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1.1 Overview and history

Fio was originally written to save me the hassle of writing special test case programs when I wanted to test a specific workload, either for performance reasons or to find/reproduce a bug. The process of writing such a test app can be tiresome, especially if you have to do it often. Hence I needed a tool that would be able to simulate a given I/O workload without resorting to writing a tailored test case again and again.

A test work load is difficult to define, though. There can be any number of processes or threads involved, and they can each be using their own way of generating I/O. You could have someone dirtying large amounts of memory in an memory mapped file, or maybe several threads issuing reads using asynchronous I/O. fio needed to be flexible enough to simulate both of these cases, and many more.

Fio spawns a number of threads or processes doing a particular type of I/O action as specified by the user. fio takes a number of global parameters, each inherited by the thread unless otherwise parameters given to them overriding that setting is given. The typical use of fio is to write a job file matching the I/O load one wants to simulate.

1.2 Source

Fio resides in a git repo, the canonical place is:

    git://git.kernel.dk/fio.git

When inside a corporate firewall, git:// URL sometimes does not work. If git:// does not work, use the http protocol instead:

    http://git.kernel.dk/fio.git

Snapshots are frequently generated and fio-git-*.tar.gz include the git meta data as well. Other tarballs are archives of official fio releases. Snapshots can download from:

    http://brick.kernel.dk/snaps/

There are also two official mirrors. Both of these are automatically synced with the main repository, when changes are pushed. If the main repo is down for some reason, either one of these is safe to use as a backup:
1.3 Mailing list

The fio project mailing list is meant for anything related to fio including general discussion, bug reporting, questions, and development. For bug reporting, see REPORTING-BUGS.

An automated mail detailing recent commits is automatically sent to the list at most daily. The list address is fio@vger.kernel.org, subscribe by sending an email to majordomo@vger.kernel.org with

```
subscribe fio
```

in the body of the email. Archives can be found here:

http://www.spinics.net/lists/fio/

and archives for the old list can be found here:

http://maillist.kernel.dk/fio-devel/

1.4 Author

Fio was written by Jens Axboe <axboe@kernel.dk> to enable flexible testing of the Linux I/O subsystem and schedulers. He got tired of writing specific test applications to simulate a given workload, and found that the existing I/O benchmark/test tools out there weren’t flexible enough to do what he wanted.

Jens Axboe <axboe@kernel.dk> 20060905

1.5 Binary packages

**Debian:** Starting with Debian “Squeeze”, fio packages are part of the official Debian repository. [http://packages.debian.org/search?keywords=fio](http://packages.debian.org/search?keywords=fio).

**Ubuntu:** Starting with Ubuntu 10.04 LTS (aka “Lucid Lynx”), fio packages are part of the Ubuntu “universe” repository. [http://packages.ubuntu.com/search?keywords=fio](http://packages.ubuntu.com/search?keywords=fio).

**Red Hat, Fedora, CentOS & Co:** Starting with Fedora 9/Extra Packages for Enterprise Linux 4, fio packages are part of the Fedora/EPEL repositories. [https://apps.fedoraproject.org/packages/fio](https://apps.fedoraproject.org/packages/fio).

**Mandriva:** Mandriva has integrated fio into their package repository, so installing on that distro should be as easy as typing `urpmi fio`.

**Arch Linux:** An Arch Linux package is provided under the Community sub-repository: [https://www.archlinux.org/packages/?sort=&q=fio](https://www.archlinux.org/packages/?sort=&q=fio)

**Solaris:** Packages for Solaris are available from OpenCSW. Install their pkgutil tool ([http://www.opencsw.org/get-it/pkgutil/](http://www.opencsw.org/get-it/pkgutil/)) and then install fio via `pkgutil -i fio`. 
Windows: Rebecca Cran <rebecca@bsdio.com> has fio packages for Windows at https://bsdio.com/fio/. The latest builds for Windows can also be grabbed from https://ci.appveyor.com/project/axboe/fio by clicking the latest x86 or x64 build, then selecting the ARTIFACTS tab.

BSDs: Packages for BSDs may be available from their binary package repositories. Look for a package “fio” using their binary package managers.

1.6 Building

Just type:

```
$ ./configure
$ make
$ make install
```

Note that GNU make is required. On BSDs it’s available from devel/gmake within ports directory; on Solaris it’s in the SUNWgmake package. On platforms where GNU make isn’t the default, type gmake instead of make.

Configure will print the enabled options. Note that on Linux based platforms, the libaio development packages must be installed to use the libaio engine. Depending on distro, it is usually called libaio-devel or libaio-dev.

For gfio, gtk 2.18 (or newer), associated glib threads, and cairo are required to be installed. gfio isn’t built automatically and can be enabled with a `--enable-gfio` option to configure.

To build fio with a cross-compiler:

```
$ make clean
$ make CROSS_COMPILE=/path/to/toolchain/prefix
```

Configure will attempt to determine the target platform automatically.

It’s possible to build fio for ESX as well, use the `--esx` switch to configure.

1.6.1 Windows

The minimum versions of Windows for building/runing fio are Windows 7/Windows Server 2008 R2. On Windows, Cygwin (https://www.cygwin.com/) is required in order to build fio. To create an MSI installer package install WiX from https://wixtoolset.org and run dobuild.cmd from the os/windows directory.

How to compile fio on 64-bit Windows:

1. Install Cygwin (http://www.cygwin.com/). Install make and all packages starting with mingw64-x86_64. Ensure mingw64-x86_64-zlib are installed if you wish to enable fio’s log compression functionality.

2. Open the Cygwin Terminal.

3. Go to the fio directory (source files).

4. Run `make clean && make -j`.

To build fio for 32-bit Windows, ensure the -i686 versions of the previously mentioned -x86_64 packages are installed and run `./configure --build-32bit-win` before `make`.

It’s recommended that once built or installed, fio be run in a Command Prompt or other ‘native’ console such as console2, since there are known to be display and signal issues when running it under a Cygwin shell (see https://github.com/mintty/mintty/issues/56 and https://github.com/mintty/mintty/wiki/Tips#inputoutput-interaction-with-alien-programs for details).
1.6.2 Documentation

Fio uses Sphinx to generate documentation from the reStructuredText files. To build HTML formatted documentation run `make -C doc html` and direct your browser to `.doc/output/html/index.html`. To build manual page run `make -C doc man` and then `man doc/output/man/fio.1`. To see what other output formats are supported run `make -C doc help`.

1.7 Platforms

Fio works on (at least) Linux, Solaris, AIX, HP-UX, OSX, NetBSD, OpenBSD, Windows, FreeBSD, and DragonFly. Some features and/or options may only be available on some of the platforms, typically because those features only apply to that platform (like the solarisaio engine, or the splice engine on Linux).

Some features are not available on FreeBSD/Solaris even if they could be implemented, I’d be happy to take patches for that. An example of that is disk utility statistics and (I think) huge page support, support for that does exist in FreeBSD/Solaris.

Fio uses pthread mutexes for signalling and locking and some platforms do not support process shared pthread mutexes. As a result, on such platforms only threads are supported. This could be fixed with sysv ipc locking or other locking alternatives.

Other *BSD platforms are untested, but fio should work there almost out of the box. Since I don’t do test runs or even compiles on those platforms, your mileage may vary. Sending me patches for other platforms is greatly appreciated. There’s a lot of value in having the same test/benchmark tool available on all platforms.

Note that POSIX aio is not enabled by default on AIX. Messages like these:

```
Symbol resolution failed for /usr/lib/libc.a(posix_aio.o) because:
   Symbol _posix_kaio_rdwr (number 2) is not exported from dependent module /unix.
```

indicate one needs to enable POSIX aio. Run the following commands as root:

```
# lsdev -C -l posix_aio0
   posix_aio0 Defined  Posix Asynchronous I/O
# cfgmgr -l posix_aio0
# lsdev -C -l posix_aio0
   posix_aio0 Available  Posix Asynchronous I/O
```

POSIX aio should work now. To make the change permanent:

```
# chdev -l posix_aio0 -P -a autoconfig='available'
   posix_aio0 changed
```

1.8 Running fio

Running fio is normally the easiest part - you just give it the job file (or job files) as parameters:

```
$ fio [options] [jobfile] ...
```

and it will start doing what the job file tells it to do. You can give more than one job file on the command line, fio will serialize the running of those files. Internally that is the same as using the stonewall parameter described in the parameter section.
If the job file contains only one job, you may as well just give the parameters on the command line. The command line parameters are identical to the job parameters, with a few extra that control global parameters. For example, for the job file parameter `iodepth=2`, the mirror command line option would be `--iodepth 2` or `--iodepth=2`. You can also use the command line for giving more than one job entry. For each `--name` option that fio sees, it will start a new job with that name. Command line entries following a `--name` entry will apply to that job, until there are no more entries or a new `--name` entry is seen. This is similar to the job file options, where each option applies to the current job until a new [] job entry is seen.

fio does not need to run as root, except if the files or devices specified in the job section requires that. Some other options may also be restricted, such as memory locking, I/O scheduler switching, and decreasing the nice value.

If `jobfile` is specified as `-`, the job file will be read from standard input.

### 1.9 How fio works

The first step in getting fio to simulate a desired I/O workload, is writing a job file describing that specific setup. A job file may contain any number of threads and/or files – the typical contents of the job file is a `global` section defining shared parameters, and one or more job sections describing the jobs involved. When run, fio parses this file and sets everything up as described. If we break down a job from top to bottom, it contains the following basic parameters:

**I/O type**

Defines the I/O pattern issued to the file(s). We may only be reading sequentially from this file(s), or we may be writing randomly. Or even mixing reads and writes, sequentially or randomly. Should we be doing buffered I/O, or direct/raw I/O?

**Block size**

In how large chunks are we issuing I/O? This may be a single value, or it may describe a range of block sizes.

**I/O size**

How much data are we going to be reading/writing.

**I/O engine**

How do we issue I/O? We could be memory mapping the file, we could be using regular read/write, we could be using splice, async I/O, or even SG (SCSI generic sg).

**I/O depth**

If the I/O engine is async, how large a queuing depth do we want to maintain?

**Target file/device**

How many files are we spreading the workload over.

**Threads, processes and job synchronization**

How many threads or processes should we spread this workload over.

The above are the basic parameters defined for a workload, in addition there’s a multitude of parameters that modify other aspects of how this job behaves.

### 1.10 Command line options

`--debug=type`

Enable verbose tracing `type` of various fio actions. May be `all` for all types or individual types separated by a
comma (e.g. --debug=file,mem will enable file and memory debugging). Currently, additional logging is available for:

- **process** Dump info related to processes.
- **file** Dump info related to file actions.
- **io** Dump info related to I/O queuing.
- **mem** Dump info related to memory allocations.
- **blktrace** Dump info related to blktrace setup.
- **verify** Dump info related to I/O verification.
- **all** Enable all debug options.
- **random** Dump info related to random offset generation.
- **parse** Dump info related to option matching and parsing.
- **diskutil** Dump info related to disk utilization updates.
- **job:x** Dump info only related to job number x.
- **mutex** Dump info only related to mutex up/down ops.
- **profile** Dump info related to profile extensions.
- **time** Dump info related to internal time keeping.
- **net** Dump info related to networking connections.
- **rate** Dump info related to I/O rate switching.
- **compress** Dump info related to log compress/decompress.
- **steadystate** Dump info related to steadystate detection.
- **helperthread** Dump info related to the helper thread.
- **zbd** Dump info related to support for zoned block devices.

? or help Show available debug options.

--parse-only
Parse options only, don’t start any I/O.

--merge-blktrace-only
Merge blktraces only, don’t start any I/O.

--output=filename
Write output to file filename.

--output-format=format
Set the reporting format to normal, terse, json, or json+. Multiple formats can be selected, separated by a comma. terse is a CSV based format. json+ is like json, except it adds a full dump of the latency buckets.

--bandwidth-log
Generate aggregate bandwidth logs.

--minimal
Print statistics in a terse, semicolon-delimited format.

--append-terse
Print statistics in selected mode AND terse, semicolon-delimited format. Deprecated, use --output-format instead to select multiple formats.
--terse-version=version
Set terse version output format (default 3, or 2 or 4 or 5).

--version
Print version information and exit.

--help
Print a summary of the command line options and exit.

--cpuclock-test
Perform test and validation of internal CPU clock.

--crctest=[test]
Test the speed of the built-in checksumming functions. If no argument is given, all of them are tested. Alternatively, a comma separated list can be passed, in which case the given ones are tested.

--cmdhelp=command
Print help information for command. May be all for all commands.

--enghelp=[ioengine[,command]]
List all commands defined by ioengine, or print help for command defined by ioengine. If no ioengine is given, list all available ioengines.

--showcmd=jobfile
Convert jobfile to a set of command-line options.

--readonly
Turn on safety read-only checks, preventing writes and trims. The --readonly option is an extra safety guard to prevent users from accidentally starting a write or trim workload when that is not desired. Fio will only modify the device under test if rw=write/randwrite/rw/randrw/trim/randtrim/trimwrite is given. This safety net can be used as an extra precaution.

--eta=when
Specifies when real-time ETA estimate should be printed. when may be always, never or auto. auto is the default, it prints ETA when requested if the output is a TTY. always disregards the output type, and prints ETA when requested. never never prints ETA.

--eta-interval=time
By default, fio requests client ETA status roughly every second. With this option, the interval is configurable. Fio imposes a minimum allowed time to avoid flooding the console, less than 250 msec is not supported.

--eta-newline=time
Force a new line for every time period passed. When the unit is omitted, the value is interpreted in seconds.

--status-interval=time
Force a full status dump of cumulative (from job start) values at time intervals. This option does not provide per-period measurements. So values such as bandwidth are running averages. When the time unit is omitted, time is interpreted in seconds. Note that using this option with --output-format=json will yield output that technically isn’t valid json, since the output will be collated sets of valid json. It will need to be split into valid sets of json after the run.

--section=name
Only run specified section name in job file. Multiple sections can be specified. The --section option allows one to combine related jobs into one file. E.g. one job file could define light, moderate, and heavy sections. Tell fio to run only the “heavy” section by giving --section=heavy command line option. One can also specify the “write” operations in one section and “verify” operation in another section. The --section option only applies to job sections. The reserved global section is always parsed and used.

--alloc-size=kb
Allocate additional internal smalloc pools of size kb in KiB. The --alloc-size option increases shared memory set aside for use by fio. If running large jobs with randommap enabled, fio can run out of memory.

1.10. Command line options
Smalloc is an internal allocator for shared structures from a fixed size memory pool and can grow to 16 pools. The pool size defaults to 16MiB.

NOTE: While running .fio_smalloc.* backing store files are visible in /tmp.

--warnings-fatal
All fio parser warnings are fatal, causing fio to exit with an error.

--max-jobs=nr
Set the maximum number of threads/processes to support to nr. NOTE: On Linux, it may be necessary to increase the shared-memory limit (/proc/sys/kernel/shmmax) if fio runs into errors while creating jobs.

--server=ARGS
Start a backend server, with ARGS specifying what to listen to. See Client/Server section.

--daemonize=pidfile
Background a fio server, writing the pid to the given pidfile file.

--client=hostname
Instead of running the jobs locally, send and run them on the given hostname or set of hostnames. See Client/Server section.

--remote-config=file
Tell fio server to load this local file.

--idle-prof=option
Report CPU idleness. option is one of the following:
  calibrate Run unit work calibration only and exit.
  system Show aggregate system idleness and unit work.
  percpu As system but also show per CPU idleness.

--inflate-log=log
Inflate and output compressed log.

--trigger-file=file
Execute trigger command when file exists.

--trigger-timeout=time
Execute trigger at this time.

--trigger=command
Set this command as local trigger.

