible with Unified Utilities on VSL 3.2.15 systems, refer to the 3.2.15 *Fusion ioMemory VSL Release Notes*.

For Unified Utilities installation, after you install the 3.2.15 Fusion ioMemory VSL and utilities packages and upgrade the firmware, you will then install the 4.2.1 (or newer) `fio-util_<version>_amd64.deb` package on your VSL 3.2.15 server. This installation will replace your VSL 3.2.15 utilities with the VSL 4.2.1 (or newer) Unified Utilities. See the end of this section for more information.

Examples:

Package	What Is Installed
`fio-util_<VSL-version>_amd64.deb`	ioMemory VSL utilities – **Recommended** **NOTE-** If you plan to run the 4.2.1 (or newer) Unified Utilities on a VSL 3.2.15 server, you will need to download both the 3.2.15 `fio-util_<version>_amd64.deb` for the VSL 3.2.15 Release, and the 4.2.1 (or newer) `fio-util_<version>_amd64.deb` for the VSL 4.2.1 (or newer) Release Version (preferably into separate folders or locations).
`fio-preinstall_<VSL-version>_amd64.deb`	This package installs the `fio-firmware` utility, which reports the version and revision of the firmware on all Fusion ioMemory devices without requiring you to load the ioMemory VSL software driver. – **Optional** For `fio-firmware` usage information, please refer to fio-firmware on page 58.
`fio-firmware-<version>.<date>-<number>_all.deb`	Firmware archive package, installs the firmware archive file in a specific location (`/usr/share/fio/firmware`) – **Optional**
`fio-firmware-<version>.<date>.fff`	Firmware archive file (not an installer package) used to upgrade the firmware, make note of where you store this file – **Recommended**
`fio-common-<VSL-version>.x86_64.deb`	Files required for the init script – **Strongly Recommended**
`fio-sysvinit-<VSL-version>.x86_64.deb`	Init script – **Strongly Recommended**, see Loading the ioMemory VSL Driver on page 20 for more information.

4. Change to the directory where you downloaded the installation packages.
5. If needed, build the Fusion ioMemory VSL software from source:
   - **If you downloaded a binary version of the software**: skip the **Building the Software from Source** instructions below and continue to the next step.
   - **If you downloaded the software source package**: follow these **Building the Software from Source** instructions:

Building the Software from Source
You only need to follow these additional instructions if you downloaded the source package. a. Install the prerequisites for building the Fusion-io source Fusion ioMemory VSL package.

```
$ sudo apt-get install gcc fakeroot build-essential debhelper
linux-headers-`uname -r` rsync
```

You can also install packages separately by running this command:

```
$ sudo apt-get install <package>
```

b. Download the software source file for your target operating system at https://link.sandisk.com/commercialsupport

c. Unpack the ioMemory VSL source file.

```
$ tar zxvf iomemory-vsl_<VSL-version>.tar.gz
```

d. Change directory to the folder created in the previous step.

```
$ cd iomemory-vsl-source-<VSL-version>
```

e. Begin the software rebuild.

```
$ sudo dpkg-buildpackage -uc -us
```

ATTENTION!

When building the source for all Debian-based installations, you must use the –uc and –us options with the dpkg-buildpackage command, or the build may fail.

You can also build the ioMemory VSL as a non-root user.

```
$ dpkg-buildpackage -rfakeroot -b -uc -us
```

ATTENTION!

When building the source for all Debian-based installations as a non-root user, you must use the –uc and –us options with the dpkg-buildpackage command, or the build may fail.

f. The new DEB packages are located in the parent directory.

NOTE-

A failure of any of these builds may be due to required packages missing from the system. The output from the failed command informs you of which packages are missing. Try installing any missing packages and then repeating the build process.

g. You have now built installation packages for your distribution and kernel.

h. Copy your custom-built software installation packages into the directory where you downloaded the installation packages.

i. Continue to the next step.

6. Use the following command to install each of the desired packages, adding package names as needed.

NOTE-

Your exact package names will depend on the file names you download. Use the ioMemory VSL software package name that is built for your kernel version.

ATTENTION!

Ensure that you install the 3.2.15 `fio-util_<VSL-version>_amd64.deb` package (and not the 4.2.1 (or newer) `fio-util_<VSL-version>_amd64.deb` package) when executing the command below.

```
$ dpkg -i iomemory-vsl-<kernel-version>_<VSL-version>_amd64.deb fio-firmware_
<firmware-version>_all.deb fio-util_<VSL-version>_amd64.deb
```

The Fusion ioMemory VSL software and utilities are installed to the following locations:

Package Type	Installation Location
Fusion ioMemory VSL software	`/lib/modules/<kernel-version>/extra/fio/`
Utilities	`/usr/bin`

NOTE-

You may also install the Fusion ioSphere software (optional GUI management software). Fusion ioSphere software and documentation are available as a separate download in the ioSphere download folder.

Once the packages are installed, continue to Loading the ioMemory VSL Driver on page 20.

ATTENTION!

Unified Utilities. After you install 3.2.15 Fusion ioMemory VSL and 3.2.15 utilities, and upgrade the firmware, you can install the 4.2.1 (or newer) Unified Utilities if so desired.

To install the Unified Utilities:

1. First, uninstall the 3.2.15 `fio-util_<version>_amd64.deb` using the following command:

```
$ dpkg --purge fio-util
```

2. Next, install the 4.2.1 (or newer) `fio-util_<version>_amd64.deb` for VSL 4.2.1 Release Version on your VSL 3.2.15 server using the following command:

   ```
   $ dpkg -i fio-util_<version>_amd64.deb
   ```

   This command will replace your VSL 3.2.15 utilities with the VSL 4.2.1 (or newer) Unified Utilities. No reboot is required.

   NOTE-

   If dependency errors display during installation, ignore the messages.

For information on using the Unified Utilities on VSL 3.2.15 systems, including command differences between 3.2.15 and 4.2.1 (or newer) utilities, refer to the 3.2.15 *Fusion ioMemory VSL Release Notes*.

Loading the ioMemory VSL Driver

To load the Fusion ioMemory VSL driver:

Run this command:

```
# modprobe iomemory-vsl
```

NOTE-

The Fusion ioMemory VSL driver automatically loads at system boot. The Fusion ioMemory device is now available to the OS as `/dev/fiox`, where *x* is a letter (i.e., a, b, c, etc.).

To confirm the Fusion ioMemory device is attached, run the `fio-status` utility from the command line. The output lists each drive and its status (attached or not attached).

ATTENTION!

If the Fusion ioMemory device is not automatically attaching, check the `/etc/modprobe.d` files to ensure that the `auto_attach` option is turned on (set to 1).

- For the `modprobe iomemory-vsl` command to work on SLES 10 systems, you must edit the `/etc/init.d/iomemory-vsl` file's init info and change `udev` to `boot.udev`. The file should look like this:

  ```
  ### BEGIN INIT INFO
  # Provides:        iomemory-vsl
  # Required-Start: boot.udev
  ```

- On SLES systems, you must also allow unsupported modules for the `modprobe iomemory-vsl` command to work.

- **SLES 12 and SLES 11 Update 2**: Please refer to the `/etc/modprobe.d/iomemory-vsl.conf` file for the most current instructions on enabling unsupported modules for your distribution.

- **SLES 10 SP4**: Modify the `/etc/sysconfig/hardware/config` file so the `LOAD_UNSUPPORTED_MODULES_AUTOMATICALLY` sysconfig variable is set to `yes`, for example:

  ```
  LOAD_UNSUPPORTED_MODULES_AUTOMATICALLY=yes
  ```

Controlling Driver Loading

You can control driver loading either through udev or the init script.

udev - In newer Linux distributions, you can rely on the udev device manager to automatically find and load drivers for the installed hardware at boot time, though udev can be disabled and the init script used in nearly all cases.

init script - On systems where udev loading of the driver doesn't work or is disabled, you can use the init script to load the Fusion ioMemory VSL driver. We recommend using the init script to load the VSL driver if you are managing a RAID array using LVM, mdadm, or Veritas Storage Foundation. For older Linux distributions (such as SLES 10) without udev functionality, users must rely on a boot-time init script to load needed drivers.

Using the init Script

The init script can be enabled to load the driver at boot. On some distros it may be enabled by default.

NOTE-

The init Script is part of the `fio-sysvinit` package, which must be installed before you can enable it. You must also install the `fio-common` package.

- To enable driver loading in the init script, use the following command:

  ```
  # chkconfig --add iomemory-vsl
  ```

- To disable driver loading in the init script, use the following command:

  ```
  # chkconfig --del iomemory-vsl
  ```

The Fusion ioMemory VSL software install process places an init script in `/etc/init.d/iomemory-vsl`. In turn, this script uses the setting options found in the options file in `/etc/sysconfig/iomemory-vsl`. The options file must have ENABLED set (non-zero) for the init script to be used:

```
ENABLED=1
```

The options file contains documentation for the various settings—including `KILL_PROCS_ON_UMOUNT`, which is discussed further in the section Handling Driver Unloads on page 23.

Mounting Filesystems when Using the init Script

There may be timing or other issues that prevent the filesystem on a Fusion ioMemory ioDrive device from coming up automatically when using the standard Linux driver load process. This means that using the standard method for mounting filesystems (/etc/fstab) may not work reliably for filesystems hosted on the Fusion ioMemory device.

Instead, to correctly set up auto-mounting of a filesystem hosted on an Fusion ioMemory device, follow the procedure below:

1. Add the filesystem mounting command to /etc/fstab as normal.
2. Add the 'noauto' option and the '0 0' flag to /etc/fstab, as shown in the two following sample entries.

```
/dev/fioa /mnt/fioa ext3 defaults,noauto 0 0
/dev/fiob1 /mnt/ioDrive ext3 defaults,noauto 0 0
```

(where the a in fioa can be a, b, c, etc., depending on how many Fusion ioMemory devices you have installed in the system). The number of lines you add will depend on how many Fusion ioMemory devices /partitions you have installed in the system.

WARNING!

Failure to add 'noauto 0 0' to fstab may cause a boot failure.

3. To configure the init script to automatically mount these drives after the driver is loaded, and unmount them before the driver is unloaded, you should add a list of mount points to the options file /etc/sysconfig/iomemory-vsl using the procedure documented there.

   For the filesystem mounts shown in the earlier example, the line in the options file would look like this:

```
MOUNTS="/mnt/fioa /mnt/iodrive"
```

Using udev

On systems that rely on udev to automatically load drivers, users can modify a Fusion ioMemory VSL software options file if they want to prevent udev from auto-loading the ioMemory VSL at boot time. To do this, locate and edit the /etc/modprobe.d/iomemory-vsl.conf file that already has the following line:

```
# blacklist iomemory-vsl
```

To disable automatic driver loading by udev, remove the "#" from the line and save the file.

With the blacklist command in place, restart Linux. The Fusion ioMemory VSL driver will not be loaded by udev.

NOTE-

If the driver is already in the initrd, you will need to rebuild the initrd for the change to take effect.

To restore the udev-loading of the driver, replace the "#" to comment out the line.

On either udev or init script systems

For diagnostic or troubleshooting purposes on both udev and init script systems, users can disable the loading of the driver at boot time, which in turn prevents the auto-attach process.

For example, if the Fusion ioMemory VSL software is preventing the system from booting normally, you can prevent the Fusion ioMemory VSL driver from loading at all by appending the following parameter at the kernel command line of your boot loader:

```
iomemory-vsl.disable=1
```

The driver will not load until the system is rebooted. However, this method is generally not preferred for diagnostic situations because it limits the amount of troubleshooting you can perform.

For many troubleshooting scenarios, disabling auto-attach alone is sufficient. You can disable auto-attach for a single load only, or in a persistent configuration.

- To disable the auto-attach functionality for a single load of the Fusion ioMemory VSL driver, append the following parameter at the kernel command line of your boot loader:

  ```
  iomemory-vsl.auto_attach=0
  ```

  > **NOTE-**
  >
  > The above command will disable auto-attach even if the driver is loaded by the initrd.

- To disable the auto-attach functionality as a persistent configuration, follow the steps in the section Disabling Auto-Attach on page 49.

Fusion ioMemory devices and Multipath Storage

If you are using Fusion ioMemory devices along with multipath storage, you must blacklist the Fusion ioMemory devices to prevent device-mapper from trying to create a dm-device for each Fusion ioMemory device. **This must be done prior to activating dm-multipath and/or loading the driver**. If Fusion ioMemory devices are not blacklisted, they will appear busy and you will not be able to attach, detach, or update the firmware on the devices.

To blacklist Fusion ioMemory devices, edit the /etc/multipath.conf file and include the following:

```
blacklist {
     devnode          "^fio[a-z]"
}
```

Handling Driver Unloads

Special consideration must be taken during Fusion ioMemory VSL driver unload time. By default, the init script searches for any processes holding open a mounted filesystem and kills them, thus allowing the filesystem to be unmounted. This behavior is controlled by the option KILL_PROCS_ON_UMOUNT in the options file located at /etc/sysconfig/iomemory-vsl. If these processes are not killed, the filesystem cannot be unmounted. This may keep the Fusion ioMemory VSL software from unloading cleanly, causing a significant delay on the subsequent boot.

Upgrading the Firmware

With the Fusion ioMemory VSL software loaded, you should check whether the Fusion ioMemory device's firmware is up-to-date and then update the firmware if needed. You can do this with either the command-line utilities or the optional Fusion ioSphere software (GUI).

NOTE-

Make sure you have downloaded the firmware archive file that goes with this version of the Fusion ioMemory VSL software.

ATTENTION!

There is a specific upgrade path that you must take when upgrading a Fusion ioMemory device. Consult the *Fusion ioMemory VSL Release Notes* for this Fusion ioMemory VSL software release before upgrading Fusion ioMemory devices.

Also refer to the *Fusion ioMemory VSL Release Notes* for this Fusion ioMemory VSL software release for any Known Issues affecting firmware upgrades.

WARNING!

Do not attempt to downgrade the firmware on any Fusion ioMemory device; doing so may void your warranty.

When installing a new Fusion ioMemory device along with existing devices, you must upgrade all of the currently installed devices to the latest available versions of the firmware and Fusion ioMemory VSL software before installing the new devices. Consult the *Fusion ioMemory VSL Release Notes* for this Fusion ioMemory VSL software release for any upgrade considerations.