--trigger-remote=command
Set this command as remote trigger.

--aux-path=path
Use the directory specified by path for generated state files instead of the current working directory.

Any parameters following the options will be assumed to be job files, unless they match a job file parameter. Multiple job files can be listed and each job file will be regarded as a separate group. Fio will stonewall execution between each group.

1.11 Job file format

As previously described, fio accepts one or more job files describing what it is supposed to do. The job file format is the classic ini file, where the names enclosed in [] brackets define the job name. You are free to use any ASCII name you want, except global which has special meaning. Following the job name is a sequence of zero or more parameters,
one per line, that define the behavior of the job. If the first character in a line is a ‘;’ or a ‘#’, the entire line is discarded as a comment.

A global section sets defaults for the jobs described in that file. A job may override a global section parameter, and a job file may even have several global sections if so desired. A job is only affected by a global section residing above it.

The --cmdhelp option also lists all options. If used with a command argument, --cmdhelp will detail the given command.

See the examples/ directory for inspiration on how to write job files. Note the copyright and license requirements currently apply to examples/ files.

So let’s look at a really simple job file that defines two processes, each randomly reading from a 128MiB file:

```
; -- start job file --
[global]
  rw=randread
  size=128m

[job1]

[job2]
; -- end job file --
```

As you can see, the job file sections themselves are empty as all the described parameters are shared. As no filename option is given, fio makes up a filename for each of the jobs as it sees fit. On the command line, this job would look as follows:

```
$ fio --name=global --rw=randread --size=128m --name=job1 --name=job2
```

Let’s look at an example that has a number of processes writing randomly to files:

```
; -- start job file --
[random-writers]
  ioengine=libaio
  iodepth=4
  rw=randwrite
  bs=32k
  direct=0
  size=64m
  numjobs=4
; -- end job file --
```

Here we have no global section, as we only have one job defined anyway. We want to use async I/O here, with a depth of 4 for each file. We also increased the buffer size used to 32KiB and define numjobs to 4 to fork 4 identical jobs. The result is 4 processes each randomly writing to their own 64MiB file. Instead of using the above job file, you could have given the parameters on the command line. For this case, you would specify:

```
$ fio --name=random-writers --ioengine=libaio --iodepth=4 --rw=randwrite --bs=32k --direct=0 --size=64m --numjobs=4
```

When fio is utilized as a basis of any reasonably large test suite, it might be desirable to share a set of standardized settings across multiple job files. Instead of copy/pasting such settings, any section may pull in an external filename.fio file with include filename directive, as in the following example:
Settings pulled into a section apply to that section only (except *global* section). Include directives may be nested in that any included file may contain further include directive(s). Include files may not contain [] sections.

### 1.11.1 Environment variables

Fio also supports environment variable expansion in job files. Any sub-string of the form `${VARNAME}` as part of an option value (in other words, on the right of the `=`), will be expanded to the value of the environment variable called `VARNAME`. If no such environment variable is defined, or `VARNAME` is the empty string, the empty string will be substituted.

As an example, let’s look at a sample fio invocation and job file:

```
$ SIZE=64m NUMJOBS=4 fio jobfile.fio
```

This will expand to the following equivalent job file at runtime:

```
[random-writers]
rw=randwrite
size=${SIZE}
numjobs=${NUMJOBS}
```

Fio ships with a few example job files, you can also look there for inspiration.
1.11.2 Reserved keywords

Additionally, fio has a set of reserved keywords that will be replaced internally with the appropriate value. Those keywords are:

$pagesize

The architecture page size of the running system.

$mb_memory

Megabytes of total memory in the system.

$ncpus

Number of online available CPUs.

These can be used on the command line or in the job file, and will be automatically substituted with the current system values when the job is run. Simple math is also supported on these keywords, so you can perform actions like:

```
size=8*$mb_memory
```

and get that properly expanded to 8 times the size of memory in the machine.

1.12 Job file parameters

This section describes in details each parameter associated with a job. Some parameters take an option of a given type, such as an integer or a string. Anywhere a numeric value is required, an arithmetic expression may be used, provided it is surrounded by parentheses. Supported operators are:

- addition (+)
- subtraction (-)
- multiplication (*)
- division (/)
- modulus (%)
- exponentiation (^)

For time values in expressions, units are microseconds by default. This is different than for time values not in expressions (not enclosed in parentheses). The following types are used:

1.12.1 Parameter types

str String: A sequence of alphanumeric characters.

time Integer with possible time suffix. Without a unit value is interpreted as seconds unless otherwise specified. Accepts a suffix of ‘d’ for days, ‘h’ for hours, ‘m’ for minutes, ‘s’ for seconds, ‘ms’ (or ‘msec’) for milliseconds and ‘us’ (or ‘usec’) for microseconds. For example, use 10m for 10 minutes.

int Integer. A whole number value, which may contain an integer prefix and an integer suffix:

```
[integer prefix] number [integer suffix]
```

The optional integer prefix specifies the number’s base. The default is decimal. 0x specifies hexadecimal.
The optional *integer suffix* specifies the number’s units, and includes an optional unit prefix and an optional unit. For quantities of data, the default unit is bytes. For quantities of time, the default unit is seconds unless otherwise specified.

With `kb_base`=1000, fio follows international standards for unit prefixes. To specify power-of-10 decimal values defined in the International System of Units (SI):

- \( K \) – means kilo (K) or 1000
- \( M \) – means mega (M) or 1000\(^2\)
- \( G \) – means giga (G) or 1000\(^3\)
- \( T \) – means tera (T) or 1000\(^4\)
- \( P \) – means peta (P) or 1000\(^5\)

To specify power-of-2 binary values defined in IEC 80000-13:

- \( Ki \) – means kibi (Ki) or 1024
- \( Mi \) – means mebi (Mi) or 1024\(^2\)
- \( Gi \) – means gibi (Gi) or 1024\(^3\)
- \( Ti \) – means tebi (Ti) or 1024\(^4\)
- \( Pi \) – means pebi (Pi) or 1024\(^5\)

**For Zone Block Device Mode:**

- \( z \) – means Zone

With `kb_base`=1024 (the default), the unit prefixes are opposite from those specified in the SI and IEC 80000-13 standards to provide compatibility with old scripts. For example, 4k means 4096.

For quantities of data, an optional unit of ‘B’ may be included (e.g., ‘kB’ is the same as ‘k’).

The *integer suffix* is not case sensitive (e.g., m/mi mean mebi/mega, not milli). ‘b’ and ‘B’ both mean byte, not bit.

Examples with `kb_base`=1000:

- 4 \( KiB \): 4096, 4096b, 4096B, 4ki, 4kib, 4kiB, 4Ki, 4KiB
- 1 \( MiB \): 1048576, 1mi, 1024ki
- 1 \( MB \): 1000000, 1m, 1000k
- 1 \( TiB \): 1099511627776, 1ti, 1024gi, 1048576mi
- 1 \( TB \): 1000000000, 1t, 1000m, 1000000k

Examples with `kb_base`=1024 (default):

- 4 \( KiB \): 4096, 4096b, 4096B, 4k, 4kb, 4kB, 4K, 4KB
- 1 \( MiB \): 1048576, 1m, 1024k
- 1 \( MB \): 1000000, 1mi, 1000ki
- 1 \( TiB \): 1099511627776, 1t, 1024g, 1048576m
- 1 \( TB \): 1000000000, 1ti, 1000mi, 1000000ki

To specify times (units are not case sensitive):

- \( D \) – means days
- \( H \) – means hours
• *M* – means minutes
• *s* – or sec means seconds (default)
• *ms* – or *msec* means milliseconds
• *us* – or *usec* means microseconds

If the option accepts an upper and lower range, use a colon `:` or minus `-' to separate such values. See irange. If the lower value specified happens to be larger than the upper value the two values are swapped.

**bool**  
Boolean. Usually parsed as an integer, however only defined for true and false (1 and 0).

**irange**  
Integer range with suffix. Allows value range to be given, such as 1024-4096. A colon may also be used as the separator, e.g. 1k:4k. If the option allows two sets of ranges, they can be specified with a ‘,’ or ‘/’ delimiter: 1k-4k/8k-32k. Also see int.

**float_list**  
A list of floating point numbers, separated by a `:` character.

With the above in mind, here follows the complete list of fio job parameters.

### 1.12.2 Units

**kb_base**=int
Select the interpretation of unit prefixes in input parameters.

- **1000**  
  Inputs comply with IEC 80000-13 and the International System of Units (SI). Use:
  - power-of-2 values with IEC prefixes (e.g., KiB)
  - power-of-10 values with SI prefixes (e.g., kB)

- **1024**  
  Compatibility mode (default). To avoid breaking old scripts:
  - power-of-2 values with SI prefixes
  - power-of-10 values with IEC prefixes

See `bs` for more details on input parameters.

Outputs always use correct prefixes. Most outputs include both side-by-side, like:

```
bw=2383.3kB/s (2327.4KiB/s)
```

If only one value is reported, then `kb_base` selects the one to use:

- **1000**  
  SI prefixes
- **1024**  
  IEC prefixes

**unit_base**=int  
Base unit for reporting. Allowed values are:

0  Use auto-detection (default).
8  Byte based.
1  Bit based.
1.12.3 Job description

**name=**str

ASCII name of the job. This may be used to override the name printed by fio for this job. Otherwise the job name is used. On the command line this parameter has the special purpose of also signaling the start of a new job.

**description=**str

Text description of the job. Doesn’t do anything except dump this text description when this job is run. It’s not parsed.

**loops=**int

Run the specified number of iterations of this job. Used to repeat the same workload a given number of times. Defaults to 1.

**numjobs=**int

Create the specified number of clones of this job. Each clone of job is spawned as an independent thread or process. May be used to setup a larger number of threads/processes doing the same thing. Each thread is reported separately; to see statistics for all clones as a whole, use group_reporting in conjunction with new_group. See --max-jobs. Default: 1.

1.12.4 Time related parameters

**runtime=**time

Tell fio to terminate processing after the specified period of time. It can be quite hard to determine for how long a specified job will run, so this parameter is handy to cap the total runtime to a given time. When the unit is omitted, the value is interpreted in seconds.

**time_based**

If set, fio will run for the duration of the runtime specified even if the file(s) are completely read or written. It will simply loop over the same workload as many times as the runtime allows.

**startdelay=**range(time)

Delay the start of job for the specified amount of time. Can be a single value or a range. When given as a range, each thread will choose a value randomly from within the range. Value is in seconds if a unit is omitted.

**ramp_time=**time

If set, fio will run the specified workload for this amount of time before logging any performance numbers. Useful for letting performance settle before logging results, thus minimizing the runtime required for stable results. Note that the ramp_time is considered lead in time for a job, thus it will increase the total runtime if a special timeout or runtime is specified. When the unit is omitted, the value is given in seconds.

**clocksource=**str

Use the given clocksource as the base of timing. The supported options are:

- **gettimeofday**
- **clock_gettime**
- **cpu** Internal CPU clock source

cpu is the preferred clocksource if it is reliable, as it is very fast (and fio is heavy on time calls). Fio will automatically use this clocksource if it's supported and considered reliable on the system it is running on, unless another clocksource is specifically set. For x86/x86-64 CPUs, this means supporting TSC Invariant.

**gtod_reduce=**bool

Enable all of the gettimeofday(2) reducing options (disable_clat, disable_slat, disable_bw_measurement) plus reduce precision of the timeout somewhat to really shrink the
gettimeofday(2) call count. With this option enabled, we only do about 0.4% of the gettimeofday(2) calls we would have done if all time keeping was enabled.


gtod_cpu=int
Sometimes it’s cheaper to dedicate a single thread of execution to just getting the current time. Fio (and databases, for instance) are very intensive on gettimeofday(2) calls. With this option, you can set one CPU aside for doing nothing but logging current time to a shared memory location. Then the other threads/processes that run I/O workloads need only copy that segment, instead of entering the kernel with a gettimeofday(2) call. The CPU set aside for doing these time calls will be excluded from other uses. Fio will manually clear it from the CPU mask of other jobs.

1.12.5 Target file/device

directory=str
Prefix filenames with this directory. Used to place files in a different location than ./. You can specify a number of directories by separating the names with a ‘:’ character. These directories will be assigned equally distributed to job clones created by \(\text{numjobs}\) as long as they are using generated filenames. If specific filename(s) are set fio will use the first listed directory, and thereby matching the filename semantic (which generates a file for each clone if not specified, but lets all clones use the same file if set).

See the filename option for information on how to escape “:” characters within the directory path itself.

Note: To control the directory fio will use for internal state files use --aux-path.

filename=str
Fio normally makes up a filename based on the job name, thread number, and file number (see filename_format). If you want to share files between threads in a job or several jobs with fixed file paths, specify a filename for each of them to override the default. If the ioengine is file based, you can specify a number of files by separating the names with a ‘:’ colon. So if you wanted a job to open /dev/sda and /dev/sdb as the two working files, you would use filename=/dev/sda:/dev/sdb. This also means that whenever this option is specified, nrfiles is ignored. The size of regular files specified by this option will be size divided by number of files unless an explicit size is specified by filesize.

Each colon in the wanted path must be escaped with a \ character. For instance, if the path is /dev/dsk/foo@3,0:c then you would use filename=/dev/dsk/foo@3,0:\c and if the path is F:\\filename then you would use filename=F:\:\filename.

On Windows, disk devices are accessed as \\.\PhysicalDrive0 for the first device, \\.\PhysicalDrive1 for the second etc. Note: Windows and FreeBSD prevent write access to areas of the disk containing in-use data (e.g. filesystems).

The filename “-” is a reserved name, meaning stdin or stdout. Which of the two depends on the read/write direction set.

filename_format=str
If sharing multiple files between jobs, it is usually necessary to have fio generate the exact names that you want. By default, fio will name a file based on the default file format specification of jobname.jobnumber.filenum. With this option, that can be customized. Fio will recognize and replace the following keywords in this string:

\$jobname The name of the worker thread or process.

\$clientuid IP of the fio process when using client/server mode.

\$jobnum The incremental number of the worker thread or process.

\$filenum The incremental number of the file for that worker thread or process.

To have dependent jobs share a set of files, this option can be set to have fio generate filenames that are shared between the two. For instance, if testfiles.$filenum is specified, file number 4 for any job will be
named testfiles.4. The default of $jobname.$jobnum.$filenum will be used if no other format specifier is given.

If you specify a path then the directories will be created up to the main directory for the file. So for example if you specify filename_format=a/b/c/$jobnum then the directories a/b/c will be created before the file setup part of the job. If you specify directory then the path will be relative that directory, otherwise it is treated as the absolute path.

unique_filename=bool
To avoid collisions between networked clients, fio defaults to prefixing any generated filenames (with a directory specified) with the source of the client connecting. To disable this behavior, set this option to 0.

opendir=str
Recursively open any files below directory str.

lockfile=str
Fio defaults to not locking any files before it does I/O to them. If a file or file descriptor is shared, fio can serialize I/O to that file to make the end result consistent. This is usual for emulating real workloads that share files. The lock modes are:

- none  No locking. The default.
- exclusive  Only one thread or process may do I/O at a time, excluding all others.
- readwrite  Read-write locking on the file. Many readers may access the file at the same time, but writes get exclusive access.

nrfiles=int
Number of files to use for this job. Defaults to 1. The size of files will be size divided by this unless explicit size is specified by filesize. Files are created for each thread separately, and each file will have a file number within its name by default, as explained in filename section.

openfiles=int
Number of files to keep open at the same time. Defaults to the same as nrfiles, can be set smaller to limit the number simultaneous opens.

file_service_type=str
Defines how fio decides which file from a job to service next. The following types are defined:

- random  Choose a file at random.
- roundrobin  Round robin over opened files. This is the default.
- sequential  Finish one file before moving on to the next. Multiple files can still be open depending on openfiles.
- zipf  Use a Zipf distribution to decide what file to access.
- pareto  Use a Pareto distribution to decide what file to access.
- normal  Use a Gaussian (normal) distribution to decide what file to access.
- gauss  Alias for normal.

For random, roundrobin, and sequential, a postfix can be appended to tell fio how many I/Os to issue before switching to a new file. For example, specifying file_service_type=random:8 would cause fio to issue 8 I/Os before selecting a new file at random. For the non-uniform distributions, a floating point postfix can be given to influence how the distribution is skewed. See random_distribution for a description of how that would work.

ioscheduler=str
Attempt to switch the device hosting the file to the specified I/O scheduler before running.
create_serialize=bool
   If true, serialize the file creation for the jobs. This may be handy to avoid interleaving of data files, which may greatly depend on the filesystem used and even the number of processors in the system. Default: true.

create_fsync=bool
   fsync(2) the data file after creation. This is the default.

create_on_open=bool
   If true, don’t pre-create files but allow the job’s open() to create a file when it’s time to do I/O. Default: false – pre-create all necessary files when the job starts.

create_only=bool
   If true, fio will only run the setup phase of the job. If files need to be laid out or updated on disk, only that will be done – the actual job contents are not executed. Default: false.

allow_file_create=bool
   If true, fio is permitted to create files as part of its workload. If this option is false, then fio will error out if the files it needs to use don’t already exist. Default: true.

allow_mounted_write=bool
   If this isn’t set, fio will abort jobs that are destructive (e.g. that write) to what appears to be a mounted device or partition. This should help catch creating inadvertently destructive tests, not realizing that the test will destroy data on the mounted file system. Note that some platforms don’t allow writing against a mounted device regardless of this option. Default: false.

pre_read=bool
   If this is given, files will be pre-read into memory before starting the given I/O operation. This will also clear the invalidate flag, since it is pointless to pre-read and then drop the cache. This will only work for I/O engines that are seek-able, since they allow you to read the same data multiple times. Thus it will not work on non-seekable I/O engines (e.g. network, splice). Default: false.

unlink=bool
   Unlink the job files when done. Not the default, as repeated runs of that job would then waste time recreating the file set again and again. Default: false.

unlink_each_loop=bool
   Unlink job files after each iteration or loop. Default: false.

zonemode=str
   Accepted values are:
   - none: The zonerange, zonesize, :option zonecapacity and option:zoneskip parameters are ignored.
   - strided: I/O happens in a single zone until zonesize bytes have been transferred. After that number of bytes has been transferred processing of the next zone starts. :option zonecapacity is ignored.
   - zbd: Zoned block device mode. I/O happens sequentially in each zone, even if random I/O has been selected. Random I/O happens across all zones instead of being restricted to a single zone. The zoneskip parameter is ignored. zonerange and zonesize must be identical.

zonerange=int
   Size of a single zone. See also zonesize and zoneskip.

zonesize=int
   For zonemode = strided, this is the number of bytes to transfer before skipping zoneskip bytes. If this parameter is smaller than zonerange then only a fraction of each zone with zonerange bytes will be accessed. If this parameter is larger than zonerange then each zone will be accessed multiple times before skipping to the next zone.
For `zonemode = zbd`, this is the size of a single zone. The `zonerange` parameter is ignored in this mode.

`zonecapacity = int`
For `zonemode = zbd`, this defines the capacity of a single zone, which is the accessible area starting from the zone start address. This parameter only applies when using `zonemode = zbd` in combination with regular block devices. If not specified it defaults to the zone size. If the target device is a zoned block device, the zone capacity is obtained from the device information and this option is ignored.

`zoneskip = int`
For `zonemode = strided`, the number of bytes to skip after `zonesize` bytes of data have been transferred. This parameter must be zero for `zonemode = zbd`.

`read_beyond_wp = bool`
This parameter applies to `zonemode = zbd` only.

Zoned block devices are block devices that consist of multiple zones. Each zone has a type, e.g. conventional or sequential. A conventional zone can be written at any offset that is a multiple of the block size. Sequential zones must be written sequentially. The position at which a write must occur is called the write pointer. A zoned block device can be either drive managed, host managed or host aware. For host managed devices the host must ensure that writes happen sequentially. Fio recognizes host managed devices and serializes writes to sequential zones for these devices.

If a read occurs in a sequential zone beyond the write pointer then the zoned block device will complete the read without reading any data from the storage medium. Since such reads lead to unrealistically high bandwidth and IOPS numbers fio only reads beyond the write pointer if explicitly told to do so. Default: false.

`max_open_zones = int`
When running a random write test across an entire drive many more zones will be open than in a typical application workload. Hence this command line option that allows to limit the number of open zones. The number of open zones is defined as the number of zones to which write commands are issued.

`zone_reset_threshold = float`
A number between zero and one that indicates the ratio of logical blocks with data to the total number of logical blocks in the test above which zones should be reset periodically.

`zone_reset_frequency = float`
A number between zero and one that indicates how often a zone reset should be issued if the zone reset threshold has been exceeded. A zone reset is submitted after each `(1 / zone_reset_frequency)` write requests. This and the previous parameter can be used to simulate garbage collection activity.

### 1.12.6 I/O type

`direct = bool`
If value is true, use non-buffered I/O. This is usually `O_DIRECT`. Note that OpenBSD and ZFS on Solaris don’t support direct I/O. On Windows the synchronous ioengines don’t support direct I/O. Default: false.

`atomic = bool`
If value is true, attempt to use atomic direct I/O. Atomic writes are guaranteed to be stable once acknowledged by the operating system. Only Linux supports `O_ATOMIC` right now.

`buffered = bool`
If value is true, use buffered I/O. This is the opposite of the `direct` option. Defaults to true.

`readwrite = str`, `rw = str`
Type of I/O pattern. Accepted values are:

- **read**  Sequential reads.
- **write** Sequential writes.
trim  Sequential trims (Linux block devices and SCSI character devices only).

randread Random reads.

randwrite Random writes.

randtrim Random trims (Linux block devices and SCSI character devices only).

rw,readwrite Sequential mixed reads and writes.

randrw Random mixed reads and writes.

trimwrite Sequential trim+write sequences. Blocks will be trimmed first, then the same blocks will be written to.

Fio defaults to read if the option is not specified. For the mixed I/O types, the default is to split them 50/50. For certain types of I/O the result may still be skewed a bit, since the speed may be different.

It is possible to specify the number of I/Os to do before getting a new offset by appending :<nr> to the end of the string given. For a random read, it would look like rw=randread:8 for passing in an offset modifier with a value of 8. If the suffix is used with a sequential I/O pattern, then the <nr> value specified will be added to the generated offset for each I/O turning sequential I/O into sequential I/O with holes. For instance, using rw=write:4k will skip 4k for every write. Also see the rw_sequencer option.

**rw_sequencer**=str

If an offset modifier is given by appending a number to the rw=<str> line, then this option controls how that number modifies the I/O offset being generated. Accepted values are:

- **sequential**  Generate sequential offset.
- **identical**  Generate the same offset.

**sequential** is only useful for random I/O, where fio would normally generate a new random offset for every I/O. If you append e.g. 8 to randread, you would get a new random offset for every 8 I/Os. The result would be a seek for only every 8 I/Os, instead of for every I/O. Use rw=randread:8 to specify that. As sequential I/O is already sequential, setting **sequential** for that would not result in any differences. **identical** behaves in a similar fashion, except it sends the same offset 8 number of times before generating a new offset.

**unified_rw_reporting**=str

Fio normally reports statistics on a per data direction basis, meaning that reads, writes, and trims are accounted and reported separately. This option determines whether fio reports the results normally, summed together, or as both options. Accepted values are:

- **none**  Normal statistics reporting.
- **mixed**  Statistics are summed per data direction and reported together.
- **both**  Statistics are reported normally, followed by the mixed statistics.
- 0  Backward-compatible alias for **none**.
- 1  Backward-compatible alias for **mixed**.
- 2  Alias for **both**.

**randrepeat**=bool

Seed the random number generator used for random I/O patterns in a predictable way so the pattern is repeatable across runs. Default: true.

**allrandrepeat**=bool

Seed all random number generators in a predictable way so results are repeatable across runs. Default: false.

**randseed**=int

Seed the random number generators based on this seed value, to be able to control what sequence of output is being generated. If not set, the random sequence depends on the **randrepeat** setting.
fallocate=str
Whether pre-allocation is performed when laying down files. Accepted values are:

- **none** Do not pre-allocate space.
- **native** Use a platform’s native pre-allocation call but fall back to **none** behavior if it fails/is not implemented.
- **posix** Pre-allocate via `posix_fallocate(3)`.
- **keep** Pre-allocate via `fallocate(2)` with `FALLOC_FL_KEEP_SIZE` set.
- **truncate** Extend file to final size via `ftruncate(2)` instead of allocating.

0  Backward-compatible alias for **none**.
1  Backward-compatible alias for **posix**.

May not be available on all supported platforms. **keep** is only available on Linux. If using ZFS on Solaris this cannot be set to **posix** because ZFS doesn’t support pre-allocation. Default: **native** if any pre-allocation methods except **truncate** are available, **none** if not.

Note that using **truncate** on Windows will interact surprisingly with non-sequential write patterns. When writing to a file that has been extended by setting the end-of-file information, Windows will backfill the unwritten portion of the file up to that offset with zeroes before issuing the new write. This means that a single small write to the end of an extended file will stall until the entire file has been filled with zeroes.

fadvise_hint=str
Use `posix_fadvise(2)` or `posix_fadvise(2)` to advise the kernel on what I/O patterns are likely to be issued. Accepted values are:

0  Backwards-compatible hint for “no hint”.
1  Backwards compatible hint for “advise with fio workload type”. This uses `FADV_RANDOM` for a random workload, and `FADV_SEQUENTIAL` for a sequential workload.

**sequential** Advise using `FADV_SEQUENTIAL`.

**random** Advise using `FADV_RANDOM`.

write_hint=str
Use `fcntl(2)` to advise the kernel what life time to expect from a write. Only supported on Linux, as of version 4.13. Accepted values are:

- **none** No particular life time associated with this file.
- **short** Data written to this file has a short life time.
- **medium** Data written to this file has a medium life time.
- **long** Data written to this file has a long life time.
- **extreme** Data written to this file has a very long life time.

The values are all relative to each other, and no absolute meaning should be associated with them.

offset=int
Start I/O at the provided offset in the file, given as either a fixed size in bytes, zones or a percentage. If a percentage is given, the generated offset will be aligned to the minimum `blocksize` or to the value of `offset_align` if provided. Data before the given offset will not be touched. This effectively caps the file size at `real_size - offset`. Can be combined with `size` to constrain the start and end range of the I/O workload. A percentage can be specified by a number between 1 and 100 followed by ‘%’, for example, `offset=20%` to specify 20%. In ZBD mode, value can be set as number of zones using ‘z’.
offset_align=int
If set to non-zero value, the byte offset generated by a percentage offset is aligned upwards to this value. Defaults to 0 meaning that a percentage offset is aligned to the minimum block size.

offset_increment=int
If this is provided, then the real offset becomes offset + offset_increment * thread_number, where the thread number is a counter that starts at 0 and is incremented for each sub-job (i.e. when numjobs option is specified). This option is useful if there are several jobs which are intended to operate on a file in parallel disjoint segments, with even spacing between the starting points. Percentages can be used for this option. If a percentage is given, the generated offset will be aligned to the minimum blocksize or to the value of offset_align if provided. In ZBD mode, value can also be set as number of zones using ‘z’.

number_ios=int
Fio will normally perform I/Os until it has exhausted the size of the region set by size, or if it exhaust the allocated time (or hits an error condition). With this setting, the range/size can be set independently of the number of I/Os to perform. When fio reaches this number, it will exit normally and report status. Note that this does not extend the amount of I/O that will be done, it will only stop fio if this condition is met before other end-of-job criteria.

fsync=int
If writing to a file, issue an fsync(2) (or its equivalent) of the dirty data for every number of blocks given. For example, if you give 32 as a parameter, fio will sync the file after every 32 writes issued. If fio is using non-buffered I/O, we may not sync the file. The exception is the sg I/O engine, which synchronizes the disk cache anyway. Defaults to 0, which means fio does not periodically issue and wait for a sync to complete. Also see end_fsync and fsync_on_close.

fdatasync=int
Like fsync but uses fdatasync(2) to only sync data and not metadata blocks. In Windows, FreeBSD, DragonFlyBSD or OSX there is no fdatasync(2) so this falls back to using fsync(2). Defaults to 0, which means fio does not periodically issue and wait for a data-only sync to complete.

write_barrier=int
Make every N-th write a barrier write.

sync_file_range=str:int
Use sync_file_range(2) for every int number of write operations. Fio will track range of writes that have happened since the last sync_file_range(2) call. str can currently be one or more of:

- wait_before SYNC_FILE_RANGE_WAIT_BEFORE
- write SYNC_FILE_RANGE_WRITE
- wait_after SYNC_FILE_RANGE_WAIT_AFTER

So if you do sync_file_range=wait_before,write:8. fio would use SYNC_FILE_RANGE_WAIT_BEFORE | SYNC_FILE_RANGE_WRITE for every 8 writes. Also see the sync_file_range(2) man page. This option is Linux specific.

overwrite=bool
If true, writes to a file will always overwrite existing data. If the file doesn’t already exist, it will be created before the write phase begins. If the file exists and is large enough for the specified write phase, nothing will be done. Default: false.

end_fsync=bool
If true, fsync(2) file contents when a write stage has completed. Default: false.

fsync_on_close=bool
If true, fio will fsync(2) a dirty file on close. This differs from end_fsync in that it will happen on every file close, not just at the end of the job. Default: false.
rwmixread=int
Percentage of a mixed workload that should be reads. Default: 50.

rwmixwrite=int
Percentage of a mixed workload that should be writes. If both rwmixread and rwmixwrite is given and the values do not add up to 100%, the latter of the two will be used to override the first. This may interfere with a given rate setting, if fio is asked to limit reads or writes to a certain rate. If that is the case, then the distribution may be skewed. Default: 50.

random_distribution=str:float[:float][,str:float][,str:float]
By default, fio will use a completely uniform random distribution when asked to perform random I/O. Sometimes it is useful to skew the distribution in specific ways, ensuring that some parts of the data is more hot than others. fio includes the following distribution models:

- **random** Uniform random distribution
- **zipf** Zipf distribution
- **pareto** Pareto distribution
- **normal** Normal (Gaussian) distribution
- **zoned** Zoned random distribution
- **zoned_abs** Zone absolute random distribution

When using a zipf or pareto distribution, an input value is also needed to define the access pattern. For zipf, this is the Zipf theta. For pareto, it's the Pareto power. Fio includes a test program, fio-genzipf, that can be used visualize what the given input values will yield in terms of hit rates. If you wanted to use zipf with a theta of 1.2, you would use random_distribution=zipf:1.2 as the option. If a non-uniform model is used, fio will disable use of the random map. For the normal distribution, a normal (Gaussian) deviation is supplied as a value between 0 and 100.

The second, optional float is allowed for pareto, zipf and normal distributions. It allows to set base of distribution in non-default place, giving more control over most probable outcome. This value is in range [0-1] which maps linearly to range of possible random values. Defaults are: random for pareto and zipf, and 0.5 for normal. If you wanted to use zipf with a theta of 1.2 centered on 1/4 of allowed value range, you would use random_distribution=zipf:1.2:0.25.