ATTENTION!

Upgrading Guest OS
If you are using your Fusion ioMemory device within a guest OS (for example, using VMDirectPathIO), you must power cycle the host server after you upgrade the device(s). Just restarting the virtual machine will not apply the firmware update.

Command-line Interface

More information on these command-line utilities is available in Command-line Utilities Reference on page 54. All command-line utilities require root permission.

1. Run the `fio-status` utility and examine the output. See fio-status on page 61 for usage information.

    - If any device is in minimal mode and the reason is listed as outdated firmware, then update the firmware.

    - If a device is not in minimal mode, but the firmware listed for that device is a lower number than the latest firmware version available with this version of the Fusion ioMemory VSL software, then the firmware is old, but not outdated.

2. If the firmware is old or outdated, update it using the `fio-update-iodrive` utility. See fio-update-iodrive on page 66 for complete information and warnings.

Optional GUI - Fusion ioSphere software

You can use the Fusion ioSphere software to check the status of your Fusion ioMemory devices. If the Fusion ioSphere software indicates that the device's firmware is outdated, you can also use the Fusion ioSphere software to upgrade the device firmware. Consult the Fusion ioSphere software documentation for more information on installing and using the software.

Configuration

Once you have your Fusion ioMemory device and Fusion ioMemory VSL software installed and loaded, and the firmware on the device is current, you may need to configure the device and/or software. This section outlines some of the common configurations that you may need to consider.

Setting the ioMemory VSL Options

This section explains how to set Fusion ioMemory VSL software options. For more information about setting specific options, see Using Module Parameters on page 71.

One-Time Configuration

Fusion ioMemory VSL software options can be set at install time, on the command line of either `insmod` or `modprobe`. For example, to set the `auto_attach` option to 0 (which disables auto_attach), run the command:

```
# modprobe iomemory-vsl auto_attach=0
```

This option takes effect only for this load of the Fusion ioMemory VSL software; subsequent calls to `modprobe` or `insmod` will not have this option set.

Persistent Configuration

To maintain a persistent setting for an option, add the desired option to `/etc/modprobe.d/iomemory-vsl.conf` or a similar file. To prevent the Fusion ioMemory devices from auto-attaching, add the following line to the `iomemory-vsl.conf` file:

```
options iomemory-vsl auto_attach=0
```

This option then takes effect for every subsequent Fusion ioMemory VSL software load, as well as on autoload of the Fusion ioMemory VSL software during boot time.

ATTENTION!

If the VSL driver is in the `initrd`, the `initrd` will need to be rebuilt in order for the change to take effect.

Enabling PCIe Power Override

If you have installed any products with multiple Fusion ioMemory devices, such as the Fusion ioMemory ioDrive Duo device, the device may require additional power to properly function (beyond the minimum 25W provided by PCIe Gen2 slots). Even if additional power is not required for your device, all dual Fusion ioMemory devices that receive additional power may benefit with improved performance.

Fusion ioMemory ioDrive2 Duo devices **must** have additional power in order to properly function. For more information on which devices require additional power, see the section on *Power Cables for Multi-device Products* in the *Fusion ioMemory Hardware Installation Guide*.

This additional power may be provided in two ways:

- **External Power Cable**: See the *Fusion ioMemory Hardware Installation Guide* for information on installing the external cable.

  NOTE-

  When a power cable is used, all of the power is drawn from the cable and no power is drawn from the PCIe slot.

- **Enabling a Specified Maximum Power Draw**: Some PCIe slots provide additional power (often up to 75W of power). You may allow the device to draw a specified maximum power from the PCIe slot by setting a Fusion ioMemory VSL software module parameter. For more information on enabling this override parameter, see the instructions in the next section.

  NOTE-

  This parameter overrides the setting that prevents device(s) from drawing more than 25W from the PCIe slot. The parameter is enabled per device (using device serial numbers with the specified maximum power value in Watts).

  Before you enable this override parameter, ensure that each PCIe slot you will use is rated to provide enough power for all slots, devices, and server accessories. Consult the server documentation, BIOS interface, setup utility, and/or use `fio-pci-check` (if available) to determine the slot power limits.

  WARNING!

  If the slot is not capable of providing the needed amount of power, enabling a specified maximum power draw from the PCIe slot may result in malfunction or even damage server hardware. You are responsible for any damage to equipment due to improper use of this override parameter and SanDisk expressly disclaims any liability for any damage arising from such improper use. Contact Customer Support if there are any questions or concerns about the override parameter use.

ATTENTION!

Confirm with Server Manufacturer
Contact the server manufacturer to confirm the power limits and capabilities of each slot, as well as the entire system.

The following are important considerations:

- If you are installing more than one dual Fusion ioMemory device and enabling the override parameter for each device, make sure the motherboard is rated to provide the specified maximum power to each slot that is used.

  ATTENTION!

  For example, some motherboards safely provide up to 75W to any one slot, but run into power constraints when multiple slots are used to provide that much power. Installing multiple devices in this situation may also result in server hardware damage. Consult with the manufacturer to determine the total PCIe slot power available.

- The override parameter, if enabled correctly, will persist in the system, and will enable the specified maximum power draw on an enabled device even if the device is removed and then placed in a different slot within the same system. If the device is placed in a slot that is not rated to provide the specified maximum power, you may damage your server hardware.
- This override parameter is a setting for the Fusion ioMemory VSL software per server, and is not stored in the device. When moved to a new server, the device will default to the power limit set by the BIOS for that PCIe slot unless this override parameter is enabled for that device in the new server. Consult with the manufacturer to determine the total PCIe slot power available for the new server.

Enabling the Override Parameter

Determine Serial Number(s)

Before you enable this parameter, determine the **adapter serial number** for each device you will put in a compatible slot. Use the `fio-status` command-line utility to determine the adapter serial number(s).

NOTE-

Serial Number Label
You may also inspect the adapter serial number label(s) on the device(s) to determine the serial number(s). However, as a best practice, confirm that each serial number is an adapter serial number by running `fio-status`. The adapter serial number label resides on the back of all Fusion ioMemory ioDrive Duo devices and Fusion ioMemory ioDrive2 Duo devices. On Fusion ioMemory ioDrive Duo devices, it is on the PCB component that is attached to the PCIe connector.

- **Using `fio-status`**: Run the `fio-status` command-line utility. Sample output:

```
fio-status
...
Adapter: Dual Controller Adapter
Fusion-io ioDrive2 DUO 2.41TB, Product Number:F01-001-2T41-CS-0001, FIO
SN:1149D0969
External Power: NOT connected
PCIe Power limit threshold: 24.75W
Connected ioMemory modules:
fct2:    SN:1149D0969-1121
fct3:    SN:1149D0969-1111
```

  In this example, `1149D0969` is the adapter serial number.

- **Using `fio-beacon`**: If you have multiple devices installed, you may use the `fio-beacon` utility to verify where each device is physically located. Consult the utility documentation fio-beacon on page 56 for more information.

Setting the Parameter in VSL 3.2.15

Set the module parameter by editing the `/etc/modprobe.d/iomemory-vsl.conf` file and changing the value for the `external_power_override` parameter. Please refer to the examples below.

Example 1:

You can use the override parameter to specify the maximum amount of power that specified devices should pull (in Watts).

```
options iomemory-vsl external_power_override=<SN-value>:<W-value>
```

Where the `<SN-value>:<W-value>` for this parameter is a comma-separated list of value pairs with adapter serial numbers and the maximum amount of power each device should pull (in Watts).

For example, `1149D0969:40,1159E0972:40,1331G0009:40` would allow three devices (with serial numbers `1149D0969, 1159E0972, and 1331G0009`) to each draw a maximum of approximately 40W.

Any cards in the server not set using this module parameter will use the power limit set by the BIOS for that PCIe slot.

Example 2:

You can use the override parameter to specify the maximum amount of power *all devices* in the system should pull (in Watts). Use the new serial number wildcard (*) to specify all devices in the system.

```
options iomemory-vsl external_power_override=*:<W-value>
```

Where the `*:<W-value>` for this parameter is the serial number wildcard (*) that includes all cards in the system, and the maximum amount of power all devices should pull (in Watts).

For example, `*:50` would allow all cards in the system to draw a maximum of approximately 50W.

ATTENTION!

Do not use serial numbers with the (*) wildcard (do not mix commands in Examples 1 and 2).

ATTENTION!

You must reboot or unload/load the driver to enforce any parameter changes.

Virtual Controller Configuration

Depending on your use case and application, you may benefit from configuring supported devices to use Virtual Controller technology.

When configured, each physical Fusion ioMemory device is split into two (virtual) logical devices. Splitting the Fusion ioMemory device into two virtual devices has the following implications:

- **Latency**: There is no affect on latency.
- **Throughput**: The total peak I/O bandwidth of the device is approximately the same.

- **IOPS**: Depending on the use of the virtual devices (especially the average I/O size), the peak IOPS for each virtual device is about the same for a non-split device. In other words, the combined peak IOPS of the two virtual devices can be nearly double that of a non-split device. For details, see in the *Maintenance* section.
- **Capacity**: Due to virtualization overhead, the combined capacity of the two virtual devices is slightly less than that of a single-controller device. See the *Fusion ioMemory VSL Release Notes* for a list of compatible devices and their Virtual Controller capacities.

Converting your Fusion ioMemory device to a Virtual Controller configuration will split the Fusion ioMemory device into two logical devices.

For 512B I/Os, the combined IOPS performance of the two virtual devices is approximately double that of a single-controller device. For 4KiB I/Os, there is more than an 80% improvement in IOPS performance with virtual devices. For 16kB and larger I/Os, there is no improvement of total IOPS performance over a non-Virtual Controller configuration.

Latency in the virtual devices is unaffected, and the combined bandwidth of the two virtual devices is the same as it would be without the split. Due to the overhead of an additional device, the combined capacity of the two virtual devices is slightly less than that of a single-controller device.

Splitting a single physical device into multiple virtualized devices, or merging multiple virtualized devices back to a single physical device, requires a low-level format, which will erase all of the data on the device. Be sure to back up all of your data.

Supported Devices

Only relatively new devices (with few writes performed) may be split or merged. Devices with too much wear are unsuitable for converting to or from a Virtual Controller configuration. Merging virtual devices may also result in additional wear (depending on the wear differences of the two virtual devices).

To be suitable for splitting or merging, devices (including Virtual Controller devices) must have 90% or more of their remaining rated endurance of Petabytes Written (PBW). This rating as well as the current percentage remaining is visible in `fio-status` with the `-a` option. For example:

```
fio-status /dev/fct1 -a
...
Rated PBW: 17.00 PB, 99.95% remaining
```

In the above example, the device is suitable for conversion because it has more than 90% of the rated PBW remaining.

If you attempt to merge or split a device that does not support Virtual Controller technology or a device that has too much wear, the update utility will not allow the conversion and the firmware upgrade will not take place. See the Release Notes for a list of devices that support Virtual Controller technology and their capacities after the conversion.

Multi-device Products

For products with more than one Fusion ioMemory device, such as a Fusion ioMemory ioDrive2 Duo device, you must configure all of the Fusion ioMemory devices to Virtual Controller technology at the same time. All of the devices must also be merged at the same time. For example, the two Fusion ioMemory devices in a Fusion ioMemory ioDrive2 Duo device will be converted into four virtual devices. The utility will not allow a conversion if you attempt to split or merge only one physical device in a multi-device product.

Splitting Controllers

Be sure to use firmware that supports Virtual Controller technology. Consult the Release Notes to determine if the firmware for that release supports Virtual Controller technology.

1. Back up all of your data. Because a low-level format is needed to complete the conversion, all of the user data on your device will be erased.

2. Use the `fio-update-iodrive` command-line utility to configure a Fusion ioMemory device to use Virtual Controller technology:

    - Use the `--split` option to split the controller.

    - Use the `-d` option to specify a device, otherwise all installed devices that can be split will be split.

    - Specify the firmware path, and check the *Fusion ioMemory VSL Release Notes* to make sure the firmware supports Virtual Controller technology.

      Example:

      ```
      fio-update-iodrive --split -d /dev/fct0 <firmware-path>
      ```

      After rebooting, each physical device will be split into two virtual devices. Each Fusion ioMemory device will therefore split into two logical devices, each with a unique device path. For example, `/dev/fct0` may become `/dev/fct0` and `/dev/fct1`. You will manage each device as a unique device.

3. Reboot.

4. Load the Fusion ioMemory VSL driver.

5. Run `fio-status` to determine which devices need to be formatted.

6. Low-level format the device(s). For example:

    ```
    fio-format /dev/fct0 /dev/fct1
    ```

    Formatting will erase all user data, be sure to back up your data. You can reverse the split by merging the controllers (without losing data) up until you format the virtual devices.

Merging Controllers

If your Fusion ioMemory device (including the two virtual devices) is suitable for merging, then you will be able to use the `fio-update-iodrive` utility to merge the virtual devices back into one physical device.

1. Back up all of your data. Because a low-level format is needed to complete the merge, all of the user data on your device will be erased.

2. Use the `fio-update-iodrive` command-line utility to configure the device for merging:

    a. Use the `--merge` option to merge the virtual devices.

    b. Use the `-d` option to specify a device.

ATTENTION!

The `fio-update-iodrive` utility only successfully works against one of the two virtual devices for each physical Fusion ioMemory device. Out of the two virtual devices, only the first virtual device (in terms of device numbering) is linked to the physical device (and the firmware). The second virtual device is not linked, and any firmware operation against that second virtual device will fail with this message:

```
Error: Device '/dev/fctx' had an error while updating. This
device does not support firmware update.
```

This is expected, and the error will not affect the update/merge of the first (linked) virtual device. The update operation will complete on all devices that can merge and otherwise accept firmware changes.

c. Specify the firmware path, and check the *Fusion ioMemory VSL Release Notes* to make sure the firmware supports Virtual Controller technology.

Example:

```
fio-update-iodrive --merge -d /dev/fct0 <firmware-path>
```

3. Reboot.

4. Load the Fusion ioMemory VSL driver.

5. Run `fio-status` to determine which devices need to be formatted.

6. Low-level format the device(s). For example:

```
fio-format /dev/fct0
```

WARNING!