For a zoned distribution, fio supports specifying percentages of I/O access that should fall within what range of the file or device. For example, given a criteria of:

- 60% of accesses should be to the first 10%
- 30% of accesses should be to the next 20%
- 8% of accesses should be to the next 30%
- 2% of accesses should be to the next 40%

we can define that through zoning of the random accesses. For the above example, the user would do:

```
random_distribution=zoned:60/10:30/20:8/30:2/40
```

A zoned_abs distribution works exactly like the zoned, except that it takes absolute sizes. For example, let's say you wanted to define access according to the following criteria:

- 60% of accesses should be to the first 20G
- 30% of accesses should be to the next 100G
- 10% of accesses should be to the next 500G

we can define an absolute zoning distribution with:
random_distribution=zoned_abs=60/20G:30/100G:10/500g

For both *zoned* and *zoned_abs*, fio supports defining up to 256 separate zones. Similarly to how `bssplit` works for setting ranges and percentages of block sizes, like `bssplit`, it's possible to specify separate zones for reads, writes, and trims. If just one set is given, it'll apply to all of them. This goes for both *zoned* *zoned_abs* distributions.

`percentage_random=int[,int][,int]`

For a random workload, set how big a percentage should be random. This defaults to 100%, in which case the workload is fully random. It can be set from anywhere from 0 to 100. Setting it to 0 would make the workload fully sequential. Any setting in between will result in a random mix of sequential and random I/O, at the given percentages. Comma-separated values may be specified for reads, writes, and trims as described in `blocksize`.

`norandommap`

Normally fio will cover every block of the file when doing random I/O. If this option is given, fio will just get a new random offset without looking at past I/O history. This means that some blocks may not be read or written, and that some blocks may be read/written more than once. If this option is used with `verify` and multiple blocksizes (via `bsrange`), only intact blocks are verified, i.e., partially-overwritten blocks are ignored. With an async I/O engine and an I/O depth > 1, it is possible for the same block to be overwritten, which can cause verification errors. Either do not use norandommap in this case, or also use the `lfsr` random generator.

`softrandommap=bool`

See `norandommap`. If fio runs with the random block map enabled and it fails to allocate the map, if this option is set it will continue without a random block map. As coverage will not be as complete as with random maps, this option is disabled by default.

`random_generator=str`

Fio supports the following engines for generating I/O offsets for random I/O:

- `tausworthe` Strong 2^88 cycle random number generator.
- `lfsr` Linear feedback shift register generator.
- `tausworthe64` Strong 64-bit 2^258 cycle random number generator.

`tausworthe` is a strong random number generator, but it requires tracking on the side if we want to ensure that blocks are only read or written once. `lfsr` guarantees that we never generate the same offset twice, and it's also less computationally expensive. It's not a true random generator, however, though for I/O purposes it's typically good enough. `lfsr` only works with single block sizes, not with workloads that use multiple block sizes. If used with such a workload, fio may read or write some blocks multiple times. The default value is `tausworthe`, unless the required space exceeds 2^32 blocks. If it does, then `tausworthe64` is selected automatically.

### 1.12.7 Block size

`blocksize=int[,int][,int], bs=int[,int][,int]`

The block size in bytes used for I/O units. Default: 4096. A single value applies to reads, writes, and trims. Comma-separated values may be specified for reads, writes, and trims. A value not terminated in a comma applies to subsequent types.

Examples:

- `bs=256k` means 256k for reads, writes and trims.
- `bs=8k,32k` means 8k for reads, 32k for writes and trims.
- `bs=8k,32k,` means 8k for reads, 32k for writes, and default for trims.
- `bs=,8k` means default for reads, 8k for writes and trims.
**bs=8k**, means default for reads, 8k for writes, and default for trims.

**blocksize_range=irange[,irange][,irange]**, **bsrange=irange[,irange][,irange]**
A range of block sizes in bytes for I/O units. The issued I/O unit will always be a multiple of the minimum size, unless blocksize_unaligned is set.

Comma-separated ranges may be specified for reads, writes, and trims as described in blocksize.

Example: `bsrange=1k-4k,2k-8k`.

**bssplit=str[,str][,str]**
Sometimes you want even finer grained control of the block sizes issued, not just an even split between them. This option allows you to weight various block sizes, so that you are able to define a specific amount of block sizes issued. The format for this option is:

```
bssplit=blocksize/percentage:blocksize/percentage
```

for as many block sizes as needed. So if you want to define a workload that has 50% 64k blocks, 10% 4k blocks, and 40% 32k blocks, you would write:

```
bssplit=4k/10:64k/50:32k/40
```

Ordering does not matter. If the percentage is left blank, fio will fill in the remaining values evenly. So a bssplit option like this one:

```
bssplit=4k/50:1k/:32k/
```

would have 50% 4k ios, and 25% 1k and 32k ios. The percentages always add up to 100, if bssplit is given a range that adds up to more, it will error out.

Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

If you want a workload that has 50% 2k reads and 50% 4k reads, while having 90% 4k writes and 10% 8k writes, you would specify:

```
bssplit=2k/50:4k/50,4k/90:8k/10
```

Fio supports defining up to 64 different weights for each data direction.

**blocksize_unaligned, bs_unaligned**
If set, fio will issue I/O units with any size within blocksize_range, not just multiples of the minimum size. This typically won’t work with direct I/O, as that normally requires sector alignment.

**bs_is_seq_rand=bool**
If this option is set, fio will use the normal read,write blocksize settings as sequential,random blocksize settings instead. Any random read or write will use the WRITE blocksize settings, and any sequential read or write will use the READ blocksize settings.

**blockalign=int[,int][,int]**, **ba=int[,int][,int]**
Boundary to which fio will align random I/O units. Default: blocksize. Minimum alignment is typically 512b for using direct I/O, though it usually depends on the hardware block size. This option is mutually exclusive with using a random map for files, so it will turn off that option. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

### 1.12.8 Buffers and memory

**zero_buffers**
Initialize buffers with all zeros. Default: fill buffers with random data.
refill_buffers
If this option is given, fio will refill the I/O buffers on every submit. Only makes sense if zero_buffers isn’t specified, naturally. Defaults to being unset i.e., the buffer is only filled at init time and the data in it is reused when possible but if any of verify, buffer_compress_percentage or dedupe_percentage are enabled then refill_buffers is also automatically enabled.

scramble_buffers=bool
If refill_buffers is too costly and the target is using data deduplication, then setting this option will slightly modify the I/O buffer contents to defeat normal de-dupe attempts. This is not enough to defeat more clever block compression attempts, but it will stop naive dedupe of blocks. Default: true.

buffer_compress_percentage=int
If this is set, then fio will attempt to provide I/O buffer content (on WRITEs) that compresses to the specified level. Fio does this by providing a mix of random data followed by fixed pattern data. The fixed pattern is either zeros, or the pattern specified by buffer_pattern. If the buffer_pattern option is used, it might skew the compression ratio slightly. Setting buffer_compress_percentage to a value other than 100 will also enable refill_buffers in order to reduce the likelihood that adjacent blocks are so similar that they over compress when seen together. See buffer_compress_chunk for how to set a finer or coarser granularity for the random/ixed data region. Defaults to unset i.e., buffer data will not adhere to any compression level.

buffer_compress_chunk=int
This setting allows fio to manage how big the random/ixed data region is when using buffer_compress_percentage. When buffer_compress_chunk is set to some non-zero value smaller than the block size, fio can repeat the random/ixed region throughout the I/O buffer at the specified interval (which particularly useful when bigger block sizes are used for a job). When set to 0, fio will use a chunk size that matches the block size resulting in a single random/ixed region within the I/O buffer. Defaults to 512. When the unit is omitted, the value is interpreted in bytes.

buffer_pattern=str
If set, fio will fill the I/O buffers with this pattern or with the contents of a file. If not set, the contents of I/O buffers are defined by the other options related to buffer contents. The setting can be any pattern of bytes, and can be prefixed with 0x for hex values. It may also be a string, where the string must then be wrapped with "". Or it may also be a filename, where the filename must be wrapped with '" in which case the file is opened and read. Note that not all the file contents will be read if that would cause the buffers to overflow. So, for example:

```
buffer_pattern='filename'
```

or:

```
buffer_pattern="abcd"
```

or:

```
buffer_pattern=-12
```

or:

```
buffer_pattern=0xdeadface
```

Also you can combine everything together in any order:

```
buffer_pattern=0xdeadface"abcd"-12'filename'
```

dedupe_percentage=int
If set, fio will generate this percentage of identical buffers when writing. These buffers will be naturally dedupeable. The contents of the buffers depend on what other buffer compression settings have been set. It’s possible to have the individual buffers either fully compressible, or not at all – this option only controls the distribution of unique buffers. Setting this option will also enable refill_buffers to prevent every buffer being identical.
dedupe_mode = str
If dedupe_percentage=<int> is given, then this option controls how fio generates the dedupe buffers.

    repeat Generate dedupe buffers by repeating previous writes
    working_set Generate dedupe buffers from working set

repeat is the default option for fio. Dedupe buffers are generated by repeating previous unique write.

working_set is a more realistic workload. With working_set, dedupe_working_set_percentage=<int> should be provided. Given that, fio will use the initial unique write buffers as its working set. Upon deciding to dedupe, fio will randomly choose a buffer from the working set. Note that by using working_set the dedupe percentage will converge to the desired over time while repeat maintains the desired percentage throughout the job.

dedupe_working_set_percentage = int
If dedupe_mode=<str> is set to working_set, then this controls the percentage of size of the file or device used as the buffers fio will choose to generate the dedupe buffers from

Note that size needs to be explicitly provided and only 1 file per job is supported

invalidate = bool
Invalidate the buffer/page cache parts of the files to be used prior to starting I/O if the platform and file type support it. Defaults to true. This will be ignored if pre_read is also specified for the same job.

sync = str
Whether, and what type, of synchronous I/O to use for writes. The allowed values are:

    none    Do not use synchronous IO, the default.
    0       Same as none.
    sync    Use synchronous file IO. For the majority of I/O engines, this means using O_SYNC.
    1       Same as sync.
    dsync   Use synchronous data IO. For the majority of I/O engines, this means using O_DSYNC.

iomem = str, mem = str
Fio can use various types of memory as the I/O unit buffer. The allowed values are:

    malloc   Use memory from malloc(3) as the buffers. Default memory type.
    shm      Use shared memory as the buffers. Allocated through shmget(2).
    shmhuge  Same as shm, but use huge pages as backing.
    mmap     Use mmap(2) to allocate buffers. May either be anonymous memory, or can be file backed if a filename is given after the option. The format is mem=mmap:/path/to/file.
    mmaphuge Use a memory mapped huge file as the buffer backing. Append filename after mmaphuge, ala mem=mmaphuge:/hugetlbfs/file.
    mmapshared Same as mmap, but use a MMAP_SHARED mapping.
    cudamalloc Use GPU memory as the buffers for GPUDirect RDMA benchmark. The ioengine must be rdma.

The area allocated is a function of the maximum allowed bs size for the job, multiplied by the I/O depth given. Note that for shmhuge and mmaphuge to work, the system must have free huge pages allocated. This can normally be checked and set by reading/writing /proc/sys/vm/nr_hugepages on a Linux system. Fio assumes a huge page is 4MiB in size. So to calculate the number of huge pages you need for a given job file, add up the I/O depth of all jobs (normally one unless iodepth is used) and multiply by the maximum bs set. Then divide that number by the huge page size. You can see the size of the huge pages in /proc/meminfo.
If no huge pages are allocated by having a non-zero number in `nr_hugepages`, using `mmaphuge` or `shmhuge` will fail. Also see `hugepage-size`.

`mmaphuge` also needs to have hugetlbfs mounted and the file location should point there. So if it's mounted in `/huge`, you would use `mem=mmaphuge:/huge/somefile`.

`iomem_align=int, mem_align=int`
This indicates the memory alignment of the I/O memory buffers. Note that the given alignment is applied to the first I/O unit buffer, if using `iodepth` the alignment of the following buffers are given by the `bs` used. In other words, if using a `bs` that is a multiple of the page sized in the system, all buffers will be aligned to this value. If using a `bs` that is not page aligned, the alignment of subsequent I/O memory buffers is the sum of the `iomem_align` and `bs` used.

`hugepage-size=int`
Defines the size of a huge page. Must at least be equal to the system setting, see `/proc/meminfo`. Defaults to 4MiB. Should probably always be a multiple of megabytes, so using `hugepage-size=Xm` is the preferred way to set this to avoid setting a non-pow-2 bad value.

`lockmem=int`
Pin the specified amount of memory with `mlock(2)`. Can be used to simulate a smaller amount of memory. The amount specified is per worker.

1.12.9 I/O size

`size=int`
The total size of file I/O for each thread of this job. Fio will run until this many bytes has been transferred, unless runtime is limited by other options (such as `runtime`, for instance, or increased/decreased by `io_size`). Fio will divide this size between the available files determined by options such as `nfiles`, `filename`, unless `filesize` is specified by the job. If the result of division happens to be 0, the size is set to the physical size of the given files or devices if they exist. If this option is not specified, fio will use the full size of the given files or devices. If the files do not exist, size must be given. It is also possible to give size as a percentage between 1 and 100. If `size=20%` is given, fio will use 20% of the full size of the given files or devices. In ZBD mode, value can also be set as number of zones using ‘z’. Can be combined with `offset` to constrain the start and end range that I/O will be done within.

`io_size=int, io_limit=int`
Normally fio operates within the region set by `size`, which means that the `size` option sets both the region and size of I/O to be performed. Sometimes that is not what you want. With this option, it is possible to define just the amount of I/O that fio should do. For instance, if `size` is set to 20GiB and `io_size` is set to 5GiB, fio will perform I/O within the first 20GiB but exit when 5GiB have been done. The opposite is also possible – if `size` is set to 20GiB, and `io_size` is set to 40GiB, then fio will do 40GiB of I/O within the 0..20GiB region.

`filesize=irange(int)`
Individual file sizes. May be a range, in which case fio will select sizes for files at random within the given range and limited to `size` in total (if that is given). If not given, each created file is the same size. This option overrides `size` in terms of file size, which means this value is used as a fixed size or possible range of each file.

`file_append=bool`
Perform I/O after the end of the file. Normally fio will operate within the size of a file. If this option is set, then fio will append to the file instead. This has identical behavior to setting `offset` to the size of a file. This option is ignored on non-regular files.

`fill_device=bool, fill_fs=bool`
Sets size to something really large and waits for ENOSPC (no space left on device) or EDQUOT (disk quota exceeded) as the terminating condition. Only makes sense with sequential write. For a read workload, the mount point will be filled first then I/O started on the result. This option doesn’t make sense if operating on a raw device.
node, since the size of that is already known by the file system. Additionally, writing beyond end-of-device will not return ENOSPC there.