Formatting will erase all user data, be sure to back up your data. You can reverse the merge by splitting the controllers (without losing data) up until you format the merged device.

Using the Device as Swap

To safely use the Fusion ioMemory device as swap space requires passing the `preallocate_memory` kernel module parameter. To set this parameter, use either the optional Fusion ioSphere software (see Fusion ioSphere software documentation), or add the following line to the `/etc/modprobe.d/iomemory-vsl.conf` file (see Using Module Parameters on page 71 for more information on using parameters):

```
options iomemory-vsl preallocate_memory=1149D2717-1121,1149D2717-1111,10345
```

- Where `1149D2717-1111,1149D2717-1111,10345` are serial numbers obtained from `fio-status`, see fio-format on page 59.

NOTE-

Be sure to provide the serial numbers for the Fusion ioMemory device, not an adapter, when applicable.

ATTENTION!

You must have enough RAM available to enable the Fusion ioMemory device with pre-allocation enabled for use as swap. Attaching a Fusion ioMemory device, with pre-allocation enabled, without sufficient RAM may result in the loss of user processes and system instability.

Consult the *Fusion ioMemory VSL Release Notes* for RAM requirements with this version of the Fusion ioMemory VSL software.

NOTE-

The `preallocate_memory` parameter is recognized by the Fusion ioMemory VSL software at load time, but the requested memory is not actually allocated until the specified device is attached.

Setting the Amount of Preallocated Memory

If you enable devices for preallocation (as described above), the Fusion ioMemory VSL software will automatically preallocate the amount of memory based on your formatted sector size. If you have a sector size that is less than 4KiB (for example, 512B sectors), then the Fusion ioMemory VSL software will preallocate a very large amount of memory (calculated for worst-case scenarios based on 512B sectors).

See the *Fusion ioMemory VSL Release Notes* for worst-case RAM requirements based on formatted sizes. The Fusion ioMemory VSL software preallocates enough memory for worst-case scenarios in order to avoid an out-of-memory situation where the Fusion ioMemory device would no longer function due to insufficient memory (resulting in a system crash).

Operating systems normally use at least 4KiB blocks of data for virtual memory, so it would be safe in most cases for the Fusion ioMemory VSL software to preallocate enough memory for a worst-case scenario based on 4KiB sectors. There are two ways to force the Fusion ioMemory VSL software to preallocate based on 4KiB block sizes:

- **Format the device to 4KiB sectors**. With preallocation enabled, the Fusion ioMemory VSL software will automatically preallocate memory based on 4KiB blocks of data. Use `fio-format` to format the Fusion ioMemory device with 4KiB sector sizes.

- **Use the `preallocate_mb` parameter**. This parameter sets the amount of memory that the Fusion ioMemory VSL software will preallocate for every Fusion ioMemory device in the system that is enabled for preallocation (as described in the previous section).

  WARNING!

  Ensure that you are preallocating enough system memory. If you do not allocate enough memory and you attempt to use the device for swap space (due to a miscalculation or entry error), the system may crash as memory resources are depleted.

1. Determine the amount of system memory needed for every device in a worst-case scenario.
    a. See the *Fusion ioMemory VSL Release Notes* for worst-case RAM requirements based on sector sizes.

    b. You can base this calculation on the sector size that aligns with the data block size that your operating system uses for virtual memory.

2. Set the parameter by adding the following line to the `/etc/modprobe.d/iomemory-vsl.conf` file (see [Using Module Parameters on page 71]() for more information on using parameters):

    ```
    options iomemory-vsl preallocate_mb=<value>
    ```

    Where `<value>` is the amount of system memory in MB that the Fusion ioMemory VSL software should preallocate for **every** Fusion ioMemory device that is enabled for preallocation. For example, if you entered a value of `3500`, then the Fusion ioMemory VSL software will preallocate about 3.5GB of RAM for every Fusion ioMemory device that is enabled for preallocation in that system.

    ATTENTION!

    In order for the preallocation of memory to be effective, this value should be larger than the default memory usage of the device (as reported by runing `fio-status -a`).

Using the Logical Volume Manager

The Logical Volume Manager (LVM) volume group management application handles mass storage devices like Fusion ioMemory devices if you add the Fusion ioMemory device as a supported type:

1. Locate and edit the `/etc/lvm/lvm.conf` configuration file.

2. Add an entry similar to the following to that file:

    ```
    types = [ "fio", 16 ]
    ```

    The parameter "16" represents the maximum number of partitions supported by the device.

    NOTE-

    If using LVM or MD, do not use udev to load the Fusion ioMemory VSL driver. The init script will ensure that the LVM volumes and MD devices are detached before attempting to detach the Fusion ioMemory device.

Mounting Filesystems when Using the init Script

If you are using the init script to load the ioMemory VSL software, once you have configured your devices you will need to follow the instructions in the *Mounting Filesystems when Using the init Script* subsection of the section [Controlling Driver Loading on page 21]().

Configuring RAID using the Logical Volume Manager

The simplest way to using your Fusion ioMemory devices with LVM is to use the entire block device with it (for example: `/dev/fioa` rather than `/dev/fioa1`, `/dev/fioa2`, etc.). This way the block device does not need to partitioned ahead of time, though partitioning is also supported. The examples that follow assumes the entire block device is used.

Whether you plan to stripe (RAID 0) or mirror (RAID 1) the devices, the first two steps are the same:

1. First, create physical volumes, for example:

```
$ pvcreate /dev/fioa  /dev/fiob
```

2. Next add these physical volumes to a volume group, for example:

```
$ vgcreate iomemory_vg /dev/fioa /dev/fiob
```

Creating a Striped Volume (RAID 0) Using LVM

With the volume group created, you can create logical volumes within this volume group. In this instance, only one will be created and we name it `iomemory_lv`:

1. Create the striped volume using the `–i2` option for two stripes, for example:

```
$ lvcreate -l 100%VG -n iomemory_lv -i2 iomemory_vg
```

2. Create a file system on the newly created volume, for example:

```
$ mkfs.ext3 /dev/iomemory_vg/iomemory_lv
```

3. In order to make this persistently mount at boot time, edit the `/etc/sysconfig/iomemory-vsl` file by adding the volume group path under the example line:

```
Example: LVM_VGS="/dev/vg0 /dev/vg1"
LVM_VGS="/dev/iomemory_vg"
```

Be sure to just add the volume group path and not the logical volume as well. For more information on using the init script and the `/etc/sysconfig/iomemory-vsl` file, see Loading the ioMemory VSL Driver on page 20.

Creating a Mirrored Volume (RAID 1) Using LVM

With the volume group created, you can create logical volumes within this volume group. In this instance, only one will be created and we name it `iomemory_lv`:

1. Create the mirrored volume using the `–m1` option for an original linear volume plus one copy, for example:

```
$ lvcreate -l 50%VG -n iomemory_lv -m1 --corelog iomemory_vg
```

You can monitor the progress of the initial mirror synchronization using the lvs command. For example:

```
lvs -a -o +devices
```

ATTENTION!

With the `\--corelog option`, LVM uses an in-memory region or log to track the state of the mirror legs. Since it is in-memory and lost at reboot, it must be regenerated at boot by scanning the mirror legs.

For alternative configurations, consult the LVM documentation.

2. Create a file system on the newly created volume, for example:

```
$ mkfs.ext3 /dev/iomemory_vg/iomemory_lv
```

3. In order to make this persistently mount at boot time, edit the `/etc/sysconfig/iomemory-vsl` file by adding the volume group path under the example line:

```
# Example: LVM_VGS="/dev/vg0 /dev/vg1"
LVM_VGS="/dev/iomemory_vg"
```

Be sure to just add the volume group path and not the logical volume as well. For more information on using the init script and the `/etc/sysconfig/iomemory-vsl` file, see Loading the ioMemory VSL Driver on page 20.

Configuring RAID Using mdadm

You can configure two or more Fusion ioMemory devices into a RAID array using software-based RAID solutions.

NOTE-

If you are using RAID1/Mirrored and one device fails, be sure to run `fio-format` on the replacement device (not the existing, good device) before rebuilding the RAID. Following are some examples of some common RAID configurations using the `mdadm` utility.

ATTENTION!

The Linux kernel RAID 5 implementation performs poorly at high data rates. This is an issue in the Linux kernel. Alternatives include using RAID 10, or possibly a third-party RAID stack.

Mounting Arrays

Once you are done making your array (by following one of the configuration samples below), you must edit the `/etc/sysconfig/iomemory-vsl` file and add the array path under the example line. This will make the array mount at boot time.

In all of the examples below, we create arrays named `md0`. Here is is how you would edit the `/etc/sysconfig/iomemory-vsl` file to include the array using `md0` as an example (you add the array just below the example line in that file):

```
# Example: MD_ARRAYS="/dev/md0 /dev/md1"
MD_ARRAYS="/dev/md0"
```

If you are using the init script to load the ioMemory VSL software, once you have configured your devices you will need to follow the instructions in the *Mounting Filesystems when Using the init Script* subsection of the section Controlling Driver Loading on page 21.

RAID 0

To create a striped set, where `fioa` and `fiob` are the two Fusion ioMemory devices you want to stripe, run this command:

```
$ mdadm --create /dev/md0 --chunk=256 --level=0 --raid-devices=2 /dev/fioa
/dev/fiob
```

Making the Array Persistent (Existing after Restart)

On some versions of Linux, the configuration file is in `/etc/mdadm/mdadm.conf`, not `/etc/mdadm.conf`.

Inspect `/etc/mdadm.conf`. If there are one or more lines declaring the devices to inspect, make sure one of those lines specifies "partitions" as an option. If it does not, add a new DEVICE line to the file specifying "partitions" like this:

```
DEVICE partitions
```

Also add a device specifier for the fio Fusion ioMemory devices:

```
DEVICE /dev/fio*
```

To see if any updates are needed to `/etc/mdadm.conf`, issue the following command:

```
$ mdadm --examine --scan
```

Compare the output of this command to what currently exists in `mdadm.conf` and add any needed sections to `/etc/mdadm.conf`.

NOTE-

For example, if the array consists of two devices, there will be three lines in the output of the command that are not present in the `mdadm.conf` file: one line for the array, and two device lines (one line for each device). Be sure to add those lines to the `mdadm.conf` so it matches the output of the command.

For further details please see the `mdadm` and `mdadm.conf` man pages for your distribution.

With these changes, on most systems the RAID 0 array will be created automatically upon restart. However, if you have problems accessing `/dev/md0` after restart, run the following command:

```
$ mdadm --assemble --scan
```

You may also want to disable udev loading of the Fusion ioMemory VSL driver, if needed, and use the init script provided for driver loading. Please see the *Using the init Script* subsection of the section Controlling Driver Loading on page 21 for further details on how to use the init script.

NOTE-

In SLES 11, you may need to run the following commands to make sure these services are run on boot:

```
chkconfig boot.md on
chkconfig mdadmd on
```

RAID 1

To create a mirrored set using the two Fusion ioMemory devices `fioa` and `fiob`, run this command:

```
$ mdadm --create /dev/md0 --level=1 --raid-devices=2 /dev/fioa /dev/fiob
```

RAID 10

To create a striped, mirrored array using four Fusion ioMemory devices (fioa, fiob, fioc, and fiod), run this command:

```
$ mdadm --create /dev/md0 -v --chunk=256 --level=raid10 --raid-devices=4 /dev/fioa
/dev/fiob /dev/fioc /dev/fiod
```

Building a RAID10 Across Multiple Devices

In a RAID10 configuration, sets of two disks are mirrored, and then those mirrors are striped. When setting up a RAID10 across multiple Fusion ioMemory devices, it is best to make sure that no mirror resides solely on the two Fusion ioMemory devices that comprise an a single product (such as a Fusion ioMemory ioDrive Duo device).

In order to get the data to lay out properly,

- Use the `--layout=n2` option when creating the RAID10 (though it should be the default)
- Ensure that no two Fusion ioMemory devices from the same device are listed side by side.

The following sample code shows some recommended configurations.

NOTE-

The following commands assume that all Fusion ioMemory devices have been freshly formatted with the `fio-format` utility.

ATTENTION!

The ordering of the fiox devices is critical.

```
# 2 Dual Device Products RAID10
$ mdadm --create --assume-clean --level=raid10 --layout=n2 -n 4 /dev/md0 \
/dev/fioa /dev/fioc \
/dev/fiob /dev/fiod
# Mirror groups are: fioa,fioc and fiob,fiod
```

```
# 3 Dual Device Products RAID10
$ mdadm --create --assume-clean --level=raid10 --layout=n2 -n 6 /dev/md0 \
/dev/fioa /dev/fiod \
/dev/fioc /dev/fiof \
/dev/fioe /dev/fiob
```

```
# 4 Dual Device Products RAID10
$ mdadm --create --assume-clean --level=raid10 --layout=n2 -n 8 /dev/md0 \
/dev/fioa /dev/fiod \
/dev/fioc /dev/fiof \
/dev/fioe /dev/fioh \
/dev/fiog /dev/fiob
```

```
# 8 Dual Device Products RAID10
$ mdadm --create --assume-clean --level=raid10 --layout=n2 -n 16 /dev/md0 \
/dev/fioa /dev/fiod \
/dev/fioc /dev/fiof \
/dev/fioe /dev/fioh \
/dev/fiog /dev/fioj \
/dev/fioi /dev/fiol \
/dev/fiok /dev/fion \
/dev/fiom /dev/fiop \
/dev/fioo /dev/fiob
```

Discard (TRIM) Support

With this version of the Fusion ioMemory VSL software, Discard (also known as TRIM) is enabled by default.

Discard addresses an issue unique to solid-state storage. When a user deletes a file, the device does not recognize that it can reclaim the space. Instead the device assumes the data is valid.

Discard is a feature on newer filesystem releases. It informs the device of logical sectors that no longer contain valid user data. This allows the wear-leveling software to reclaim that space (as reserve) to handle future write operations.

Discard (TRIM) on Linux

Discard is enabled by default in the Fusion ioMemory VSL software release. However, for discard to be implemented, the Linux distribution must support this feature, and discard must be turned on.

In other words, if your Linux distribution supports discard, and discard is enabled on the system, then discard will be implemented on your Fusion ioMemory device.