1.12.10 I/O engine

ioengine=str

Defines how the job issues I/O to the file. The following types are defined:

- **sync**: Basic read(2) or write(2) I/O. lseek(2) is used to position the I/O location. See fsync and fdatasync for syncing write I/Os.
- **psync**: Basic pread(2) or pwrite(2) I/O. Default on all supported operating systems except for Windows.
- **vsync**: Basic readv(2) or writev(2) I/O. Will emulate queuing by coalescing adjacent I/Os into a single submission.
- **pvsync**: Basic preadv(2) or pwritev(2) I/O.
- **pvsync2**: Basic preadv2(2) or pwritev2(2) I/O.
- **io_uring**: Fast Linux native asynchronous I/O. Supports async IO for both direct and buffered IO. This engine defines engine specific options.
- **libaio**: Linux native asynchronous I/O. Note that Linux may only support queued behavior with non-buffered I/O (set direct=1 or buffered=0). This engine defines engine specific options.
- **posixaio**: POSIX asynchronous I/O using aio_read(3) and aio_write(3).
- **solarisaio**: Solaris native asynchronous I/O.
- **windowsaio**: Windows native asynchronous I/O. Default on Windows.
- **mmap**: File is memory mapped with mmap(2) and data copied to/from using memcpy(3).
- **splice**: splice(2) is used to transfer the data and vmsplice(2) to transfer data from user space to the kernel.
- **sg**: SCSI generic sg v3 I/O. May either be synchronous using the SG_IO ioctl, or if the target is an sg character device we use read(2) and write(2) for asynchronous I/O. Requires filename option to specify either block or character devices. This engine supports trim operations. The sg engine includes engine specific options.
- **null**: Doesn’t transfer any data, just pretends to. This is mainly used to exercise fio itself and for debugging/testing purposes.
- **net**: Transfer over the network to given host:port. Depending on the protocol used, the hostname, port, listen and filename options are used to specify what sort of connection to make, while the protocol option determines which protocol will be used. This engine defines engine specific options.
- **netsplice**: Like net, but uses splice(2) and vmsplice(2) to map data and send/receive. This engine defines engine specific options.
- **cpuio**: Doesn’t transfer any data, but burns CPU cycles according to the cpuload, cpuchunks and cpumode options. Setting cpuload=85 will cause that job to do nothing but burn 85% of the CPU. In case of SMP machines, use numjobs=<nr_of_cpu> to get desired CPU usage, as the cpuload only loads a single CPU at the desired rate. A job never finishes unless there is at least one non-cpuio job. Setting cpumode=qsort replace the default noop instructions loop by a qsort algorithm to consume more energy.
rdma The RDMA I/O engine supports both RDMA memory semantics (RDMA_WRITE/RDMA_READ) and channel semantics (Send/Recv) for the InfiniBand, RoCE and iWARP protocols. This engine defines engine specific options.

falloc I/O engine that does regular fallocate to simulate data transfer as fio ioengine.

    DDIR_READ does fallocate,(mode = FALLOC_FL_KEEP_SIZE,).
    DDIR_WRITE does fallocate,(mode = 0).
    DDIR_TRIM does fallocate,(mode = FALLOC_FL_KEEP_SIZE|FALLOC_FL_PUNCH_HOLE).

ftruncate I/O engine that sends ftruncate(2) operations in response to write (DDIR_WRITE) events. Each ftruncate issued sets the file’s size to the current block offset. blocksize is ignored.

e4defrag I/O engine that does regular EXT4_IOC_MOVE_EXT ioctls to simulate defragment activity in request to DDIR_WRITE event.

rados I/O engine supporting direct access to Ceph Reliable Autonomic Distributed Object Store (RADOS) via librados. This ioengine defines engine specific options.

rbd I/O engine supporting direct access to Ceph Rados Block Devices (RBD) via librbd without the need to use the kernel rbd driver. This ioengine defines engine specific options.

http I/O engine supporting GET/PUT requests over HTTP(S) with libcurl to a WebDAV or S3 endpoint. This ioengine defines engine specific options.

This engine only supports direct IO of iodepth=1; you need to scale this via numjobs. blocksize defines the size of the objects to be created.

TRIM is translated to object deletion.

gfapi Using GlusterFS libgfapi sync interface to direct access to GlusterFS volumes without having to go through FUSE. This ioengine defines engine specific options.

gfapi_async Using GlusterFS libgfapi async interface to direct access to GlusterFS volumes without having to go through FUSE. This ioengine defines engine specific options.

libhdfs Read and write through Hadoop (HDFS). The filename option is used to specify host.port of the hdfs name-node to connect. This engine interprets offsets a little differently. In HDFS, files once created cannot be modified so random writes are not possible. To imitate this the libhdfs engine expects a bunch of small files to be created over HDFS and will randomly pick a file from them based on the offset generated by fio backend (see the example job file to create such files, use rw=write option). Please note, it may be necessary to set environment variables to work with HDFS/libhdfs properly. Each job uses its own connection to HDFS.

mtd Read, write and erase an MTD character device (e.g., /dev/mtd0). Discards are treated as erases. Depending on the underlying device type, the I/O may have to go in a certain pattern, e.g., on NAND, writing sequentially to erase blocks and discarding before overwriting. The trimwrite mode works well for this constraint.

pmemblk Read and write using filesystem DAX to a file on a filesystem mounted with DAX on a persistent memory device through the PMDK libpmemblk library.

dev-dax Read and write using device DAX to a persistent memory device (e.g., /dev/dax0.0) through the PMDK libpmem library.

external Prefix to specify loading an external I/O engine object file. Append the engine filename, e.g. ioengine=external:/tmp/foo.o to load ioengine foo.o in /tmp. The path can be either absolute or relative. See engines/skeleton_external.c for details of writing an external I/O engine.
filecreate  Simply create the files and do no I/O to them. You still need to set `filesize` so that all the accounting still occurs, but no actual I/O will be done other than creating the file.

filestat  Simply do stat() and do no I/O to the file. You need to set ‘filesize’ and ‘nrfiles’, so that files will be created. This engine is to measure file lookup and meta data access.

filedelete  Simply delete the files by unlink() and do no I/O to them. You need to set ‘filesize’ and ‘nrfiles’, so that the files will be created. This engine is to measure file delete.

libpmem  Read and write using mmap I/O to a file on a filesystem mounted with DAX on a persistent memory device through the PMDK libpmem library.

ime_psync  Synchronous read and write using DDN’s Infinite Memory Engine (IME). This engine is very basic and issues calls to IME whenever an IO is queued.

ime_psyncv  Synchronous read and write using DDN’s Infinite Memory Engine (IME). This engine uses iovecs and will try to stack as much IOs as possible (if the IOs are “contiguous” and the IO depth is not exceeded) before issuing a call to IME.

ime_aio  Asynchronous read and write using DDN’s Infinite Memory Engine (IME). This engine will try to stack as much IOs as possible by creating requests for IME. FIO will then decide when to commit these requests.

libiscsi  Read and write iscsi lun with libriscsi.

nbd  Read and write a Network Block Device (NBD).

libcufile  I/O engine supporting libcufile synchronous access to nvidia-fs and a GPUDirect Storage-supported filesystem. This engine performs I/O without transferring buffers between user-space and the kernel, unless `verify` is set or `cuda_io` is `posix`. `iomem` must not be `cudamalloc`. This ioengine defines engine specific options.

dfs  I/O engine supporting asynchronous read and write operations to the DAOS File System (DFS) via libdfs.

nfs  I/O engine supporting asynchronous read and write operations to NFS filesystems from userspace via libnfs. This is useful for achieving higher concurrency and thus throughput than is possible via kernel NFS.

exec  Execute 3rd party tools. Could be used to perform monitoring during jobs runtime.

1.12.11 I/O engine specific parameters

In addition, there are some parameters which are only valid when a specific `ioengine` is in use. These are used identically to normal parameters, with the caveat that when used on the command line, they must come after the `ioengine` that defines them is selected.

`cmdprio_percentage=int : [io_uring] [libaio]`
Set the percentage of I/O that will be issued with higher priority by setting the priority bit. Non-read I/O is likely unaffected by `cmdprio_percentage`. This option cannot be used with the `prio` or `prioclass` options. For this option to set the priority bit properly, NCQ priority must be supported and enabled and `direct=1` option must be used. fio must also be run as the root user.

`fixedbufs : [io_uring]`
If fio is asked to do direct IO, then Linux will map pages for each IO call, and release them when IO is done. If this option is set, the pages are pre-mapped before IO is started. This eliminates the need to map and release for each IO. This is more efficient, and reduces the IO latency as well.

`hipri : [io_uring]`
If this option is set, fio will attempt to use polled IO completions. Normal IO completions generate interrupts to
signal the completion of IO, polled completions do not. Hence they are require active reaping by the application. The benefits are more efficient IO for high IOPS scenarios, and lower latencies for low queue depth IO.

**registerfiles : [io_uring]**

With this option, fio registers the set of files being used with the kernel. This avoids the overhead of managing file counts in the kernel, making the submission and completion part more lightweight. Required for the below sqthread_poll option.

**sqthread_poll : [io_uring]**

Normally fio will submit IO by issuing a system call to notify the kernel of available items in the SQ ring. If this option is set, the act of submitting IO will be done by a polling thread in the kernel. This frees up cycles for fio, at the cost of using more CPU in the system.

**sqthread_poll_cpu : [io_uring]**

When sqthread_poll is set, this option provides a way to define which CPU should be used for the polling thread.

**userspace_reap : [libaio]**

Normally, with the libaio engine in use, fio will use the `io_getevents(2)` system call to reap newly returned events. With this flag turned on, the AIO ring will be read directly from user-space to reap events. The reaping mode is only enabled when polling for a minimum of 0 events (e.g. when `iodepth_batch_complete = 0`).

**hipri : [pvsync2]**

Set RWF_HIPRI on I/O, indicating to the kernel that it’s of higher priority than normal.

**hipri_percentage : [pvsync2]**

When hipri is set this determines the probability of a pvsync2 I/O being high priority. The default is 100%.

**nowait : [pvsync2] [libaio] [io_uring]**

By default if a request cannot be executed immediately (e.g. resource starvation, waiting on locks) it is queued and the initiating process will be blocked until the required resource becomes free.

This option sets the RWF_NOWAIT flag (supported from the 4.14 Linux kernel) and the call will return instantly with EAGAIN or a partial result rather than waiting.

It is useful to also use ignore_error=EAGAIN when using this option.

Note: glibc 2.27, 2.28 have a bug in syscall wrappers preadv2, pwritev2. They return EOPNOTSUP instead of EAGAIN.

For cached I/O, using this option usually means a request operates only with cached data. Currently the RWF_NOWAIT flag does not supported for cached write.

For direct I/O, requests will only succeed if cache invalidation isn’t required, file blocks are fully allocated and the disk request could be issued immediately.

**cpuload= int : [cpuio]**

Attempt to use the specified percentage of CPU cycles. This is a mandatory option when using cpuio I/O engine.

**cpuchunks= int : [cpuio]**

Split the load into cycles of the given time. In microseconds.

**exit_on_io_done= bool : [cpuio]**

Detect when I/O threads are done, then exit.

**namenode= str : [libhdfs]**

The hostname or IP address of a HDFS cluster namenode to contact.

**port= int**

[libhdfs]

The listening port of the HFDS cluster namenode.
The TCP or UDP port to bind to or connect to. If this is used with `numjobs` to spawn multiple instances of the same job type, then this will be the starting port number since fio will use a range of ports.

The port to use for RDMA-CM communication. This should be the same value on the client and the server side.

The hostname or IP address to use for TCP, UDP or RDMA-CM based I/O. If the job is a TCP listener or UDP reader, the hostname is not used and must be omitted unless it is a valid UDP multicast address.

The IP address to be used for RDMA-CM based I/O.

Set to 1 only when Direct Write to PMem from the remote host is possible. Otherwise, set to 0.

Set to 0 to wait for completion instead of busy-wait polling completion. Default: 1.

The IP address of the network interface used to send or receive UDP multicast.


Set TCP_NODELAY on TCP connections.

The network protocol to use. Accepted values are:
- tcp Transmission control protocol.
- tcpv6 Transmission control protocol V6.
- udp User datagram protocol.
- udpv6 User datagram protocol V6.
- unix UNIX domain socket.

When the protocol is TCP or UDP, the port must also be given, as well as the hostname if the job is a TCP listener or UDP reader. For unix sockets, the normal `filename` option should be used and the port is invalid.

For TCP network connections, tell fio to listen for incoming connections rather than initiating an outgoing connection. The hostname must be omitted if this option is used.

Normally a network writer will just continue writing data, and a network reader will just consume packages. If `pingpong=1` is set, a writer will send its normal payload to the reader, then wait for the reader to send the same payload back. This allows fio to measure network latencies. The submission and completion latencies then measure local time spent sending or receiving, and the completion latency measures how long it took for the other end to receive and send back. For UDP multicast traffic `pingpong=1` should only be set for a single reader when multiple readers are listening to the same address.

Set the desired socket buffer size for the connection.
mss : [netsplice] [net]
  Set the TCP maximum segment size (TCP_MAXSEG).

donorname=str : [e4defrag]
  File will be used as a block donor (swap extents between files).
 inplace=int : [e4defrag]
  Configure donor file blocks allocation strategy:
    0 Default. Preallocate donor's file on init.
    1 Allocate space immediately inside defragment event, and free right after event.

clustername=str : [rbd,rados]
  Specifies the name of the Ceph cluster.

rbdname=str : [rbd]
  Specifies the name of the RBD.

pool=str : [rbd,rados]
  Specifies the name of the Ceph pool containing RBD or RADOS data.

clientname=str : [rbd,rados]
  Specifies the username (without the ‘client.’ prefix) used to access the Ceph cluster. If the clustername
  is specified, the clientname shall be the full type.id string. If no type. prefix is given, fio will add ‘client.’ by
  default.

busy_poll=bool : [rbd,rados]
  Poll store instead of waiting for completion. Usually this provides better throughput at cost of higher(up to
  100%) CPU utilization.

touch_objects=bool : [rados]
  During initialization, touch (create if do not exist) all objects (files). Touching all objects affects ceph caches
  and likely impacts test results. Enabled by default.

skip_bad=bool : [mtd]
  Skip operations against known bad blocks.

hdfsdirectory : [libhdfs]
  libhdfs will create chunk in this HDFS directory.

chunk_size : [libhdfs]
  The size of the chunk to use for each file.

verb=str : [rdma]
  The RDMA verb to use on this side of the RDMA ioengine connection. Valid values are write, read, send and
  recv. These correspond to the equivalent RDMA verbs (e.g. write = rdma_write etc.). Note that this only needs
  to be specified on the client side of the connection. See the examples folder.

bindname=str : [rdma]
  The name to use to bind the local RDMA-CM connection to a local RDMA device. This could be a hostname
  or an IPv4 or IPv6 address. On the server side this will be passed into the rdma_bind_addr() function and on
  the client site it will be used in the rdma_resolve_add() function. This can be useful when multiple paths exist
  between the client and the server or in certain loopback configurations.

stat_type=str : [filestat]
  Specify stat system call type to measure lookup/getattr performance. Default is stat for stat(2).

readfua=bool : [sg]
  With readfua option set to 1, read operations include the force unit access (fua) flag. Default is 0.

writefua=bool : [sg]
  With writefua option set to 1, write operations include the force unit access (fua) flag. Default is 0.
sg_write_mode=str : [sg]
Specify the type of write commands to issue. This option can take three values:

write  This is the default where write opcodes are issued as usual.

verify Issue WRITE AND VERIFY commands. The BYTCHK bit is set to 0. This directs the device to carry out a medium verification with no data comparison. The writefua option is ignored with this selection.

same Issue WRITE SAME commands. This transfers a single block to the device and writes this same block of data to a contiguous sequence of LBAs beginning at the specified offset. fio’s block size parameter specifies the amount of data written with each command. However, the amount of data actually transferred to the device is equal to the device’s block (sector) size. For a device with 512 byte sectors, blocksize=8k will write 16 sectors with each command. fio will still generate 8k of data for each command but only the first 512 bytes will be used and transferred to the device. The writefua option is ignored with this selection.

hipri : [sg]
If this option is set, fio will attempt to use polled IO completions. This will have a similar effect as (io_uring)hipri. Only SCSI READ and WRITE commands will have the SGV4_FLAG_HIPRI set (not UNMAP (trim) nor VERIFY). Older versions of the Linux sg driver that do not support hipri will simply ignore this flag and do normal IO. The Linux SCSI Low Level Driver (LLD) that “owns” the device also needs to support hipri (also known as iopoll and mq_poll). The MegaRAID driver is an example of a SCSI LLD. Default: clear (0) which does normal (interrupted based) IO.

http_host=str : [http]
Hostname to connect to. For S3, this could be the bucket hostname. Default is localhost

http_user=str : [http]
Username for HTTP authentication.

http_pass=str : [http]
Password for HTTP authentication.

https=str : [http]
Enable HTTPS instead of http. on enables HTTPS; insecure will enable HTTPS, but disable SSL peer verification (use with caution!). Default is off

http_mode=str : [http]
Which HTTP access mode to use: webdav, swift, or s3. Default is webdav

http_s3_region=str : [http]
The S3 region/zone string. Default is us-east-1

http_s3_key=str : [http]
The S3 secret key.

http_s3_keyid=str : [http]
The S3 key/access id.

http_swift_auth_token=str : [http]
The Swift auth token. See the example configuration file on how to retrieve this.

http_verbose=int : [http]
Enable verbose requests from libcurl. Useful for debugging. 1 turns on verbose logging from libcurl, 2 additionally enables HTTP IO tracing. Default is 0

uri=str : [nbd]
Specify the NBD URI of the server to test. The string is a standard NBD URI (see https://github.com/NetworkBlockDevice/nbd/tree/master/doc). Example URIs: nbd://localhost:10809 nbd+unix:///?socket=/tmp/socket nbds://tlshost/exportname
gpu_dev_ids=str : [libcufile]
Specify the GPU IDs to use with CUDA. This is a colon-separated list of int. GPUs are assigned to workers roundrobin. Default is 0.

cuda_io=str : [libcufile]
Specify the type of I/O to use with CUDA. Default is cufile.

cufile Use libcufile and nvidia-fs. This option performs I/O directly between a GPUDirect Storage filesystem and GPU buffers, avoiding use of a bounce buffer. If verify is set, cudaMemcpy is used to copy verification data between RAM and GPU. Verification data is copied from RAM to GPU before a write and from GPU to RAM after a read. direct must be 1.

posix Use POSIX to perform I/O with a RAM buffer, and use cudaMemcpy to transfer data between RAM and the GPUs. Data is copied from GPU to RAM before a write and copied from RAM to GPU after a read. verify does not affect use of cudaMemcpy.

pool=str : [dfs]
Specify the UUID of the DAOS pool to connect to.

cont=str : [dfs]
Specify the UUID of the DAOS container to open.

chunk_size=int : [dfs]
Specify a different chunk size (in bytes) for the dfs file. Use DAOS container’s chunk size by default.

object_class=str : [dfs]
Specify a different object class for the dfs file. Use DAOS container’s object class by default.

nfs_url=str : [nfs]
URL in libnfs format, eg nfs://<server|ipv4|ipv6>/path[?arg=val[&arg=val]*] Refer to the libnfs README for more details.

program=str : [exec]
Specify the program to execute.

arguments=str : [exec]
Specify arguments to pass to program. Some special variables can be expanded to pass fio’s job details to the program.

%r Replaced by the duration of the job in seconds.

%n Replaced by the name of the job.

grace_time=int : [exec]
Specify the time between the SIGTERM and SIGKILL signals. Default is 1 second.

std_redirect=boot : [exec]
If set, stdout and stderr streams are redirected to files named from the job name. Default is true.

1.12.12 I/O depth

iodepth=int
Number of I/O units to keep in flight against the file. Note that increasing iodepth beyond 1 will not affect synchronous ioengines (except for small degrees when verify_async is in use). Even async engines may impose OS restrictions causing the desired depth not to be achieved. This may happen on Linux when using libaio and not setting direct=1, since buffered I/O is not async on that OS. Keep an eye on the I/O depth distribution in the fio output to verify that the achieved depth is as expected. Default: 1.

iodepth_batch_submit=int, iodepth_batch=int
This defines how many pieces of I/O to submit at once. It defaults to 1 which means that we submit each I/O as
soon as it is available, but can be raised to submit bigger batches of I/O at the time. If it is set to 0 the iodepth value will be used.

**iodepth_batch_complete_min**=int, **iodepth_batch_complete**=int
This defines how many pieces of I/O to retrieve at once. It defaults to 1 which means that we’ll ask for a minimum of 1 I/O in the retrieval process from the kernel. The I/O retrieval will go on until we hit the limit set by iodepth_low. If this variable is set to 0, then fio will always check for completed events before queuing more I/O. This helps reduce I/O latency, at the cost of more retrieval system calls.

**iodepth_batch_complete_max**=int
This defines maximum pieces of I/O to retrieve at once. This variable should be used along with iodepth_batch_complete_min=int variable, specifying the range of min and max amount of I/O which should be retrieved. By default it is equal to the iodepth_batch_complete_min value.

Example #1:

```plaintext
iodepth_batch_complete_min=1
iodepth_batch_complete_max=<iodepth>
```

which means that we will retrieve at least 1 I/O and up to the whole submitted queue depth. If none of I/O has been completed yet, we will wait.

Example #2:

```plaintext
iodepth_batch_complete_min=0
iodepth_batch_complete_max=<iodepth>
```

which means that we can retrieve up to the whole submitted queue depth, but if none of I/O has been completed yet, we will NOT wait and immediately exit the system call. In this example we simply do polling.

**iodepth_low**=int
The low water mark indicating when to start filling the queue again. Defaults to the same as iodepth, meaning that fio will attempt to keep the queue full at all times. If iodepth is set to e.g. 16 and iodepth_low is set to 4, then after fio has filled the queue of 16 requests, it will let the depth drain down to 4 before starting to fill it again.

**serialize_overlap**=bool
Serialize in-flight I/Os that might otherwise cause or suffer from data races. When two or more I/Os are submitted simultaneously, there is no guarantee that the I/Os will be processed or completed in the submitted order. Further, if two or more of those I/Os are writes, any overlapping region between them can become indeterminate/undefined on certain storage. These issues can cause verification to fail erratically when at least one of the racing I/Os is changing data and the overlapping region has a non-zero size. Setting serialize_overlap tells fio to avoid provoking this behavior by explicitly serializing in-flight I/Os that have a non-zero overlap. Note that setting this option can reduce both performance and the iodepth achieved.

This option only applies to I/Os issued for a single job except when it is enabled along with io_submit_mode=offload. In offload mode, fio will check for overlap among all I/Os submitted by offload jobs with serialize_overlap enabled.

Default: false.

**io_submit_mode**=str
This option controls how fio submits the I/O to the I/O engine. The default is **inline**, which means that the fio job threads submit and reap I/O directly. If set to **offload**, the job threads will offload I/O submission to a dedicated pool of I/O threads. This requires some coordination and thus has a bit of extra overhead, especially for lower queue depth I/O where it can increase latencies. The benefit is that fio can manage submission rates independently of the device completion rates. This avoids skewed latency reporting if I/O gets backed up on the device side (the coordinated omission problem). Note that this option cannot reliably be used with async I/O engines.
1.12.13 I/O rate

**thinktime**=time
Stall the job for the specified period of time after an I/O has completed before issuing the next. May be used to simulate processing being done by an application. When the unit is omitted, the value is interpreted in microsseconds. See thinktime_blocks and thinktime_spin.

**thinktime_spin**=time
Only valid if thinktime is set - pretend to spend CPU time doing something with the data received, before falling back to sleeping for the rest of the period specified by thinktime. When the unit is omitted, the value is interpreted in microsseconds.

**thinktime_blocks**=int
Only valid if thinktime is set - control how many blocks to issue, before waiting thinktime usecs after every block. This effectively makes any queue depth setting redundant, since no more than 1 I/O will be queued before we have to complete it and do our thinktime. In other words, this setting effectively caps the queue depth if the latter is larger.

**thinktime_blocks_type**=str
Only valid if thinktime is set - control how thinktime_blocks triggers. The default is complete, which triggers thinktime when fio completes thinktime_blocks blocks. If this is set to issue, then the trigger happens at the issue side.

**rate**=int[,int][,int]
Cap the bandwidth used by this job. The number is in bytes/sec, the normal suffix rules apply. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

For example, using rate=1m,500k would limit reads to 1MiB/sec and writes to 500KiB/sec. Capping only reads or writes can be done with rate=.500k or rate=500k, where the former will only limit writes (to 500KiB/sec) and the latter will only limit reads.

**rate_min**=int[,int][,int]
Tell fio to do whatever it can to maintain at least this bandwidth. Failing to meet this requirement will cause the job to exit. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

**rate_iops**=int[,int][,int]
Cap the bandwidth to this number of IOPS. Basically the same as rate, just specified independently of bandwidth. If the job is given a block size range instead of a fixed value, the smallest block size is used as the metric. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

**rate_iops_min**=int[,int][,int]
If fio doesn’t meet this rate of I/O, it will cause the job to exit. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

**rate_process**=str
This option controls how fio manages rated I/O submissions. The default is linear, which submits I/O in a linear fashion with fixed delays between I/Os that gets adjusted based on I/O completion rates. If this is set to poisson, fio will submit I/O based on a more real world random request flow, known as the Poisson process (https://en.wikipedia.org/wiki/Poisson_point_process). The lambda will be 10^6 / IOPS for the given workload.

**rate_ignore_thinktime**=bool
By default, fio will attempt to catch up to the specified rate setting, if any kind of thinktime setting was used. If this option is set, then fio will ignore the thinktime and continue doing IO at the specified rate, instead of entering a catch-up mode after thinktime is done.
1.12.14 I/O latency

**latency_target=time**
If set, fio will attempt to find the max performance point that the given workload will run at while maintaining a latency below this target. When the unit is omitted, the value is interpreted in microseconds. See latency_window and latency_percentile.

**latency_window=time**
Used with latency_target to specify the sample window that the job is run at varying queue depths to test the performance. When the unit is omitted, the value is interpreted in microseconds.

**latency_percentile=float**
The percentage of I/Os that must fall within the criteria specified by latency_target and latency_window. If not set, this defaults to 100.0, meaning that all I/Os must be equal or below to the value set by latency_target.

**latency_run=bool**
Used with latency_target. If false (default), fio will find the highest queue depth that meets latency_target and exit. If true, fio will continue running and try to meet latency_target by adjusting queue depth.

**max_latency=time[,time][,time]**
If set, fio will exit the job with an ETIMEDOUT error if it exceeds this maximum latency. When the unit is omitted, the value is interpreted in microseconds. Comma-separated values may be specified for reads, writes, and trims as described in blocksize.

**rate_cycle=int**
Average bandwidth for rate and rate_min over this number of milliseconds. Defaults to 1000.

1.12.15 I/O replay

**write_iolog=str**
Write the issued I/O patterns to the specified file. See read_iolog. Specify a separate file for each job, otherwise the iologs may be interspersed and the file may be corrupt.

**read_iolog=str**
Open an iolog with the specified filename and replay the I/O patterns it contains. This can be used to store a workload and replay it sometime later. The iolog given may also be a blktrace binary file, which allows fio to replay a workload captured by blktrace. See blktrace(8) for how to capture such logging data. For blktrace replay, the file needs to be turned into a blkparse binary data file first (blkparse <device> -o /dev/null -d file_for_fio.bin). You can specify a number of files by separating the names with a ‘:’ character. See the filename option for information on how to escape ‘:’ characters within the file names. These files will be sequentially assigned to job clones created by numjobs. ‘-’ is a reserved name, meaning read from stdin, notably if filename is set to ‘-’ which means stdin as well, then this flag can’t be set to ‘-’.

**read_iolog_chunked=bool**
Determines how iolog is read. If false(default) entire read_iolog will be read at once. If selected true, input from iolog will be read gradually. Useful when iolog is very large, or it is generated.

**merge_blktrace_file=str**
When specified, rather than replaying the logs passed to read_iolog, the logs go through a merge phase which aggregates them into a single blktrace. The resulting file is then passed on as the read_iolog parameter. The intention here is to make the order of events consistent. This limits the influence of the scheduler compared to replaying multiple blktraces via concurrent jobs.

**merge_blktrace_scalars=float_list**
This is a percentage based option that is index paired with the list of files passed to read_iolog.
When merging is performed, scale the time of each event by the corresponding amount. For example, `--merge_blktrace_scalars="50:100"` runs the first trace in halftime and the second trace in real-time. This knob is separately tunable from `replay_time_scale` which scales the trace during runtime and does not change the output of the merge unlike this option.

**merge_blktrace_iters=float_list**

This is a whole number option that is index paired with the list of files passed to `read_iolog`. When merging is performed, run each trace for the specified number of iterations. For example, `--merge_blktrace_iters="2:1"` runs the first trace for two iterations and the second trace for one iteration.

**replay_no_stall=bool**

When replaying I/O with `read_iolog` the default behavior is to attempt to respect the timestamps within the log and replay them with the appropriate delay between IOPS. By setting this variable fio will not respect the timestamps and attempt to replay them as fast as possible while still respecting ordering. The result is the same I/O pattern to a given device, but different timings.

**replay_time_scale=int**

When replaying I/O with `read_iolog`, fio will honor the original timing in the trace. With this option, it’s possible to scale the time. It’s a percentage option, if set to 50 it means run at 50% the original IO rate in the trace. If set to 200, run at twice the original IO rate. Defaults to 100.

**replay_redirect=str**

While replaying I/O patterns using `read_iolog` the default behavior is to replay the IOPS onto the major/minor device that each IOP was recorded from. This is sometimes undesirable because on a different machine those major/minor numbers can map to a different device. Changing hardware on the same system can also result in a different major/minor mapping. `replay_redirect` causes all I/Os to be replayed onto the single specified device regardless of the device it was recorded from. i.e. `replay_redirect=/dev/sdc` would cause all I/O in the blktrace or iolog to be replayed onto `/dev/sdc`. This means multiple devices will be replayed onto a single device, if the trace contains multiple devices. If you want multiple devices to be replayed concurrently to multiple redirected devices you must blkparse your trace into separate traces and replay them with independent fio invocations. Unfortunately this also breaks the strict time ordering between multiple device accesses.

**replay_align=int**

Force alignment of the byte offsets in a trace to this value. The value must be a power of 2.

**replay_scale=int**

Scale byte offsets down by this factor when replaying traces. Should most likely use `replay_align` as well.

**replay_skip=str**

Sometimes it’s useful to skip certain IO types in a replay trace. This could be, for instance, eliminating the writes in the trace. Or not replaying the trims/discards, if you are redirecting to a device that doesn’t support them. This option takes a comma separated list of read, write, trim, sync.

### 1.12.16 Threads, processes and job synchronization

**thread**

Fio defaults to creating jobs by using fork, however if this option is given, fio will create jobs by using POSIX Threads’ function `pthread_create(3)` to create threads instead.

**wait_for=str**

If set, the current job won’t be started until all workers of the specified waitee job are done.

`wait_for` operates on the job name basis, so there are a few limitations. First, the waitee must be defined prior to the waiter job (meaning no forward references). Second, if a job is being referenced as a waitee, it must have a unique name (no duplicate waitees).
nice=int
Run the job with the given nice value. See man nice(2).

On Windows, values less than -15 set the process class to “High”; -1 through -15 set “Above Normal”; 1 through 15 “Below Normal”; and above 15 “Idle” priority class.

prio=int
Set the I/O priority value of this job. Linux limits us to a positive value between 0 and 7, with 0 being the highest. See man ionice(1). Refer to an appropriate manpage for other operating systems since meaning of priority may differ. For per-command priority setting, see I/O engine specific cmdprio_percentage and hipri_percentage options.

prioclass=int
Set the I/O priority class. See man ionice(1). For per-command priority setting, see I/O engine specific cmdprio_percentage and hipri_percentage options.

cpus_allowed=str
Controls the same options as cpumask, but accepts a textual specification of the permitted CPUs instead and CPUs are indexed from 0. So to use CPUs 0 and 5 you would specify cpus_allowed=0,5. This option also allows a range of CPUs to be specified – say you wanted a binding to CPUs 0, 5, and 8 to 15, you would set cpus_allowed=0,5,8-15.