Under Linux, discards are not limited to being created by the filesystem; discard requests can also be generated directly from userspace applications using the kernel's discard ioctl.

ATTENTION!

There is a known issue that ext4 in Kernel.org 2.6.33 or earlier may silently corrupt data when discard is enabled. This has been fixed in many kernels provided by distribution vendors. Please check with your kernel provider to be sure your kernel properly supports discard. For more information, see the Errata in the *Fusion ioMemory VSL Release Notes* for this version of the software

NOTE-

On Linux, MD and LVM support discards on newer kernels. LVM supports this on kernels 2.6.29 and newer. MD supports discard on kernels 3.7 and newer.

Performance and Tuning

Fusion ioMemory devices provide high bandwidth, high Input/Output per Second (IOPS), and are specifically designed to achieve low latency.

As Fusion ioMemory devices improve IOPS and low latency, the device performance may be limited by operating system settings and BIOS configuration. These settings may need to be tuned to take advantage of the revolutionary performance of Fusion ioMemory devices.

While Fusion ioMemory devices generally perform well out of the box, this section describes some of the common areas where tuning may help achieve optimal performance.

Disable CPU Frequency Scaling

Dynamic Voltage and Frequency Scaling (DVFS) are power management techniques that adjust the CPU voltage and/or frequency to reduce power consumption by the CPU. These techniques help conserve power and reduce the heat generated by the CPU, but they adversely affect performance while the CPU transitions between low-power and high-performance states.

These power-savings techniques are known to have a negative impact on I/O latency and IOPS. When tuning for performance, you may benefit from reducing or disabling DVFS completely, even though this may increase power consumption.

DVFS, if available, is often configurable as part of your operating systems power management features as well as within your system's BIOS interface. Within the operating system and BIOS, DVFS features are often found under the Advanced Configuration and Power Interface (ACPI) sections; consult your computer documentation for details.

Limiting ACPI C-States

Newer processors have the ability to go into lower power modes when they are not fully utilized. These idle states are known as ACPI C-states. The `C0` state is the normal, full power, operating state. Higher C-states (`C1`, `C2`, `C3`, etc.) are lower power states.

While ACPI C-states save on power, they can have a negative impact on I/O latency and maximum IOPS. With each higher C-state, typically more processor functions are limited to save power, and it takes time to restore the processor to the `C0` state.

When tuning for maximum performance you may benefit from limiting the C-states or turning them off completely, even though this may increase power consumption.

Setting ACPI C-State Options

If your processor has ACPI C-states available, you can typically limit or disable them in the BIOS interface (sometimes referred to as a Setup Utility). APCI C-states may be part of of the Advanced Configuration and Power Interface (ACPI) menu. Consult your computer documentation for details.

C-States Under Linux

Newer Linux kernels have drivers that may attempt to enable APCI C-states even if they are disabled in the BIOS. You can limit the C-state in Linux (with or without the BIOS setting) by adding the following to the kernel boot options:

```
intel_idle.max_cstate=0 processor.max_cstate=0
```

In this example, the maximum C-state allowed will be `C0` (disabled).

Setting NUMA Affinity

Servers with a NUMA (Non-Uniform Memory Access) architecture may require special installation instructions in order to maximize Fusion ioMemory device performance. This includes most multi-socket servers.

On some servers with NUMA architecture, during system boot, the BIOS will not associate PCIe slots with the correct NUMA node. Incorrect mappings result in inefficient I/O handling that can significantly degrade performance. To prevent this, you must manually assign Fusion ioMemory devices optimally among the available NUMA nodes.

See NUMA Configuration on page 73 for more information on setting this affinity.

Setting the Interrupt Handler Affinity

Device latency can be affected by placement of interrupts on NUMA systems. We recommend placing interrupts for a given device on the same NUMA node that the application is issuing I/O from. If the CPUs on this node are overwhelmed with user application tasks, in some cases it may benefit performance to move the the interrupts to a remote node to help load-balance the system.

Many operating systems will attempt to dynamically place interrupts across the nodes, and generally make good decisions.

Linux IRQ Balancing

In Linux this dynamic placement is called IRQ Balancing. You can check to see if the IRQ balancer is effective by checking `/proc/interrupts`. If the interrupts are unbalanced (too many device interrupts on one node) or on an overwhelmed node, you may need to stop the IRQ balancer and manually distribute the interrupts in order to balance the load and improve performance.

NOTE-

Restarting the IRQ Balancer after the Fusion ioMemory VSL software loads (and the Fusion ioMemory devices are attached) may resolve interrupt affinity issues. For example, run one of the following commands (depending on your distribution):

```
/etc/init.d/irqbalance restart
```

```
/etc/init.d/irq_balancer restart
```

If that does not resolve the affinity issues, then we recommend manual pinning the device interrupts to specific nodes.

Hand-tuning interrupt placement in Linux is an advanced option that requires profiling of application performance on any given hardware. Please see your operating system documentation for information on how to pin specific device interrupts to specific nodes.

Monitoring and Managing Devices

SanDisk provides many tools for managing your Fusion ioMemory devices. These tools will allow you to monitor the devices for errors, warnings, and potential problems. They will also allow you to manage the devices including performing the following functions:

- Firmware upgrades
- Low-level formatting
- Attach and detach actions
- Device status and performance information
- Configuring Swap and Paging
- Generating bug reports

Management Tools

SanDisk has provided several tools for monitoring and managing Fusion ioMemory devices. These include stand-alone tools that require no additional software and data-source tools that can be integrated with other applications.

Consider the descriptions of each tool to decide which tool (or combination of tools) best fits your needs.

ATTENTION!

The Fusion ioMemory VSL software does print some error messages to the system logs, and while these messages are very useful for troubleshooting purposes, the Fusion ioMemory VSL software log messages are not designed for continual monitoring purposes (as each is based on a variety of factors that could produce different log messages depending on environment and use case). For best results, use the tools described in this section to regularly monitor your devices.

Stand-alone Tools

These stand-alone tools do not require any additional software.

- **Command-line Utilities**: These utilities are installed with the ioMemory VSL software and are run manually in a terminal. The `fio-status` utility provides status for all devices within a host. The other utilities allow you to perform other management functions. See Command-line Utilities Reference on page 54 for full details.
- **Fusion ioSphere software**: The GUI browser-based Fusion ioSphere software allows you to monitor and manage every Fusion ioMemory device installed in multiple hosts across your network. It collects all of the alerts for all Fusion ioMemory devices and displays them in the Alert Tab. You may also set up the Fusion ioSphere software to send email or SMS messages for specific types of alerts or all alerts. The Fusion ioSphere software packages and documentation are available as separate downloads.

Data-source Tools

These data-source tools provide comprehensive data, just like the stand-alone tools, but they do require integration with additional software. At a minimum, some tools can interface with a browser. ***However, the benefit of these tools is that they can be integrated into existing management software that is customized for your organization.***

These tool packages and documentation are also available as separate downloads (separate from the Fusion ioMemory VSL software packages).

- **SNMP Subagent**: The SanDisk SNMP AgentX subagent allows you to monitor and manage your Fusion ioMemory devices using the Simple Network Management Protocol. You can use a normal SNMP browser, or customize your existing application to interface with the subagent.
- **SMI-S CIM Provider**: The CIM provider allows you to monitor and manage your devices using the Common Information Model. You can use a normal CIM browser, or customize your existing application to interface with the CIM provider.
- **Fusion ioMemory VSL Management SDK**: This C programing API allows you to write customize applications for monitoring and managing Fusion ioMemory devices.

Example Conditions to Monitor

This section gives examples of conditions you can monitor. It is intended as an introduction and not as a comprehensive reference. These conditions will have slightly different names, states, and values, depending on the tool you choose. For example, an SNMP MIB may have a different name than a SMI-S object or an API function.

In order to properly monitor these conditions, you should become familiar with the tool you choose to implement and read the documentation for that tool. You may also discover additional conditions that you wish to frequently monitor.

For quick reference, the possible states/values of these conditions are described as Normal (**GREEN**), Caution/Alert (**YELLOW**), or Error/Warning (**RED**). You may implement your own ranges of acceptable states/values, especially if you use a data-source tool.

Device Status

All of the monitoring tools return information on the status of the Fusion ioMemory devices, including the following states:

GREEN	Attached
YELLOW	Detached, Busy (including: Detaching, Attaching, Scanning, Formatting, and Updating)
RED	Minimal Mode, Powerloss Protect Disabled

If the device is in Minimal Mode, the monitoring tool can display the reason for the Minimal Mode status.

Required Actions

If the device is in Minimal Mode, the action will depend on the reason. For example, if the reason is outdated firmware, then you will need to update the firmware.

Temperature

Fusion ioMemory devices require adequate cooling. In order to prevent thermal damage, the Fusion ioMemory VSL software will start throttling write performance once the on-board controller reaches a specified temperature. If the controller temperature continues to rise, the software will shut down the device once the controller temperature reaches the maximum operating temperature.

These temperatures depend on the device. Newer Fusion ioMemory devices have higher thermal tolerances. Consult the *Fusion ioMemory Hardware Installation Guide* to determine the thermal tolerances of all devices you will monitor. **This table uses the follwing controller thermal tolerances**: 93°C throttling, 100°C shutdown.

GREEN	<93°C

YELLOW	93-99°C
RED	100°C

You may wish to shift the conditions by a few degrees so the **YELLOW** condition exists before throttling occurs. For example:

GREEN	<90°C
YELLOW	90-96°C
RED	97°C

ATTENTION!

NAND Board Temperature
Newer Fusion ioMemory devices also report the temperature of the NAND Boards. This is also a critical temperature to monitor. Consult the *Fusion ioMemory Hardware Installation Guide* to see if your device reports this temperature and to see the temperature thresholds.

Required Actions

If the temperature is at or approaching the **YELLOW** condition, you must increase the cooling for your system. This may include increasing the fan speed, bringing down the ambient temperature, reducing write load, or moving the device to a different slot.

Health Reserves Percentage

Fusion ioMemory devices are highly fault-tolerant storage subsystem with many levels of protection against component failure and the loss nature of solid-state storage. As in all storage subsystems, component failures may occur.

By pro-actively monitoring device age and health, you can ensure reliable performance over the intended product life. The following table describes the Health Reserve conditions.

GREEN	>10%
YELLOW	4% -10%
RED	0% - 3%

At the 10% healthy threshold, a one-time warning is issued. At 3%, the device is considered unhealthy and enters *write-reduced* mode. At the 1% threshold, the device will enter *read-only* mode.

For complete information on Health Reserve conditions and their impact on performance, see Monitoring the Health of Devices on page 69.

Required Actions

The device needs close monitoring as it approaches 0% reserves and goes into write-reduced mode, which will result in reduced write performance. Prepare to replace the device soon.

Write (Health Reserves) Status

In correlation with the Health Reserves Percentage, the management tools will return write states similar to these:

GREEN	Device is healthy
YELLOW	Device is getting close to entering reduced write mode.
RED	Device has entered reduced-write or read-only mode to preserve the flash from further wearout.

Required Actions

The device needs close monitoring as it approaches 0% reserves and goes into write-reduced mode, which will result in reduced write performance. Prepare to replace the device soon.

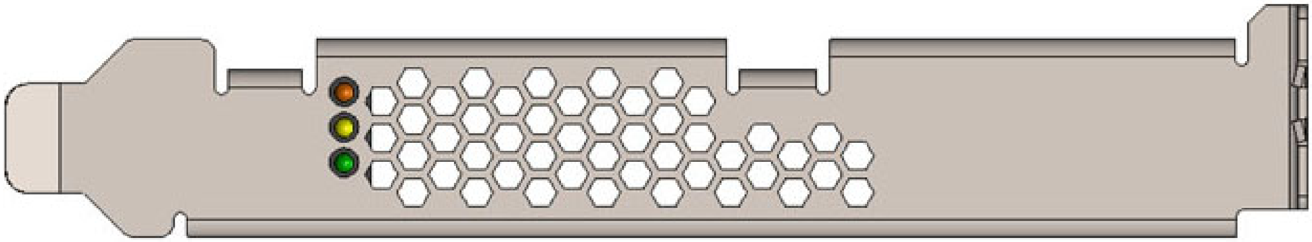
Device LED Indicators

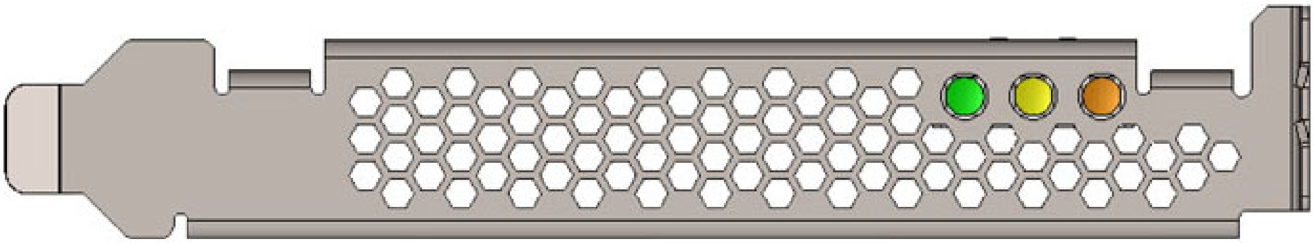
If you have physical access to the devices and depending on your device configuration, you can use the LED indicator(s) on the bracket to monitor their status. Consult the subsections below to determine if your device uses one or more LED indictors and what behaviors are indicated.

> **ATTENTION!**
>
> Fusion ioMemory devices may have an additional LEDs (that are not on the bracket, as shown below. You can ignore those other LEDs, as they are not meant for monitoring device and software functionality.