On Windows, when cpus_allowed is unset only CPUs from fio’s current processor group will be used and affinity settings are inherited from the system. An fio build configured to target Windows 7 makes options that set CPUs processor group aware and values will set both the processor group and a CPU from within that group. For example, on a system where processor group 0 has 40 CPUs and processor group 1 has 32 CPUs, cpus_allowed values between 0 and 39 will bind CPUs from processor group 0 and cpus_allowed values between 40 and 71 will bind CPUs from processor group 1. When using cpus_allowed_policy=shared all CPUs specified by a single cpus_allowed option must be from the same processor group. For Windows fio builds not built for Windows 7, CPUs will only be selected from (and be relative to) whatever processor group fio happens to be running in and CPUs from other processor groups cannot be used.

cpus_allowed_policy=str
Set the policy of how fio distributes the CPUs specified by cpus_allowed or cpumask. Two policies are supported:

  shared  All jobs will share the CPU set specified.

  split   Each job will get a unique CPU from the CPU set.

shared is the default behavior, if the option isn’t specified. If split is specified, then fio will assign one cpu per job. If not enough CPUs are given for the jobs listed, then fio will roundrobin the CPUs in the set.

cpumask=int
Set the CPU affinity of this job. The parameter given is a bit mask of allowed CPUs the job may run on. So if you want the allowed CPUs to be 1 and 5, you would pass the decimal value of (1 << 1 | 1 << 5), or 34. See man sched_setaffinity(2). This may not work on all supported operating systems or kernel versions. This option doesn’t work well for a higher CPU count than what you can store in an integer mask, so it can only control cpus 1-32. For boxes with larger CPU counts, use cpus_allowed.

numa_cpu_nodes=str
Set this job running on specified NUMA nodes’ CPUs. The arguments allow comma delimited list of cpu numbers, A-B ranges, or all. Note, to enable NUMA options support, fio must be built on a system with libnuma-dev(el) installed.

numa_mem_policy=str
Set this job’s memory policy and corresponding NUMA nodes. Format of the arguments:
mode is one of the following memory policies: default, prefer, bind, interleave or local. For default and local memory policies, no node needs to be specified. For prefer, only one node is allowed. For bind and interleave the nodelist may be as follows: a comma delimited list of numbers, A-B ranges, or all.

cgroup=\texttt{str}
Add job to this control group. If it doesn’t exist, it will be created. The system must have a mounted cgroup blkio mount point for this to work. If your system doesn’t have it mounted, you can do so with:

```bash
# mount -t cgroup -o blkio none /cgroup
```

cgroup\_weight=\texttt{int}
Set the weight of the cgroup to this value. See the documentation that comes with the kernel, allowed values are in the range of 100..1000.

cgroup\_nodelete=\texttt{bool}
Normally fio will delete the cgroups it has created after the job completion. To override this behavior and to leave cgroups around after the job completion, set cgroup\_nodelete=1. This can be useful if one wants to inspect various cgroup files after job completion. Default: false.

flow\_id=\texttt{int}
The ID of the flow. If not specified, it defaults to being a global flow. See flow.

flow=\texttt{int}
Weight in token-based flow control. If this value is used, then there is a ‘flow counter’ which is used to regulate the proportion of activity between two or more jobs. Fio attempts to keep this flow counter near zero. The flow parameter stands for how much should be added or subtracted to the flow counter on each iteration of the main I/O loop. That is, if one job has flow=8 and another job has flow=-1, then there will be a roughly 1:8 ratio in how much one runs vs the other.

flow\_sleep=\texttt{int}
The period of time, in microseconds, to wait after the flow counter has exceeded its proportion before retrying operations.

stonewall, wait\_for\_previous
Wait for preceding jobs in the job file to exit, before starting this one. Can be used to insert serialization points in the job file. A stone wall also implies starting a new reporting group, see group\_reporting.

exitall
By default, fio will continue running all other jobs when one job finishes. Sometimes this is not the desired action. Setting exitall will instead make fio terminate all jobs in the same group, as soon as one job of that group finishes.

exit\_what
By default, fio will continue running all other jobs when one job finishes. Sometimes this is not the desired action. Setting exit\_all will instead make fio terminate all jobs in the same group. The option exit\_what allows to control which jobs get terminated when exitall is enabled. The default is group and does not change the behaviour of exitall. The setting all terminates all jobs. The setting stonewall terminates all currently running jobs across all groups and continues execution with the next stonewalled group.

exec\_prerun=\texttt{str}
Before running this job, issue the command specified through system(3). Output is redirected in a file called jobname.prerun.txt.

exec\_postrun=\texttt{str}
After the job completes, issue the command specified though system(3). Output is redirected in a file called jobname.postrun.txt.

uid=\texttt{int}
Instead of running as the invoking user, set the user ID to this value before the thread/process does any work.
gid=int
Set group ID, see uid.

1.12.17 Verification

verify_only
Do not perform specified workload, only verify data still matches previous invocation of this workload. This option allows one to check data multiple times at a later date without overwriting it. This option makes sense only for workloads that write data, and does not support workloads with the time_based option set.

do_verify=bool
Run the verify phase after a write phase. Only valid if verify is set. Default: true.

verify=str
If writing to a file, fio can verify the file contents after each iteration of the job. Each verification method also implies verification of special header, which is written to the beginning of each block. This header also includes meta information, like offset of the block, block number, timestamp when block was written, etc. verify can be combined with verify_pattern option. The allowed values are:

- **md5** Use an md5 sum of the data area and store it in the header of each block.
- **crc64** Use an experimental crc64 sum of the data area and store it in the header of each block.
- **crc32c** Use a crc32c sum of the data area and store it in the header of each block. This will automatically use hardware acceleration (e.g. SSE4.2 on an x86 or CRC crypto extensions on ARM64) but will fall back to software crc32c if none is found. Generally the fastest checksum fio supports when hardware accelerated.
- **crc32c-intel** Synonym for crc32c.
- **crc32** Use a crc32 sum of the data area and store it in the header of each block.
- **crc16** Use a crc16 sum of the data area and store it in the header of each block.
- **crc7** Use a crc7 sum of the data area and store it in the header of each block.
- **xxhash** Use xxhash as the checksum function. Generally the fastest software checksum that fio supports.
- **sha512** Use sha512 as the checksum function.
- **sha256** Use sha256 as the checksum function.
- **sha1** Use optimized sha1 as the checksum function.
- **sha3-224** Use optimized sha3-224 as the checksum function.
- **sha3-256** Use optimized sha3-256 as the checksum function.
- **sha3-384** Use optimized sha3-384 as the checksum function.
- **sha3-512** Use optimized sha3-512 as the checksum function.
- **meta** This option is deprecated, since now meta information is included in generic verification header and meta verification happens by default. For detailed information see the description of the verify setting. This option is kept because of compatibility’s sake with old configurations. Do not use it.
- **pattern** Verify a strict pattern. Normally fio includes a header with some basic information and checksumming, but if this option is set, only the specific pattern set with verify_pattern is verified.
- **null** Only pretend to verify. Useful for testing internals with ioengine=null, not for much else.
This option can be used for repeated burn-in tests of a system to make sure that the written data is also correctly read back. If the data direction given is a read or random read, fio will assume that it should verify a previously written file. If the data direction includes any form of write, the verify will be of the newly written data.

To avoid false verification errors, do not use the norandommap option when verifying data with async I/O engines and I/O depths > 1. Or use the norandommap and the lfsr random generator together to avoid writing to the same offset with multiple outstanding I/Os.

**verify_offset=int**
Swap the verification header with data somewhere else in the block before writing. It is swapped back before verifying.

**verify_interval=int**
Write the verification header at a finer granularity than the blocksize. It will be written for chunks the size of verify_interval.blocksize should divide this evenly.

**verify_pattern=str**
If set, fio will fill the I/O buffers with this pattern. Fio defaults to filling with totally random bytes, but sometimes it’s interesting to fill with a known pattern for I/O verification purposes. Depending on the width of the pattern, fio will fill 1/2/3/4 bytes of the buffer at the time (it can be either a decimal or a hex number). The verify_pattern if larger than a 32-bit quantity has to be a hex number that starts with either “0x” or “0X”. Use with verify. Also, verify_pattern supports %o format, which means that for each block offset will be written and then verified back, e.g.:

```
verify_pattern=%o
```

Or use combination of everything:

```
verify_pattern=0xff%o"abcd"-12
```

**verify_fatal=bool**
Normally fio will keep checking the entire contents before quitting on a block verification failure. If this option is set, fio will exit the job on the first observed failure. Default: false.

**verify_dump=bool**
If set, dump the contents of both the original data block and the data block we read off disk to files. This allows later analysis to inspect just what kind of data corruption occurred. Off by default.

**verify_async=int**
Fio will normally verify I/O inline from the submitting thread. This option takes an integer describing how many async offload threads to create for I/O verification instead, causing fio to offload the duty of verifying I/O contents to one or more separate threads. If using this offload option, even sync I/O engines can benefit from using an iodepth setting higher than 1, as it allows them to have I/O in flight while verifies are running. Defaults to 0 async threads, i.e. verification is not asynchronous.

**verify_async_cpus=str**
Tell fio to set the given CPU affinity on the async I/O verification threads. See cpus_allowed for the format used.

**verify_backlog=int**
Fio will normally verify the written contents of a job that utilizes verify once that job has completed. In other words, everything is written then everything is read back and verified. You may want to verify continually instead for a variety of reasons. Fio stores the meta data associated with an I/O block in memory, so for large verify workloads, quite a bit of memory would be used up holding this meta data. If this option is enabled, fio will write only N blocks before verifying these blocks.

**verify_backlog_batch=int**
Control how many blocks fio will verify if verify_backlog is set. If not set, will default to the value of verify_backlog (meaning the entire queue is read back and verified). If verify_backlog_batch is
less than `verify_backlog` then not all blocks will be verified, if `verify_backlog_batch` is larger than `verify_backlog`, some blocks will be verified more than once.

**verify_state_save** = bool

When a job exits during the write phase of a verify workload, save its current state. This allows fio to replay up until that point, if the verify state is loaded for the verify read phase. The format of the filename is, roughly:

```
<type>-<jobname>-<jobindex>-verify.state.
```

`<type>` is “local” for a local run, “sock” for a client/server socket connection, and “ip” (192.168.0.1, for instance) for a networked client/server connection. Defaults to true.

**verify_state_load** = bool

If a verify termination trigger was used, fio stores the current write state of each thread. This can be used at verification time so that fio knows how far it should verify. Without this information, fio will run a full verification pass, according to the settings in the job file used. Default false.

**trim_percentage** = int

Number of verify blocks to discard/trim.

**trim_verify_zero** = bool

Verify that trim/discard blocks are returned as zeros.

**trim_backlog** = int

Trim after this number of blocks are written.

**trim_backlog_batch** = int

Trim this number of I/O blocks.

**experimental_verify** = bool

Enable experimental verification.

### 1.12.18 Steady state

**steadystate** = str:float, **ss** = str:float

Define the criterion and limit for assessing steady state performance. The first parameter designates the criterion whereas the second parameter sets the threshold. When the criterion falls below the threshold for the specified duration, the job will stop. For example, `iops_slope:0.1%` will direct fio to terminate the job when the least squares regression slope falls below 0.1% of the mean IOPS. If `group_reporting` is enabled this will apply to all jobs in the group. Below is the list of available steady state assessment criteria. All assessments are carried out using only data from the rolling collection window. Threshold limits can be expressed as a fixed value or as a percentage of the mean in the collection window.

When using this feature, most jobs should include the `time_based` and `runtime` options or the `loops` option so that fio does not stop running after it has covered the full size of the specified file(s) or device(s).

- **iops** Collect IOPS data. Stop the job if all individual IOPS measurements are within the specified limit of the mean IOPS (e.g., `iops:2` means that all individual IOPS values must be within 2 of the mean, whereas `iops:0.2%` means that all individual IOPS values must be within 0.2% of the mean IOPS to terminate the job).

- **iops_slope** Collect IOPS data and calculate the least squares regression slope. Stop the job if the slope falls below the specified limit.

- **bw** Collect bandwidth data. Stop the job if all individual bandwidth measurements are within the specified limit of the mean bandwidth.

- **bw_slope** Collect bandwidth data and calculate the least squares regression slope. Stop the job if the slope falls below the specified limit.
steadystate_duration=time, ss_dur=time
A rolling window of this duration will be used to judge whether steady state has been reached. Data will be
collected once per second. The default is 0 which disables steady state detection. When the unit is omitted, the
value is interpreted in seconds.

steadystate_ramp_time=time, ss_ramp=time
Allow the job to run for the specified duration before beginning data collection for checking the steady state job
termination criterion. The default is 0. When the unit is omitted, the value is interpreted in seconds.

1.12.19 Measurements and reporting

per_job_logs=bool
If set, this generates bw/clat/iops log with per file private filenames. If not set, jobs with identical names will
share the log filename. Default: true.

group_reporting
It may sometimes be interesting to display statistics for groups of jobs as a whole instead of for each individual
job. This is especially true if numjobs is used; looking at individual thread/process output quickly becomes
unwieldy. To see the final report per-group instead of per-job, use group_reporting. Jobs in a file will be
part of the same reporting group, unless separated by a stonewall, or by using new_group.

new_group
Start a new reporting group. See: group_reporting. If not given, all jobs in a file will be part of the same
reporting group, unless separated by a stonewall.

stats=bool
By default, fio collects and shows final output results for all jobs that run. If this option is set to 0, then fio will
ignore it in the final stat output.

write_bw_log=str
If given, write a bandwidth log for this job. Can be used to store data of the bandwidth of the jobs in their
lifetime.

    write_bw_log=foo

The actual log name will be foo_bw.x.log where x is the index of the job (1..N, where N is the number of
jobs). If per_job_logs is false, then the filename will not include the .x job index.