Three LEDs

The LEDs on your device should be similar to one of these configurations:



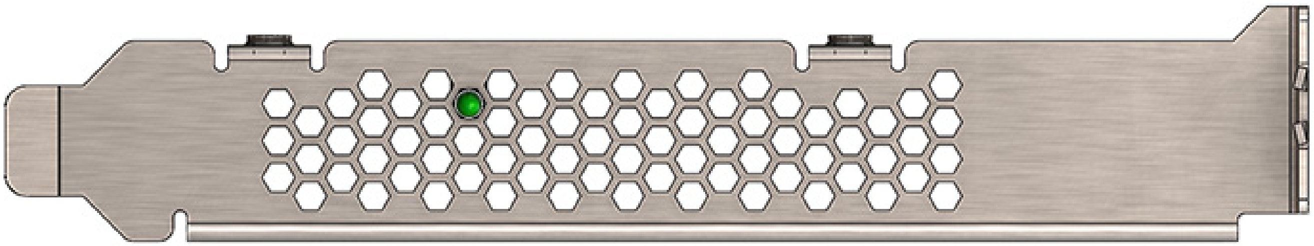


This table explains the information that these LEDs convey:

Green	Yellow	Amber	Indication	Notes
OFF	**OFF**	**OFF**	Power is off.	
OFF	**OFF**	**LIT**	Power is on. Problem with device, or driver not loaded (and device unattached).	Use `fio-status` to view problem, or load driver (and attach device).
LIT	**OFF**	**OFF**	Power is on. Driver loaded (device may or may not be attached).	You may need to attach the device.
LIT	**FLASHING**	**OFF**	Writing (Rate indicates volume of writes).	Can appear in combination with the Read LED indication.
FLASHING	**OFF**	**OFF**	Read (rate indicated volume of reads).	Can appear in combination with the Write LED indication.
LIT	**LIT**	**LIT**	Location Beacon.	Use the `fio-beacon` utility to initiate this behavior.

One LED

If your device has one LED, it should be similar to this configuration:



This table explains the information that the LED conveys:

LED	Indications	Notes
LIT	Power is on and driver is working.	
FLASHING (Fast)	Read and/or write activity.	The faster flashing only indicates activity, it does not reflect the amount of data that is read or written. The flashing may not indicate reads from empty sectors (all zeros).
FLASHING (Slow)	Location beacon.	Use the `fio-beacon` utility to initiate this behavior.
OFF	This indicates one of the following: Power is off, driver is not loaded, or driver is not working.	Check `fio-status` to see if device is attached and there are no errors.

Maintenance

This section explains additional software maintenance functions not covered in the sections Configuration on page 26 and Monitoring and Managing Devices on page 42.

NOTE-

All commands require administrator privileges. Log in as "root" or use sudo to run the commands.

Uninstalling the Software

NOTE-

If you came to this section from the *Installation Overview* section, return to Installation Overview on page 9 after you uninstall previous versions of the Fusion ioMemory VSL software and utilities.

Uninstalling the Fusion ioMemory VSL Utilities and Other Support Packages

Uninstalling 2.x Support Packages

To uninstall the support RPM packages, run this command (adding or removing package names as needed):

```
# rpm -e fio-util fio-snmp-agentx fio-common fio-firmware iomanager-gui iomanager-
jre libfio libfio-doc libfusionjni fio-sysvinit fio-smis fio-snmp-mib libfio-dev
```

To uninstall the support DEB packages, run this command (adding or removing package names as needed):

```
# dpkg -r fio-util fio-snmp-agentx fio-common fio-firmware iomanager-gui
iomanager-jre libfio libfio-doc libfusionjni fio-sysvinit fio-smis fio-snmp-mib
libfio-dev
```

Uninstalling 3.x Support Packages

To uninstall the support RPM packages, run this command (adding or removing package names as needed):

```
# rpm -e fio-util fio-snmp-agentx fio-common fio-firmware libvsl libvsl-doc fio-
sysvinit fio-smis fio-snmp-mib libvsl-dev
```

To uninstall the support DEB packages, run this command (adding or removing package names as needed):

```
# dpkg -r fio-util fio-snmp-agentx fio-common fio-firmware libvsl libvsl-doc fio-
sysvinit fio-smis fio-snmp-mib libvsl-dev
```

Uninstalling the Fusion ioMemory VSL RPM Package

With versions 2.x and later (including 3.x releases) of the Fusion ioMemory VSL software, you must specify the kernel version of the package you are uninstalling. Run this command to find the installed driver packages:

```
#  rpm -qa | grep -i iomemory
```

Sample output:

```
iomemory-vsl-2.6.18-194.el5-2.2.2.82-1.0
```

Uninstall the Fusion ioMemory VSL software by running a command similar to this example (specify the kernel version of the driver you wish to uninstall):

```
# rpm -e iomemory-vsl-2.6.18-194.el5-2.2.0.82-1.0
```

Uninstalling the Fusion ioMemory VSL software DEB Package

With versions 2.x and later (including 3.x releases) of the Fusion ioMemory VSL software, you must specify the kernel version of the package you are uninstalling. Run this command to find the installed packages:

```
# dpkg -l | grep -i iomemory
```

Sample output:

```
iomemory-vsl-2.6.32-24-server
```

Uninstall the Fusion ioMemory VSL software by running a command similar to this example (specify the kernel version of the software you wish to uninstall):

```
# dpkg -r iomemory-vsl-2.6.32-24-server
```

Unloading the Software Driver

To unload the driver, run this command:

```
# modprobe -r iomemory-vsl
```

Upgrading the Kernel

If you ever plan to upgrade the kernel when the Fusion ioMemory VSL software is installed, you **must**:

1. Unload the Fusion ioMemory VSL driver.
2. Uninstall the Fusion ioMemory VSL software.
3. Upgrade the kernel.
4. Install a Fusion ioMemory VSL software package that is compiled for the new kernel.

Failure to follow this procedure may result in driver load issues.

Disabling the ioMemory VSL Software

The Fusion ioMemory VSL software automatically loads by default when the operating system starts. You can disable the Fusion ioMemory VSL software for diagnostic or troubleshooting purposes.

To disable auto-load, you can use one of the following methods:

- Uninstall the Fusion ioMemory VSL software to keep it from loading.
- Move the Fusion ioMemory VSL software out of the `/lib/modules/<kernel_version>` directory to keep it from loading.

- On systems that rely on udev to load drivers, locate and edit the /etc/modprobe.d/iomemory-vsl.conf file that already has the following line:

  ```
  # blacklist iomemory-vsl
  ```

  To disable loading, remove the "#" from the line and save the file. With the blacklist command in place, restart Linux. The Fusion ioMemory VSL software will not be loaded by udev.

  ATTENTION!

  If the driver is in the `initrd`, the `initrd` will need to be rebuilt in order for the `modprobe` configuration changes to take effect.

  To re-enable udev-loading of the driver, replace the "#" to commment out the line.

Disabling Auto-Attach

When the Fusion ioMemory VSL software is installed, it is configured to automatically attach any devices when the Fusion ioMemory VSL software is loaded. Sometimes you may want to disable the auto-attach feature (to assist in troubleshooting or diagnostics). To do so:

NOTE-

You can also use the Fusion ioSphere software to enable or disable auto-attach. See the Fusion ioSphere software documentation for more information.

1. Edit the following file:

   ```
   /etc/modprobe.d/iomemory-vsl.conf
   ```

2. Add the following line to that file:

   ```
   options iomemory-vsl auto_attach=0
   ```

3. Save the file. To re-enable auto-attach, simply edit the file and either remove that line or change it to the following:

   ```
   options iomemory-vsl auto_attach=1
   ```

Unmanaged Shutdown Issues

Unmanaged shutdowns due to power loss or other circumstances can force the Fusion ioMemory device to perform a consistency check during the restart. This may take several minutes or more to complete.

Although data written to the Fusion ioMemory device is not lost due to unmanaged shutdowns, important data structures may not have been properly committed to the device. This consistency check (also called a rescan) repairs these data structures.

Improving Rescan Times

The rescan of the device (also called a consistency check) the VSL performs after an unmanaged shutdown may take an extended period of time depending on the total capacity of the device(s) that the Fusion ioMemory VSL software needs to scan.

Default Fast Rescan

By default, all Fusion ioMemory devices formatted with the fio-format utility or ioSphere are formatted to have improved rescan times. You can disable this default fast rescan by reformatting the device and using the `-R` option. Disabling this feature will reclaim some reserve capacity that is normally set aside to help improve rescan times.

If you leave the default fast rescan feature in place you can also take further steps to improve rescan times by implementing one of the following module parameters.

Faster Rescans Using Module Parameters

These two module parameters require the default fast rescan formatting structure, and they also use system memory (RAM) to help improve rescan times. The extra memory enables the rescan process to complete faster, which reduces downtime after a hard shutdown. This memory allocation is only temporary and is freed up after the rescan process is complete.

If you decide to use one of these parameters, you will need to set the upper limit of RAM used by that parameter. To do this, you will need to determine how much RAM each parameter may use in your scenario, how much system RAM is available, and (therefore) which parameter is more suited for your use case.

For more information on setting module parameters, see Using Module Parameters on page 71.

Here is a quick comparison of the two parameters:

- **RMAP Parameter**
  - **Fastest**: This improvement results in the fastest rescan times.
  - **Less Scalable**: (All or nothing.) This parameter requires enough RAM to function. If the RAM limit is set too low, then the Fusion ioMemory VSL software will not use RMAP at all, and it will revert back to the default fast rescan process.
  - **Target Scenario**: This parameter will improve any use case if there is enough RAM available for the parameter. It is more suited for smaller capacity Fusion ioMemory devices and/or systems with fewer Fusion ioMemory devices installed. We also recommend it for devices that have been used for many small random writes.
- **RSORT Parameter**
  - **Faster**: This improves rescan times over the default fast rescan process.
  - **Scalable**: With this parameter, the Fusion ioMemory VSL software works with the system RAM to improve rescan times until it reaches the RAM limit set in the parameter. At that point, the software reverts back to the default fast rescan process.
  - **Target Scenario**: This parameter will improve rescan times in any use scenario. It is especially useful in

systems with multiple Fusion ioMemory devices and/or larger-capacity Fusion ioMemory devices. We also recommend it when Fusion ioMemory devices are used to store databases.

RMAP Parameter

The `rmap_memory_limit_MiB` parameter sets the upper memory (RAM) limit (in mebibytes) used by the Fusion ioMemory VSL software to perform the RMAP rescan process. You should only use this option if you have enough memory for all of your Fusion ioMemory devices in the system. If you do not have enough memory to use this option, use the RSORT parameter instead.

Because this parameter requires a set amount of memory, it often works best with fewer Fusion ioMemory devices and/or smaller-capacity Fusion ioMemory devices in a system, but the determining factor is how much memory is in the system and whether there is enough to set the appropriate memory limit.

This parameter requires `4.008` bytes of RAM per block of Fusion ioMemory device capacity.

1. First determine the number of blocks that are formatted for each device.

   a. This information is visible when you format the device using the `fio-format` utility.

   b. Or you can estimate the number of block using the device capacity and the formatted sector size.

      This example shows a quick estimation of the number of blocks on a `400GB` device with `512B` size sectors (`2` sectors per KB):

      ```
      400GB * 1000MB/GB * 1000KB/MB * 2 Blocks/kB = 800,000,000 Blocks
      ```

2. Multiply the number of blocks by `4.008` bytes of RAM per block (and translate that into MiB) to determine the memory limit that is required for this parameter to function.

   a. In the example above there were `800 million` blocks:

      ```
      800,000,000 Blocks * 4.008B/Block * 1KiB/1024B * 1MiB/1024KiB = ~3058MiB
      of RAM
      ```

   b. In this example, you would need about 3100 MiB of RAM available in your system for a 400GB Fusion ioMemory device formatted for 512B sectors, and you would need to set the RMAP parameter to `3100`.

> **NOTE-**
>
> **Default Value**
> The RMAP parameter is, by default, set to `3100`. It is set to this low default value so the rescan process does not use all of the RAM in systems that have less available memory.

- If the RMAP value is too low for the number of Fusion ioMemory device blocks in the system, then the Fusion ioMemory VSL software will not use the RMAP process to improve rescan times, it will just use the default fast rescan process. (RMAP is an all-or-nothing setting.)

- If you don't have enough system memory to use the RMAP parameter, consider using the

RSORT parameter. The RSORT parameter will use its RAM limit to improve the rescan process, and then the Fusion ioMemory VSL software will revert to the default fast rescan process to finish the consistency check.

3. Set the module parameter to the value you have determined. See Using Module Parameters on page 71 for more information on setting parameters.

RSORT Parameter

The `rsort_memory_limit_MiB` parameter sets the memory (RAM) limit used by the Fusion ioMemory VSL software to perform the RSORT rescan process. The RSORT rescan process is faster than the default rescan process and we recommend using it to rescan devices that are used as datastores for databases.

If this parameter is given any memory limit, the Fusion ioMemory VSL software will use the RSORT process until either the rescan is done or it consumes the memory limit. If the process runs out of memory, it will revert to the default fast rescan process. However, in order to optimize the use of this process, you can calculate the target RAM usage and set the limit based on that target. There is no penalty for setting a high limit, the RSORT process will only use the RAM it needs (up to the limit that is set).

This target is based on `32` bytes per write extent. For example, if your database writes 16kB at a time, there is one write extent per 16kB of Fusion ioMemory device capacity.

NOTE-

Blocks per Write Extent
One measure of the the benefits of the RSORT process is to see how many blocks are written per write extent. The RSORT process improves rescan times over the default fast rescan process on when a device has `8` or more blocks written per extent. For example, if your Fusion ioMemory device is formatted to `512B` sector sizes (`2` sectors per KB), and your database writes in `8KB` chunks, then your database writes `16` blocks per write extent and RSORT would improve the rescan times.

1. First determine the number of blocks that are formatted for each device.

   a. This information is visible when you format the device using the `fio-format` utility.

   b. Or you can estimate the number of block using the total device capacities and their formatted sector sizes.

   This example shows a quick estimation of the number of blocks on `1200GB` of Fusion ioMemory device capacity with `512B` size sectors (`2` sectors per KB):

```
1200GB * 1000MB/GB * 1000KB/MB * 2 Blocks/kB = 2,400,000,000 Blocks
```

2. Divide the number of blocks by the write extents per block to determine the total possible number of write extents on the device(s).

   a. In the example above there were `2.4 billion` blocks. We will assume `16KB` write extents (`32 blocks` per write on 512B sectors):

```
2,400,000,000 Blocks * 1 Write Extent/32 Blocks = 150,000,000 Writes
```

3. Multiply the number of writes by 32 bytes of RAM per write (and translate that into MiB) to determine the memory target for this parameter.

    a. In the example above there were `150 million` write extents:

    ```
    150,000,000 Writes * 32B/Write * 1KiB/1024B * 1MiB/1024KiB = ~4578MiB of
    RAM
    ```

    b. In this example, you would want to set the RSORT limit to about 4600 MiB of RAM available in your system for 1200GB of Fusion ioMemory device capacity formatted for 512B sectors.

NOTE-

Default Value

The RMAP parameter is, by default, set to `0`m and it has a maximim of 100000 (100GB).

4. Set the module parameter to the value you have determined. See Using Module Parameters on page 71 for more information on setting parameters.

Appendix A - Command-line Utilities Reference

The Fusion ioMemory VSL software installation packages include various command-line utilities, installed by default in `/usr/sbin`. These provide a number of useful ways to access, test, and manipulate your device.

ATTENTION!

Unified Utilities. If you plan to use the 4.2.1 (or later) utilities (Unified Utilities) on a VSL 3.2.15 server, please refer to the 3.2.15 *Fusion ioMemory VSL Release Notes* for information on which 3.2.15 operating systems can use Unified Utilities, and for differences between the 3.2.15 and 4.2.1 (or later) utilities.

ATTENTION!

There are some additional utilities installed in the `/usr/sbin` directory that are not listed below. Those additional utilities are dependencies (used by the main Fusion ioMemory VSL utilities), and you should not use them directly unless Customer Support advises you to do so.

Utility	Purpose
`fio-attach`	Makes a Fusion ioMemory device available to the OS.
`fio-beacon`	Lights the Fusion ioMemory device's external LEDs.
`fio-bugreport`	Prepares a detailed report for use in troubleshooting problems.
`fio-detach`	Temporarily removes a Fusion ioMemory device from OS access.
`fio-firmware`	Reports the version and revision of the firmware on Fusion ioMemory devices without requiring you to load the Fusion ioMemory VSL software driver. By reporting the firmware version(s) on installed devices, this utility can help you determine which version of the Fusion ioMemory VSL software to load.
`fio-format`	Used to perform a low-level format of a Fusion ioMemory device.
`fio-pci-check`	Checks for errors on the PCI bus tree, specifically for Fusion ioMemory devices.
`fio-status`	Displays information about the device.
`fio-sure-erase`	Clears or purges data from the device.

Utility	Purpose
fio-update-iodrive	Updates the Fusion ioMemory device's firmware.

NOTE-

There are -h (Help) and -v (Version) options for all of the utilities. Also, -h and -v cause the utility to exit after displaying the information.

fio-attach

Description

Attaches the Fusion ioMemory device and makes it available to the operating system. This creates a block device in /dev named fiox (where x is a, b, c, etc.). You can then partition or format the Fusion ioMemory device, or set it up as part of a RAID array. The command displays a progress bar and percentage as it operates.

NOTE-

In most cases, the Fusion ioMemory VSL software automatically attaches the device on load and does a scan. You only need to run fio-attach if you ran fio-detach or if you set the Fusion ioMemory VSL software's auto_attach parameter to 0.

NOTE-

If the Fusion ioMemory device is in minimal mode, then auto-attach is disabled until the cause of the device being in minimal mode is fixed.

Syntax

```
fio-attach <device> [options]
```

where <device> is the name of the device node (/dev/fctx), where *x* indicates the device number: 0, 1, 2, etc. For example, /dev/fct0 indicates the first Fusion ioMemory device detected on the system.

You can specify multiple Fusion ioMemory devices. For example, /dev/fct1 /dev/fct2 indicates the second and third Fusion ioMemory devices installed on the system.

Option	Description
-r	Force a metadata rescan. This may take an extended period of time, and is not normally required. **ATTENTION!** Only use this option when directed by Customer Support.

Option	Description
`-c`	Attach only if clean.
`-q`	Quiet: disables the display of the progress bar and percentage.

fio-beacon

Description

Lights the Fusion ioMemory device's LED(s) to locate the device.

Syntax

```
fio-beacon <device> [options]
```

where `<device>` is the name of the device node (`/dev/fctx`), where *x* indicates the card number: 0, 1, 2, etc. For example, `/dev/fct0` indicates the first Fusion ioMemory device detected on the system. The device numbers are visible using `fio-status`.

Option	Description
`-0`	Off: (Zero) Turns off the LED beacon.
`-1`	On: Lights the LED beacon.
`-p`	Prints the PCI bus ID of the device at `<device>` to standard output. Usage and error information may be written to standard output rather than to standard error.

fio-bugreport

Description

Prepares a detailed report of the device for use in troubleshooting problems. The results are saved in the `/tmp` directory in the file that indicates the date and time the utility was run.

Example:

```
/tmp/fio-bugreport-20100121.173256-sdv9ko.tar.bz2
```

Syntax

```
fio-bugreport
```

Notes

This utility captures the current state of the device. When a performance or stability problem occurs with the device, run the `fio-bugreport` utility and contact Customer Support at https://link.sandisk.com/commercialsupport for assistance in troubleshooting.

ATTENTION!

Upload Report

For best results, do not email the bug report file. Instead please create a case on the SanDisk Support site at https://link.sandisk.com/commercialsupport, and then upload the report to the case using a web browser.

Sample Output

```
-bash-3.2# fio-bugreport
Collecting fio-status -a
Collecting fio-status
Collecting fio-pci-check
Collecting fio-pci-check -v
Collecting fio-read-lebmap /dev/fct0
Collecting fio-read-lebmap -x /dev/stdout/dev/fct0
Collecting fio-read-lebmap -t /dev/fct0
Collecting fio-get-erase-count/dev/fct0
Collecting fio-get-erase-count -b /dev/fct0
Collecting lspci
Collecting lspci -vvvvv
Collecting lspci -tv
Collecting messages file(s)
Collecting procfusion file(s)
Collecting lsmod
Collecting uname -a
Collecting hostname
Collecting sar -r
Collecting sar
Collecting sar -A
Collecting syslog file(s)
Collecting proc file(s)
Collecting procirq file(s)
Collecting dmidecode
Collecting rpm -qa iodrive*
Collecting find /lib/modules
Please attach the bugreport tar file
   /tmp/fio-bugreport-20090921.173256-sdv9ko.tar.bz2
 to your support case, including steps to reproduce the problem.
 If you do not have an open support case for this issue, please open a support
 case with a problem description and then attach this file to your new case.
```

For example, the filename for a bug report file named `fiobugreport-20090921.173256-sdv9ko.tar.bz2` indicates the following:

- Date (20090921)
- Time (173256, or 17:32:56)
- Misc. information (`sdv9ko.tar.bz2`)

fio-detach

Description

Detaches the Fusion ioMemory device and removes the corresponding `fctx` Fusion ioMemory device block device from the OS. The `fio-detach` utility waits until the device completes all read/write activity before executing the detach operation. By default, the command also displays a progress bar and percentage as it completes the detach.

> **ATTENTION!**
>
> Before using this utility, ensure that the device you want to detach is **NOT** currently mounted and in use.

Syntax

```
fio-detach <device> [options]
```

where `<device>` is the name of the device node (`/dev/fctx`), where *x* indicates the card number: 0, 1, 2, etc. For example, `/dev/fct0` indicates the first Fusion ioMemory device detected on the system.

You can specify multiple Fusion ioMemory devices. For example, `/dev/fct1 /dev/fct2` indicates the second and third Fusion ioMemory devices installed on the system. You can also use a wildcard to indicate all Fusion ioMemory devices on the system. For example, `/dev/fct*`

Option	Description
`-q`	Quiet: Disables the display of the progress bar and percentage.

Notes

Attempting to detach a Fusion ioMemory device may fail with an error indicating that the device is busy. This typically may occur if the Fusion ioMemory device is part of a software RAID (0,1,5) volume, is mounted, or some process has the device open.

The tools `fuser`, `mount`, and `lsof` can be helpful in determining what is holding the device open.

fio-firmware

Description

This utility is useful for diagnosing system issues. The utility reports the version and revision of the firmware on all Fusion ioMemory devices without requiring you to load the Fusion ioMemory VSL software driver. By indicating the firmware version(s) on installed devices, this utility can help you determine which version of the Fusion ioMemory VSL software to load.

> **ATTENTION!**
>
> The 3.2.15 `fio-firmware` utility will **not report** firmware version information on Gen3 devices including Fusion ioMemory SX300 devices, Fusion ioMemory SX350 devices, and Fusion ioMemory PX600 devices.
>
> If you need to run `fio-firmware` across product generations, please use the latest VSL 4 `fio-firmware`

version.

Output is in CSV format, with each Fusion ioMemory device on a separate line:

```
<PCIe address>, <FW Version>, <FW Revision>
```

Syntax

```
fio-firmware [options]
```

Option	Description
-f	Print only x.y.z firmware version.
-n	Disable printing header information on columns.
-p	Print pending version of firmware to be activated on next reboot
-r	Print only firmware revision.

fio-format

Description

NOTE-

Fusion ioMemory devices ship pre-formatted, so `fio-format` is generally not required except to change the logical size or block size of a device, or to erase user data on a device. To ensure the user data is truly erased, use `fio-sure-erase`, see fio-sure-erase on page 64 for more information.

Performs a low-level format of the Fusion ioMemory device. By default, `fio-format` displays a progress-percentage indicator as it runs.

ATTENTION!

Use this utility with care, as it deletes all user information on the device. You will be prompted as to whether you want to proceed with the format.

NOTE-

Using a larger block (sector) size, such as 4096 bytes, can significantly reduce worst-case Fusion ioMemory VSL host memory consumption. However, some applications are not compatible with non-512-byte sector sizes.

NOTE-

If you do not include the `-s` or `-o` options, the device size defaults to the advertised capacity. If used, the `-s` and `-o` options must include the size or percentage indicators.

WARNING!

Do not interrupt the formatting! We recommend adding power backup to your system to prevent power failures during formatting. If formatting is interrupted, please contact Customer Support.

Syntax

```
fio-format [options] <device>
```

where `<device>` is the name of the device node (`/dev/fctx`), where *x* indicates the device number: 0, 1, 2, etc. For example, `/dev/fct0` indicates the first Fusion ioMemory device detected on the system. Use `fio-status` to view this number.

Options	Description
`-b <size B|K>`	Set the block (sector) size, in bytes or kibibytes (base 2). The default is 512 bytes. For example: `-b 512B` or `-b 4K` (`B` in `512B` is optional).
`-f`	Force the format size, bypassing normal checks and warnings. This option may be needed in rare situations when `fio-format` does not proceed properly. (The "Are you sure?" prompt still appears unless you use the `-y` option.)
`-q`	Quiet mode: Disable the display of the progress-percentage indicator.
`-s <size M|G|T|%>`	Set the device capacity as a specific size (in TB, GB, or MB) or as a percentage of the advertised capacity: • `T` Number of terabytes (TB) to format • `G` Number of gigabytes (GB) to format • `M` Number of megabytes (MB) to format • `%` Percentage, such as 70% (the percent sign must be included)
`-o <size B|K|M|G|T|%>`	Over-format the device size (to greater than the advertised capacity), where the maximum size equals the maximum physical capacity. If a percentage is used, it corresponds to the maximum physical capacity of the device. (Size is required for the `-o` option; see the `-s` option above for size indicator descriptions.) **ATTENTION!** Before you use this option, please discuss your use case with Customer Support.
`-R`	Disable fast rescan on unclean shutdown to reclaim some reserve capacity.
`-y`	Auto-answer "yes" to all queries from the application (bypass prompts).

You must re-attach the device in order to use the Fusion ioMemory device. See fio-attach on page 55 for details.

fio-pci-check

Description

Checks for errors on the PCI bus tree, specifically for Fusion ioMemory devices. This utility displays the current status of each Fusion ioMemory device. It also prints the standard PCI Express error information and resets the state.

> **NOTE-**
>
> It is perfectly normal to see a few correctable errors when `fio-pci-check` is initially run. Subsequent runs should reveal only one or two errors during several hours of operation.

Syntax

```
fio-pci-check [options]
```

Option	Description
`-d <value>`	`1` = Disable the link; `0` = bring the link up (Not recommended).
`-e`	Enable PCI-e error reporting.
`-f`	Scan every device in the system.
`-n`	Do not perform any writes to config space. Will prevent errors from being cleared.
`-o`	Optimize the Fusion ioMemory device PCIe link settings by increasing the maximum read request size if it is too low.
`-r`	Force the link to retrain.
`-v`	Verbose: Print extra data about the hardware.

fio-status

Description

Provides detailed information about the installed devices. This utility operates on either `fctx` or `fiox` devices. The utility depends on running as root and having the Fusion ioMemory VSL driver loaded. If no driver is loaded, a smaller set of status information is returned.

`fio-status` provides alerts for certain error modes, such as a minimal-mode, read-only mode, and write-reduced mode, describing what is causing the condition.

Syntax

```
fio-status [<device>] [<options>]
```

where `<device>` is the name of the device node (`/dev/fctx`), where *x* indicates the card number: 0, 1, 2, etc. For example, `/dev/fct0` indicates the first Fusion ioMemory device detected on the system.

If <device> is not specified, fio-status displays information for all cards in the system. If the Fusion ioMemory VSL driver is not loaded, this parameter is ignored.

Option	Description
-a	Report all available information for each device.
-e	Show all errors and warnings for each device. This option is for diagnosing issues, and it hides other information such as format sizes.
-c	Count: Report only the number of Fusion ioMemory devices installed.
-d	Show basic information set plus the total amount of data read and written (lifetime data volumes). This option is not necessary when the -a option is used.
-fj	Format JSON: creates the output in JSON format, which can be used for scripted management applications.
-fx	Format XML: creates the output in XML format.
-u	Show unavailable fields. Only valid with -fj or -fx.
-U	Show unavailable fields and details why. Only valid with -fj or -fx. **NOTE-** Some fio-status fields are unavailable depending on the operating system or device. For example, some legacy fields are unavailable on newer Fusion ioMemory devices.
-F<field>	Print the value for a single field (see the next option for field names). Requires that a device be specified. Multiple -F options may be specified.
-l	List the fields that can be individually accessed with -F.

ATTENTION!

Output Change

The standard formatting of fio-status ouput has changed compared to the output from Fusion ioMemory VSL software version 2.x. This will affect any custom management tools that used the output of this utility.

Basic Information: If no options are used, fio-status reports the following basic information:

- Number and type of devices installed in the system
- Fusion ioMemory VSL software version

Adapter information:

- Adapter type
- Product number
- External power status
- PCIe power limit threshold (if available)
- Connected Fusion ioMemory devices

Block device information:

- Attach status
- Product name
- Product number
- Serial number
- PCIe address and slot
- Firmware version
- Size of the device, out of total capacity
- Internal temperature (average and maximum, since Fusion ioMemory VSL software load) in degrees Centigrade
- Health status: healthy, nearing wearout, write-reduced or read-only
- Reserve capacity (percentage)
- Warning capacity threshold (percentage)

Data Volume Information: If the `-d` option is used, the following data volume information is reported *in addition* to the basic information:

- Physical bytes written
- Physical bytes read

All Information: If the `-a` option is used, all information is printed, which includes the following information *in addition* to basic and data volume information:

Adapter information:

- Manufacturer number
- Part number
- Date of manufacture
- Power loss protection status
- PCIe bus voltage (avg, min, max)
- PCIe bus current (avg, max)
- PCIe bus power (avg, max)
- PCIe power limit threshold (watts)
- PCIe slot available power (watts)
- PCIe negotiated link information (lanes and throughput)

Block device information:

- Manufacturer's code
- Manufacturing date
- Vendor and sub-vendor information
- Format status and sector information (if device is attached)
- FPGA ID and Low-level format GUID
- PCIe slot available power
- PCIe negotiated link information
- Card temperature, in degrees Centigrade
- Internal voltage (avg and max)
- Auxiliary voltage (avg and max)
- Percentage of good blocks, data and metadata
- Lifetime data volume statistics
- RAM usage

Error Mode Information: If the Fusion ioMemory VSL software is in minimal mode, read-only mode, or write-reduced mode when `fio-status` is run, the following differences occur in the output:

- Attach status is "Status unknown: Driver is in MINIMAL MODE:"
- The reason for the minimal mode state is displayed (such as "Firmware is out of date. Update firmware.")
- "Geometry and capacity information not available." is displayed.
- No media health information is displayed.

fio-sure-erase

ATTENTION!

As a best practice, do not use this utility if there are any Fusion ioMemory devices installed in the system that you do not want to clear or purge. First remove any devices that you do not want to accidentally erase. Once the data is removed with this utility it is gone forever. **It is not recoverable**.

WARNING!

Before you use this utility, be sure to back up any data that you wish to preserve.

WARNING!

Do not interrupt `fio-sure-erase` (by issuing a forced kill command, or powering down or resetting the system)! Interrupting `fio-sure-erase` could cause the Fusion ioMemory device to become unusable.

ATTENTION!

If the device is in Read-only mode, perform a format using `fio-format` before running `fio-sure-erase`. If the device is in Minimal mode, then `fio-sure-erase` cannot erase the device. Updating the firmware may take the device out of Minimal Mode. If the device remains in Minimal mode, contact Customer Support at https://link.sandisk.com/commercialsupport for further assistance.

In order to run `fio-sure-erase`, the block device **must be detached**. See fio-detach on page 58 section for more information.

Description

The `fio-sure-erase` is a command-line utility that securely removes data from Fusion ioMemory devices.

Syntax

```
fio-sure-erase [options] <device>
```

Where `<device>` is the name of the device node (`/dev/fctx`), where *x* indicates the card number: 0, 1, 2, etc. For example, `/dev/fct0` indicates the first Fusion ioMemory device detected on the system. Use `fio-status` to view this device node, see fio-status on page 61.

NOTE-

Products with Multiple Devices

fio-sure-erase works on individual Fusion ioMemory devices. For example, if you are planning to purge a Fusion ioMemory ioDrive Duo device, you will need to perform this operation on each of the product's two Fusion ioMemory devices.

Option	Description
-p	Purge instead of Clear: performs a write followed by an erase. For more information on Purge, see below. **ATTENTION!** Purging the device may take hours to accomplish, depending on the size of the device that needs to be purged.
-y	No confirmation: do not require a yes/no response to execute the utility.
-t	Do not preserve current format parameters, including device and sector size (reset to default).
-q	Quiet: do not display the status bar.

NOTE-

If you run fio-sure-erase with no options, a Clear is performed. For more information, see below.

When the utility completes, each block of memory consists of uniform 1 bits or 0 bits.

Clear Support

A "Clear" is the default state of running fio-sure-erase (with no options), and refers to the act of performing a full low-level erase (every cell pushed to "1") of the entire NAND media, including retired erase blocks.

Metadata that is required for operation will not be destroyed (media event log, erase counts, physical bytes read/written, performance and thermal history), but any user-specific metadata will be destroyed.

The following describes the steps taken in the Clear operation:

1. Creates a unity map of every addressable block (this allows fio-sure-erase to address every block, including previously unmapped bad blocks).
2. For each block, performs an erase cycle (every cell is pushed to "1").
3. Restores the bad block map.
4. Formats the device (the purpose of this is to make the device usable again, the utility erases all of the headers during the clear).

Purge Support

A "Purge" is invoked by using the -p option with fio-sure-erase. Purge refers to the act of first overwriting the entire NAND media (including retired erase blocks) with a single character (every cell written to logical "0"), and then performing a full chip erase (every cell pushed to "1") across all media (including retired erase blocks).

Metadata that is required for operation will **not** be destroyed (media event log, erase counts, physical bytes read/written, performance and thermal history), but any user-specific metadata will be destroyed.

The following describes the steps taken in the Purge operation:

1. Creates a unity map of every addressable block (this allows `fio-sure-erase` to address every block, including previously unmapped bad blocks).
2. For each block, performs a write cycle (every cell written to "0").
3. For each block, performs an erase cycle (every cell pushed to "1").
4. Restores the bad block map.
5. Formats the drive (the purpose of this is to make the drive usable again, the utility erases all of the headers during the clear).

fio-update-iodrive

ATTENTION!

You should back up the data on the Fusion ioMemory device prior to any upgrade as a precaution.

Description

Updates the Fusion ioMemory device's firmware. This utility scans the PCIe bus for all Fusion ioMemory devices and updates them. A progress bar and percentage are shown for each device as the update completes.

WARNING!

It is extremely important that the power not be turned off during a firmware upgrade, as this could cause device failure. If a UPS is not already in place, consider adding one to the system prior to performing a firmware upgrade.

WARNING!

Note that when running multiple firmware upgrades in sequence, it is critical to reboot and then both load the Fusion ioMemory VSL driver and attach the Fusion ioMemory device(s) after each firmware upgrade step. Otherwise the on-device format will not be changed, and there will be data loss.

WARNING!

Do not use this utility to downgrade the Fusion ioMemory device to an earlier version of the firmware. **Doing so may result in data loss and void your warranty**. Contact Customer Support at https://link.sandisk.com/commercialsupport if you have issues with your upgrade.

NOTE-

The default action (without using the `-d` or `-s` option) is to upgrade all Fusion ioMemory devices with the firmware contained in the `fusion_<version>.<date>.fff` firmware archive file. Confirm that all devices need the upgrade prior to running the update. If in doubt, use the `-p` (Pretend) option to view the possible results of the update.

ATTENTION!

You must detach all Fusion ioMemory devices before updating the firmware.

ATTENTION!

Upgrade Path

There is a specific upgrade path that you must take when upgrading Fusion ioMemory device. Consult the *Fusion ioMemory VSL Release Notes* for this Fusion ioMemory VSL software release before upgrading Fusion ioMemory devices.

NOTE-

If you receive an error message when updating the firmware that instructs you to update the midprom information, contact Customer Support.

To update one or more specific devices:

- If the Fusion ioMemory VSL driver is loaded, use the `-d` option with the device number.

Syntax

```
fio-update-iodrive [options] <firmware-path>
```

where `<firmware-path>` is the full path to the firmware archive file `fusion_<version>.<date>.fff` available at https://link.sandisk.com/commercialsupport. If you downloaded the `.fff` firmware archive file, then the firmware is most likely with the other downloaded packages. If you installed the firmware from the firmware package, the default path is `/usr/share/fio/firmware/`. This parameter is required.

Option	Description
`-d`	Updates the specified devices (by `fctx`, where *x* is the number of the device shown in `fio-status`). If this option is not specified, all devices are updated. **ATTENTION!** Use the `-d` or `-s` option with care, as updating the wrong Fusion ioMemory device could damage your device.
`-f`	Force upgrade (used when directed by Customer Support). If the Fusion ioMemory VSL driver is not loaded, this option also requires the `-s` option. **ATTENTION!** Use the `-f` option with care, as it could damage your card.
`-l`	List the firmware available in the archive.

Option	Description
`-p`	Pretend: Shows what updates would be done. However, the actual firmware is not modified.
`-c`	Clears locks placed on a device.
`-q`	Runs the update process without displaying the progress bar or percentage.
`-y`	Confirm all warning messages.
`-s`	Updates the devices in the specified slots using '*' as a wildcard for devices. The slots are identified in the following PCIe format (as shown in lspci): `[[[[<domain>]:]<bus>]:][<slot>][.[<func>]]`
`--split`	Split the Fusion ioMemory device into virtual devices.
`--merge`	Merge the virtual devices of a Fusion ioMemory device.

If you arrived at this section from Upgrading the Firmware on page 23, you should return to that section.

Appendix B - Monitoring the Health of Devices

This section describes how the health of Fusion ioMemory devices can be measured and monitored in order to safeguard data and prolong device lifetime.

Health Metrics

The Fusion ioMemory VSL software manages block retirement using pre-determined retirement thresholds. The Fusion ioSphere software and the `fio-status` utilities show a health indicator that starts at 100 and counts down to 0. As certain thresholds are crossed, various actions are taken.

At the 10% healthy threshold, a one-time warning is issued. See Health Monitoring Techniques on page 69 for methods for capturing this alarm event.

At 0%, the device is considered unhealthy. It enters *write-reduced* mode, which somewhat prolongs its lifespan so data can be safely migrated off. In this state the Fusion ioMemory device behaves normally, except for the reduced write performance.

After the 0% threshold, the device will soon enter *read-only* mode -- any attempt to write to the Fusion ioMemory device causes an error. Some filesystems may require special mount options in order to mount a read-only block device in addition to specifying that the mount should be read-only.

For example, under Linux, `ext3` requires that "`-o ro,noload`" is used. The "`noload`" option tells the filesystem to not try and replay the journal.

Read-only mode should be considered a final opportunity to migrate data off the device, as device failure is more likely with continued use.

The Fusion ioMemory device may enter failure mode. In this case, the device is offline and inaccessible. This can be caused by an internal catastrophic failure, improper firmware upgrade procedures, or device wearout.

NOTE-

For service or warranty-related questions, contact Customer Support at https://link.sandisk.com/commercialsupport .

NOTE-

For products with multiple Fusion ioMemory devices, these modes are maintained independently for each device.

Health Monitoring Techniques

`fio-status -a`: Output from the `fio-status` utility (using the `-a` option) shows the health percentage and device state. These items are referenced as "`Media status`" in the sample output below.

```
Found 3 ioMemory devices in this system
Fusion driver version: 3.x.x build xxxx

Adapter: Single Adapter
        Fusion-io ioDrive 1.30TB, Product Number:F00-001-1T30-CS-0001,
SN:1133D0248, FIO SN:1134D9565
...
Media status: Healthy; Reserves: 100.00%, warn at 10.00%; Data: 99.12%
Lifetime data volumes:
   Physical bytes written: 6,423,563,326,064
   Physical bytes read   : 5,509,006,756,312
```

The following Health Status messages are produced by the `fio-status` utility:

- Healthy
- Read-only
- Reduced-write
- Unknown

Fusion ioSphere software: In the Device Report tab, look for the Reserve Space percentage in the right column. The higher the percentage, the healthier the drive is likely to be.

Software RAID and Health Monitoring

Software RAID stacks are typically designed to detect and mitigate the failure modes of traditional storage media. The Fusion ioMemory device attempts to fail as gracefully as possible, and these new failure mechanisms are compatible with existing software RAID stacks. A Fusion ioMemory device in a RAID group will fail to receive data at a sufficient rate if: a) the device is in a write-reduced state, and b) it is participating in a write-heavy workload. In this case, the device will be evicted from the RAID group. A device in read-only mode will be evicted when write I/Os are returned from the device as failed. Catastrophic failures are detected and handled just as though they are on traditional storage devices.

Appendix C - Using Module Parameters

The following table describes the module parameters you can set by editing the /etc/modprobe.d/iomemory-vsl.conf file and changing their values.

Each module parameter in the configuration file must be preceded by options iomemory-vsl. The /etc/modprobe.d/iomemory-vsl.conf file has some example parameters that are commented out. You may use these examples as templates and/or uncomment them in order to use them.

NOTE-

These changes must be completed before the Fusion ioMemory VSL software is loaded in order to take effect.

Module Parameter	Default (min/max)	Description
auto_attach	1 (0, 1)	1 (default) = Always attach the device on driver load. 0 = Don't attach the device on driver load.
external_power_override	No devices selected	Allows designated device(s) to draw the specified amount (s) of power in Watts from the PCIe slot. Where the <SN-value>:<W-value> for this parameter is a comma-separated list of value pairs with adapter serial numbers and the maximum amount of power each device should pull (in Watts). **ATTENTION!** You can use a serial number wildcard (*) to set this module parameter for all cards in the system. Please see Enabling PCIe Power Override on page 26 for more information.
fio_dev_wait_timeout_secs	30	Number of seconds to wait for /dev/fio* files to show up during driver load. For systems not using udev, this should be set to 0 to disable the timeout and avoid an unneeded pause during driver load.
force_minimal_mode	0	1 = Force minimal mode on the device. 0 = Do not force minimal mode on the device.
numa_node_forced_local	0	1 = Enable, 0 = Disable. See NUMA Configuration on page 73 for more information.

Module Parameter	Default (min/max)	Description
`numa_node_override`	Nothing Selected	A list of `<affinity specification>` couplets that specify the affinity settings of all devices in the system. Each item in the couplet is separated by a colon, and each couplet set is separated by a comma. Where each `<affinity specification>` couplet has the following syntax: `<device-id>=<node-number>` See NUMA Configuration on page 73 for more information on using this parameter.
`parallel_attach`	1	1 = Enable parallel attach of multiple devices. 0 = Disable parallel attach of multiple devices.
`preallocate_memory`	No devices selected	For the selected devices, pre-allocate all memory necessary to have the drive usable as swap space. Where the `<value>` for this parameter is a comma-separated list of device serial numbers.
`tintr_hw_wait`	0 (0, 255)	Interval (microseconds) to wait between hardware interrupts. Also known as interrupt coalescing. 0 is off.
`use_workqueue`	0 (0 or 3)	Linux only: 3 = use standard OS I/O elevators; 0 = bypass.

NOTE-

Other than `external_power_override` and `preallocate_memory`, module parameters are global — they apply to all Fusion ioMemory devices in the computer.

Appendix D - NUMA Configuration

About NUMA Architecture

Servers with a NUMA (Non-Uniform Memory Access) architecture may require special installation instructions in order to maximize Fusion ioMemory device performance. This includes most multi-socket servers.

On some servers with NUMA architecture, during system boot the BIOS will not associate PCIe slots with the correct NUMA node. Incorrect mappings result in inefficient I/O handling that can significantly degrade performance. Here are two methods for correcting the NUMA affinity:

- **`numa_node_forced_local` Parameter**: Forces I/O completions to happen on the same CPU that is running VSL processes for a particular device. This parameter is simple to implement (enabled or disabled), and is persistent.
- **`numa_node_override` Parameter**: Used to manually assign devices to specific NUMA nodes. This parameter is more complex. For optimal implementation, you should understand the NUMA architecture of the system in order to assign devices to the nodes that are closely linked to the device's PCIe slot. This parameter is persistent until any new I/O devices are installed in the system (thus changing the PCIe bus numbers in the system.

Using the numa_node_forced_local Parameter

The `numa_node_forced_local` parameter is either enabled or disabled, and therefore does not offer as much user control as other options. It is persistent and it is enabled by modifying the `/etc/modprobe.d/iomemory-vsl.conf` file and editing or adding the following line:

```
numa_node_forced_local=1
```

This parameter forces an I/O completion for a particular device to happen on a CPU within the local `numa_node` that the other Fusion ioMemory VSL processes are running on (rather than trying to complete an I/O on the CPU that the host issued it on). Because the I/O completions are grouped with other Fusion ioMemory VSL processes, they are less likely to compete with processes from other device drivers.

This parameter may or may not improve performance depending on your configuration and workloads. You should test this parameter with your use case to determine if it improves performance.

Using the numa_node_override Parameter

Use this parameter to map devices with specific NUMA nodes.

ATTENTION!

The example below shows the final implementation of custom affinity settings. This implementation required an analysis of the specific system, including the system architecture, type and number of Fusion ioMemory devices installed, and the particular PCIe slots that were used. Your particular circumstances will require a custom analysis of your set-up. This analysis requires understanding of your system's NUMA architecture compared to your particular installation.

Your actual settings may be different than the example below, depending on your server configuration. In order to create the correct settings for your specific system, use `fio-status` to list all of the devices and determine the `<device-id>` (see below). Then use the example below of setting the `numa_node_override` parameter as a template and modify it for your particular system.

Determining the Device ID

You should present each `<device-id>` in the following format:

```
<domain>:<bus>:<device>.<function>
```

Typically the domain is `0000`, consult your server documentation to determine your device ID. The remainder of the device ID string is visible in `fio-status` output. For example:

```
# fio-status
Found 2 ioMemory devices in this system
...
       PCI:04:00.0
...
       PCI:15:00.0
```

In the example above the device IDs would be `0000:04:00.0` and `0000:15:00.0` on a system that had a domain of `0000`.

WARNING!

Note that the PCI device ID, including the bus number, may change if you change any of the PCI devices in the system. For example, if you add a network card or another Fusion ioMemory device. If the device ID changes, you will have to update the configuration.

numa_node_override Parameter

Configuring your Fusion ioMemory devices for servers with NUMA architecture requires the use of the `numa_node_override` parameter by modifying the `iomemory-vsl.conf` file.

The `numa_node_override` parameter is a list of `<affinity specification>` couplets that specify the affinity settings of all devices in the system. Each item in the couplet is separated by an equal sign (=), and each couplet set is separated by a comma.

Syntax:

```
numa_node_override=<affinity specification>[,<affinity specification>...]
```

Where each `<affinity specification>` has the following syntax:

```
<device-id>=<node-number>
```

Simple Example:

```
numa_node_override=0000:04:00.0=1,0000:1d:00.0=0,0000:05:00.0=2,0000:1e:00.0=3
```

Has the effect of creating :

<device-id>	Node/Group	Processor Affinity
0000:04:00.0	node 1	all processors in node 1
0000:1d:00.0	node 0	all processors in node 0
0000:05:00.0	node 2	all processors in node 2
0000:1e:00.0	node 3	all processors in node 3

Advanced Configuration

If your server has multiple NUMA nodes and multiple Fusion ioMemory devices installed, you will need to make sure that the Fusion ioMemory devices are spread out among the various nodes.

While it may be optimal to pair devices to nodes that are electronically closer each device's PCIe slot (which would require an advanced understanding of your server's NUMA architechure and an analysis of the device installation), just simply spreading out all of the devices' node affinity among the available nodes should result in improved performance.

In the example above the device IDs would be `0000:04:00.0` and `0000:15:00.0` on a system that had a domain of `0000`.

WARNING!

Note that the PCI device ID may change if you change any of the PCI devices in the system. For example, if you add a network card or another Fusion ioMemory device. If the device ID changes, you will have to update the configuration.

<device-id>	Node/Group	Processor Affinity
0000:04:00.0	node 1	all processors in node 1
0000:1d:00.0	node 0	all processors in node 0
0000:05:00.0	node 2	all processors in node 2
0000:1e:00.0	node 3	all processors in node 3

Appendix E - Upgrading Devices from VSL 2.x to 3.x

This version of the Fusion ioMemory VSL software supports new features, including the latest generation of ioMemory architecture and improved Flashback protection. These features require the latest version of the Fusion ioMemory device firmware. Every Fusion ioMemory device in a system running 3.1.x or later must be upgraded to the latest version of the firmware.

For example, if you have a system running 2.x Fusion ioMemory VSL software with Fusion ioMemory ioDrive devices previously installed, and you want to install new Fusion ioMemory ioDrive2 devices (that require the latest version of the firmware), then you will need to upgrade all of the existing devices to the latest firmware version.

WARNING!

You cannot revert a device's firmware to an earlier version once you have upgraded the device (without voiding your warranty). If you experience problems with your upgrade, please contact Customer Support at https://link.sandisk.com/commercialsupport .

WARNING!

Upgrading devices (previously configured for VSL 2.x.x) to work with VSL 3.x.x will require a low-level media format of the device. No user data will be maintained during the process. **Be sure to back up all data as instructed**.

ATTENTION!

Upgrade Path

Depending on the current firmware version of your devices, you may need to upgrade your device's firmware multiple times in order to preserve internal structures. Consult the *Fusion ioMemory VSL Release Notes* for the upgrade path. Visit https://link.sandisk.com/commercialsupport for all of the required software and firmware versions.

For more information on upgrading from one version to the next, see the *Fusion ioMemory VSL Release Notes* (available at https://link.sandisk.com/commercialsupport) for the version to which you will upgrade the device. Then follow the upgrade instructions in that version's user guide for your operating system (including the firmware update instructions).

Upgrade Procedure

While upgrading from VSL 2.x to 3.x, ensure that you follow the device upgrade path as described in the *Fusion ioMemory VSL Release Notes*. The device upgrade path outlines the specific order of firmware and VSL driver upgrades required for the VSL 2.x to 3.x upgrade.

Make sure that all previously installed Fusion ioMemory ioDrive devices are updated with the appropriate firmware and VSL software versions required for this upgrade.

ATTENTION!

Make sure to upgrade all existing Fusion ioMemory ioDrive devices to VSL 3.x **before** installing a new Fusion ioMemory ioDrive device in the same host.

If you install a new Fusion ioMemory ioDrive device before upgrading existing devices to VSL 3.x, the OS may not recognize the new device. This means that when you enter the `fio-status` command, the OS may return incomplete or incorrect information about the new device. In addition, the VSL 2.x driver may put the new device into minimal mode until the upgrade process is completed for the existing devices.

1. Prepare each existing Fusion ioMemory ioDrive device for upgrade.

   a. Back up user data on each device.

   WARNING!

   The upgrade process will require a low-level media format of the device. No user data will be retained during the process; **be sure to make a complete backup**.

   Use a backup method of your choice. For best results, use software and backup devices that have proven effective in the past. Do not back up the data onto another Fusion ioMemory device on the same system. The backup must be to a local disk or to an externally attached volume.

   b. Run the `fio-bugreport` utility and save the resulting file. This will capture the device information for each device in the system. This device information will be useful in troubleshooting any upgrade issues. Sample command:

   ```
   fio-bugreport
   ```

   c. Detach Fusion ioMemory ioDrive devices, for example:

   ```
   fio-detach /dev/fct*
   ```

   For more information, see fio-detach on page 58.

2. Unload the current Fusion ioMemory VSL driver, for example:

```
$ modprobe -r iomemory-vsl
```

3. Uninstall the 2.x Fusion ioMemory VSL software.

   a. Uninstall the utilities:

   - Sample RPM command:

   ```
   $ rpm -e fio-util fio-snmp-agentx fio-common fio-firmware
   iomanager-gui iomanager-jre libfio libfio-doc libfusionjni fio-
   sysvinit fio-smis fio-snmp-mib libfio-dev
   ```

- Sample DEB command:

```
$ dpkg -r fio-util fio-snmp-agentx fio-common fio-firmware
iomanager-gui iomanager-jre libfio libfio-doc libfusionjni fio-
sysvinit fio-smis fio-snmp-mib libfio-dev
```

b. To uninstall the software, you must specify the kernel version of the package you are uninstalling. Run the appropriate command to find the installed packages:

- RPM command:

```
$  rpm -qa | grep -i iomemory
```

- DEB command:

```
$ dpkg -l | grep -i iomemory
```

- Sample output:

```
iomemory-vsl-2.6.18-194.el5-2.2.2.82-1.0
```

c. Uninstall the Fusion ioMemory VSL software by running a command similar to this example (specify the kernel version of the package you wish to uninstall):

- Sample RPM command:

```
$ rpm -e iomemory-vsl-2.6.18-194.el5-2.2.0.82-1.0
```

- Sample DEB command:

```
$ dpkg -r iomemory-vsl-2.6.32-24-server
```

4. Install the new Fusion ioMemory VSL software and related packages.

a. Download the Fusion ioMemory VSL software binary package for your kernel and all supporting packages at https://link.sandisk.com/commercialsupport

NOTE-

If you don't see a binary for your kernel, follow the instructions in the **Building the ioMemory VSL from Source** section of Installing RPM Packages on page 10 or Installing DEB Packages on page 15. To see your current kernel version, run: uname -r

b. Install the Fusion ioMemory VSL software and utilities using the appropriate commands:

- RPM commands:

  ```
  rpm -Uvh iomemory-vsl-<kernel-version>-<VSL-version>.x86_64.rpm
  rpm -Uvh lib*.rpm
  rpm -Uvh fio*.rpm
  ```

- DEB commands:

  ```
  dpkg -i iomemory-vsl-<kernel-version>_<VSL-version>_amd64.deb
  dpkg -i lib*.deb
  dpkg -i fio*.deb
  ```

- See Installing RPM Packages on page 10or Installing DEB Packages on page 15 for full instructions on installing those packages.

c. Reboot the system.

5. Update the firmware on each device to the latest version using `fio-update-iodrive`.

   WARNING!

   Prevent Power Loss
   Take measures to prevent power loss during the update, such as using a UPS. Power loss during a firmware update may result in device failure. For all warnings, alerts, and options pertaining to this utility, see fio-update-iodrive on page 66.

   Sample syntax:

   ```
   fio-update-iodrive <firmware-path>
   ```

   Where `<firmware-path>` is the full path to the firmware archive file (`fusion_<version>.<date>.fff`) available at https://link.sandisk.com/commercialsupport . This command will update all of the devices to the selected firmware. If you wish to update specific devices, consult fio-update-iodrive on page 66 for more options.

6. Reboot the system

7. Load the Fusion ioMemory VSL software, for example:

   ```
   $ modprobe iomemory-vsl
   ```

   For more information, see Loading the ioMemory VSL Driver on page 20.

   NOTE-

   If run, `fio-status` will warn that the upgraded devices are missing a lebmap. This is expected, and will be fixed in the next step.

8. **Destructive Step**

WARNING!

Running `fio-format` in the next step will erase the entire device, including user data. Once this format is started, the device cannot be downgraded to the 2.x driver without voiding your warranty. If you experience problems with your upgrade, please contact Customer Support at https://link.sandisk.com/commercialsupport .

9. Format each device using `fio-format`, for example:

```
fio-format <device>
```

You will be prompted to confirm you wish to erase all data on the device.

ATTENTION!

The format may take an extended period of time, depending on the wear on the device.

10. Attach all Fusion ioMemory ioDrive devices, for example:

```
fio-attach /dev/fct*
```

11. Check the status of all devices using fio-status, for example:

```
fio-status -a
```

Your Fusion ioMemory ioDrive devices have now been successfully upgraded for this version of the Fusion ioMemory VSL software. You may now safely install any new Fusion ioMemory ioDrive devices.

Support

We offer SanDisk Customer Services and Support on the Web and by telephone.

Website Support

The following support is available on the SanDisk Commercial Support Website at: https://link.sandisk.com/commercialsupport.

- Customer Support. **Creating a support Case is the best way to get questions answered and issues addressed**. Please give a detailed description of your problem with your complete contact information (name, phone number, email address, location address).

- Warranty Support. Warranty Support is available on the SanDisk Commercial Support Website.

- Downloads. You can find tips, FAQs, and troubleshooting help, or download the latest user guides, software, and support packages on the SanDisk Commercial Support Website.

Telephone Support

ioFX Support

North America: (855) 322-5767

Enterprise Support

North America: (877) 816-5740

Country Numbers

For product support outside of North America, please use the number for the country/region closest to you. If that is not possible, please contact North America at +1 801 424 5474.

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