The included fio_generate_plots script uses gnuplot to turn these text files into nice graphs. See Log
File Formats for how data is structured within the file.

write_lat_log=str
Same as write_bw_log, except this option creates I/O submission (e.g., name_slat.x.log), completion
(e.g., name_clat.x.log), and total (e.g., name_lat.x.log) latency files instead. See write_bw_log
for details about the filename format and Log File Formats for how data is structured within the files.

write_hist_log=str
Same as write_bw_log but writes an I/O completion latency histogram file (e.g., name_hist.x.log)
instead. Note that this file will be empty unless log_hist_msec has also been set. See write_bw_log
for details about the filename format and Log File Formats for how data is structured within the file.

write_iops_log=str
Same as write_bw_log, but writes an IOPS file (e.g. name_iops.x.log) instead. Because fio de-
faults to individual I/O logging, the value entry in the IOPS log will be 1 unless windowed logging (see

1.12. Job file parameters
log_avg_msec) has been enabled. See write_bw_log for details about the filename format and Log File Formats for how data is structured within the file.

log_avg_msec=int
By default, fio will log an entry in the iops, latency, or bw log for every I/O that completes. When writing to the disk log, that can quickly grow to a very large size. Setting this option makes fio average the each log entry over the specified period of time, reducing the resolution of the log. See log_max_value as well. Defaults to 0, logging all entries. Also see Log File Formats.

log_hist_msec=int
Same as log_avg_msec, but logs entries for completion latency histograms. Computing latency percentiles from averages of intervals using log_avg_msec is inaccurate. Setting this option makes fio log histogram entries over the specified period of time, reducing log sizes for high IOPS devices while retaining percentile accuracy. See log_hist_coarseness and write_hist_log as well. Defaults to 0, meaning histogram logging is disabled.

log_hist_coarseness=int
Integer ranging from 0 to 6, defining the coarseness of the resolution of the histogram logs enabled with log_hist_msec. For each increment in coarseness, fio outputs half as many bins. Defaults to 0, for which histogram logs contain 1216 latency bins. See write_hist_log and Log File Formats.

log_max_value=bool
If log_avg_msec is set, fio logs the average over that window. If you instead want to log the maximum value, set this option to 1. Defaults to 0, meaning that averaged values are logged.

log_offset=bool
If this is set, the iolog options will include the byte offset for the I/O entry as well as the other data values. Defaults to 0 meaning that offsets are not present in logs. Also see Log File Formats.

log_compression=int
If this is set, fio will compress the I/O logs as it goes, to keep the memory footprint lower. When a log reaches the specified size, that chunk is removed and compressed in the background. Given that I/O logs are fairly highly compressible, this yields a nice memory savings for longer runs. The downside is that the compression will consume some background CPU cycles, so it may impact the run. This, however, is also true if the logging ends up consuming most of the system memory. So pick your poison. The I/O logs are saved normally at the end of a run, by decompressing the chunks and storing them in the specified log file. This feature depends on the availability of zlib.

log_compression_cpus=str
Define the set of CPUs that are allowed to handle online log compression for the I/O jobs. This can provide better isolation between performance sensitive jobs, and background compression work. See cpus_allowed for the format used.

log_store_compressed=bool
If set, fio will store the log files in a compressed format. They can be decompressed with fio, using the --inflate-log command line parameter. The files will be stored with a .fz suffix.

log_unix_epoch=bool
If set, fio will log Unix timestamps to the log files produced by enabling write_type_log for each log type, instead of the default zero-based timestamps.

block_error_percentiles=bool
If set, record errors in trim block-sized units from writes and trims and output a histogram of how many trims it took to get to errors, and what kind of error was encountered.

bwavgtime=int
Average the calculated bandwidth over the given time. Value is specified in milliseconds. If the job also does bandwidth logging through write_bw_log, then the minimum of this option and log_avg_msec will be used. Default: 500ms.
**ioavgtime**=int
Average the calculated IOPS over the given time. Value is specified in milliseconds. If the job also does IOPS logging through `write_iops_log`, then the minimum of this option and `log_avg_msec` will be used. Default: 500ms.

**disk_util**=bool
Generate disk utilization statistics, if the platform supports it. Default: true.

**disable_lat**=bool
Disable measurements of total latency numbers. Useful only for cutting back the number of calls to `gettimeofday(2)`, as that does impact performance at really high IOPS rates. Note that to really get rid of a large amount of these calls, this option must be used with `disable_slat` and `disable_bw_measurement` as well.

**disable_clat**=bool
Disable measurements of completion latency numbers. See `disable_lat`.

**disable_slat**=bool
Disable measurements of submission latency numbers. See `disable_lat`.

**disable_bw_measurement**=bool, **disable_bw**=bool
Disable measurements of throughput/bandwidth numbers. See `disable_lat`.

**slat_percentiles**=bool
Report submission latency percentiles. Submission latency is not recorded for synchronous ioengines.

**clat_percentiles**=bool
Report completion latency percentiles.

**lat_percentiles**=bool
Report total latency percentiles. Total latency is the sum of submission latency and completion latency.

**percentile_list**=float_list
Overwrite the default list of percentiles for latencies and the block error histogram. Each number is a floating point number in the range (0,100], and the maximum length of the list is 20. Use : to separate the numbers. For example, `--percentile_list=99.5:99.9` will cause fio to report the latency durations below which 99.5% and 99.9% of the observed latencies fell, respectively.

**significant_figures**=int
If using `--output-format` of `normal`, set the significant figures to this value. Higher values will yield more precise IOPS and throughput units, while lower values will round. Requires a minimum value of 1 and a maximum value of 10. Defaults to 4.

### 1.12.20 Error handling

**exitall_on_error**
When one job finishes in error, terminate the rest. The default is to wait for each job to finish.

**continue_on_error**=str
Normally fio will exit the job on the first observed failure. If this option is set, fio will continue the job when there is a ‘non-fatal error’ (EIO or EILSEQ) until the runtime is exceeded or the I/O size specified is completed. If this option is used, there are two more stats that are appended, the total error count and the first error. The error field given in the stats is the first error that was hit during the run.

The allowed values are:

- **none** Exit on any I/O or verify errors.
- **read** Continue on read errors, exit on all others.
- **write** Continue on write errors, exit on all others.
io  Continue on any I/O error, exit on all others.

verify Continue on verify errors, exit on all others.

all  Continue on all errors.

0  Backward-compatible alias for ‘none’.

1  Backward-compatible alias for ‘all’.

ignore_error=str

Sometimes you want to ignore some errors during test in that case you can specify error list for each error type, instead of only being able to ignore the default ‘non-fatal error’ using continue_on_error. ignore_error=READ_ERR_LIST, WRITE_ERR_LIST, VERIFY_ERR_LIST errors for given error type is separated with ‘,’. Error may be symbol (‘ENOSPC’, ‘ENOMEM’) or integer. Example:

```
ignore_error=EAGAIN, ENOSPC:122
```

This option will ignore EAGAIN from READ, and ENOSPC and 122(EDQUOT) from WRITE. This option works by overriding continue_on_error with the list of errors for each error type if any.

error_dump=bool

If set dump every error even if it is non fatal, true by default. If disabled only fatal error will be dumped.

### 1.13 Running predefined workloads

Fio includes predefined profiles that mimic the I/O workloads generated by other tools.

**profile=str**

The predefined workload to run. Current profiles are:

- **tiobench**  Threaded I/O bench (tiotest/tiobench) like workload.
- **act**  Aerospike Certification Tool (ACT) like workload.

To view a profile’s additional options use --cmdhelp after specifying the profile. For example:

```
$ fio --profile=act --cmdhelp
```

#### 1.13.1 Act profile options

**device-names=str**

Devices to use.

**load=int**


**test-duration=time**

How long the entire test takes to run. When the unit is omitted, the value is given in seconds. Default: 24h.

**threads-per-queue=int**

Number of read I/O threads per device. Default: 8.

**read-num-512-blocks=int**

Number of 512B blocks to read at the time. Default: 3.

**large-block-op-kbytes=int**

Size of large block ops in KiB (writes). Default: 131072.
prep
Set to run ACT prep phase.

### 1.13.2 Tiobench profile options

**size=**str
Size in MiB.

**block=**int
Block size in bytes. Default: 4096.

**numruns=**int
Number of runs.

**dir=**str
Test directory.

**threads=**int
Number of threads.

### 1.14 Interpreting the output

Fio spits out a lot of output. While running, fio will display the status of the jobs created. An example of that would be:

```
Jobs: 1 (f=1): [_(1),M(1)] [24.8%] [r=20.5MiB/s, w=23.5MiB/s] [r=82, w=94 IOPS] [eta _01m:31s]
```

The characters inside the first set of square brackets denote the current status of each thread. The first character is the first job defined in the job file, and so forth. The possible values (in typical life cycle order) are:

<table>
<thead>
<tr>
<th>Idle</th>
<th>Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Thread setup, but not started.</td>
</tr>
<tr>
<td>C</td>
<td>Thread created.</td>
</tr>
<tr>
<td>I</td>
<td>Thread initialized, waiting or generating necessary data.</td>
</tr>
<tr>
<td>p</td>
<td>Thread running pre-reading file(s).</td>
</tr>
<tr>
<td>/</td>
<td>Thread is in ramp period.</td>
</tr>
<tr>
<td>R</td>
<td>Running, doing sequential reads.</td>
</tr>
<tr>
<td>r</td>
<td>Running, doing random reads.</td>
</tr>
<tr>
<td>W</td>
<td>Running, doing sequential writes.</td>
</tr>
<tr>
<td>w</td>
<td>Running, doing random writes.</td>
</tr>
<tr>
<td>M</td>
<td>Running, doing mixed sequential reads/writes.</td>
</tr>
<tr>
<td>m</td>
<td>Running, doing mixed random reads/writes.</td>
</tr>
<tr>
<td>D</td>
<td>Running, doing sequential trims.</td>
</tr>
<tr>
<td>d</td>
<td>Running, doing random trims.</td>
</tr>
<tr>
<td>F</td>
<td>Running, currently waiting for fsync(2).</td>
</tr>
<tr>
<td>V</td>
<td>Running, doing verification of written data.</td>
</tr>
<tr>
<td>f</td>
<td>Thread finishing.</td>
</tr>
<tr>
<td>E</td>
<td>Thread exited, not reaped by main thread yet.</td>
</tr>
<tr>
<td>_</td>
<td>Thread reaped.</td>
</tr>
<tr>
<td>X</td>
<td>Thread reaped, exited with an error.</td>
</tr>
<tr>
<td>K</td>
<td>Thread reaped, exited due to signal.</td>
</tr>
</tbody>
</table>
Fio will condense the thread string as not to take up more space on the command line than needed. For instance, if you have 10 readers and 10 writers running, the output would look like this:

```
Jobs: 20 (f=20): [R(10), W(10)] [4.0%] [r=20.5 MiB/s, w=23.5 MiB/s] [r=82, w=94 IOPS] [eta 57m:36s]
```

Note that the status string is displayed in order, so it’s possible to tell which of the jobs are currently doing what. In the example above this means that jobs 1–10 are readers and 11–20 are writers.

The other values are fairly self explanatory – number of threads currently running and doing I/O, the number of currently open files (f=), the estimated completion percentage, the rate of I/O since last check (read speed listed first, then write speed and optionally trim speed) in terms of bandwidth and IOPS, and time to completion for the current running group. It’s impossible to estimate runtime of the following groups (if any).

When fio is done (or interrupted by Ctrl-C), it will show the data for each thread, group of threads, and disks in that order. For each overall thread (or group) the output looks like:

```
Client1: (groupid=0, jobs=1): err= 0: pid=16109: Sat Jun 24 12:07:54 2017
write: IOPS=88, BW=623 KiB/s (638kB/s) (30.4MiB/50032msec)
  slat (nsec): min=500, max=145500, avg=8318.00, stdev=4781.50
  clat (usec): min=170, max=78367, avg=4019.02, stdev=8293.31
  lat (usec): min=174, max=78375, avg=4027.34, stdev=8291.79
  clat percentiles (usec):
    | 1.00th=[ 302], 5.00th=[ 326], 10.00th=[ 343], 20.00th=[ 363],
    | 30.00th=[ 392], 40.00th=[ 404], 50.00th=[ 416], 60.00th=[ 445],
    | 70.00th=[ 816], 80.00th=[ 6718], 90.00th=[12911], 95.00th=[21627],
    | 99.00th=[43779], 99.50th=[51643], 99.90th=[68682], 99.95th=[72877],
    | 99.99th=[78119]
  bw ( KiB/s): min= 532, max= 686, per=0.10%, avg=622.87, stdev=24.82, samples= 100
  iops : min= 76, max= 98, avg=88.98, stdev= 3.54, samples= 100
  lat (usec) : 2=4.16%, 4=1.84%, 10=4.90%, 20=11.33%, 50=5.37%
  lat (msec) : 1=85.0%, 2=13.1%, 4=1.8%, 8=0.1%, 16=0.0%, 32=0.0%, >=64=0.0%
  submit : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  complete : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  issued rwt: total=0,4450,0, short=0,0,0, dropped=0,0,0
  latency : target=0, window=0, percentile=100.00%, depth=8
```

The job name (or first job’s name when using group_reporting) is printed, along with the group id, count of jobs being aggregated, last error id seen (which is 0 when there are no errors), pid/tid of that thread and the time the job/group completed. Below are the I/O statistics for each data direction performed (showing writes in the example above). In the order listed, they denote:

read/write/trim The string before the colon shows the I/O direction the statistics are for. IOPS is the average I/Os performed per second. BW is the average bandwidth rate shown as: value in power of 2 format (value in power of 10 format). The last two values show: (total I/O performed in power of 2 format / runtime of that thread).

slat Submission latency (min being the minimum, max being the maximum, avg being the average, stdev being the standard deviation). This is the time it took to submit the I/O. For sync I/O this row is not displayed as the slat is really the completion latency (since queue/complete is one operation there). This value can be in nanoseconds, microseconds or milliseconds — fio will choose the most appropriate base and print that (in the example above nanoseconds was the best scale). Note: in --minimal mode latencies are always expressed in microseconds.

clat Completion latency. Same names as slat, this denotes the time from submission to completion of the I/O pieces. For sync I/O, clat will usually be equal (or very close) to 0, as the time from submit to complete is basically just CPU time (I/O has already been done, see slat explanation).
lat  Total latency. Same names as slat and clat, this denotes the time from when fio created the I/O unit to completion of the I/O operation.

bw  Bandwidth statistics based on samples. Same names as the xlat stats, but also includes the number of samples taken (samples) and an approximate percentage of total aggregate bandwidth this thread received in its group (per). This last value is only really useful if the threads in this group are on the same disk, since they are then competing for disk access.

iops IOPS statistics based on samples. Same names as bw.

lat (nsec/usec/msec)  The distribution of I/O completion latencies. This is the time from when I/O leaves fio and when it gets completed. Unlike the separate read/write/trim sections above, the data here and in the remaining sections apply to all I/Os for the reporting group. 250=0.04% means that 0.04% of the I/Os completed in under 250us. 500=64.11% means that 64.11% of the I/Os required 250 to 499us for completion.

cpu  CPU usage. User and system time, along with the number of context switches this thread went through, usage of system and user time, and finally the number of major and minor page faults. The CPU utilization numbers are averages for the jobs in that reporting group, while the context and fault counters are summed.

IO depths  The distribution of I/O depths over the job lifetime. The numbers are divided into powers of 2 and each entry covers depths from that value up to those that are lower than the next entry – e.g., 16= covers depths from 16 to 31. Note that the range covered by a depth distribution entry can be different to the range covered by the equivalent submit/complete distribution entry.

IO submit  How many pieces of I/O were submitting in a single submit call. Each entry denotes that amount and below, until the previous entry – e.g., 16=100% means that we submitted anywhere between 9 to 16 I/Os per submit call. Note that the range covered by a submit distribution entry can be different to the range covered by the equivalent depth distribution entry.

IO complete  Like the above submit number, but for completions instead.

IO issued rwt  The number of read/write/trim requests issued, and how many of them were short or dropped.

IO latency  These values are for latency_target and related options. When these options are engaged, this section describes the I/O depth required to meet the specified latency target.

After each client has been listed, the group statistics are printed. They will look like this:

```
Run status group 0 (all jobs):
   READ: bw=20.9MiB/s (21.9MB/s), 10.4MiB/s-10.8MiB/s (10.9MB/s-11.3MB/s), io=64.0MiB-(67.1MB), run=2973-3069msec
   WRITE: bw=1231KiB/s (1261kB/s), 616KiB/s-621KiB/s (630kB/s-636kB/s), io=64.0MiB (67.1MB), run=52747-53223msec
```

For each data direction it prints:

bw  Aggregate bandwidth of threads in this group followed by the minimum and maximum bandwidth of all the threads in this group. Values outside of brackets are power-of-2 format and those within are the equivalent value in a power-of-10 format.

io  Aggregate I/O performed of all threads in this group. The format is the same as bw.

run  The smallest and longest runtimes of the threads in this group.

And finally, the disk statistics are printed. This is Linux specific. They will look like this:

```
Disk stats (read/write):
 sda: ios=16398/16511, merge=30/162, ticks=6853/819634, in_queue=826487, util=100.00%
```

Each value is printed for both reads and writes, with reads first. The numbers denote:

ios  Number of I/Os performed by all groups.
merge  Number of merges performed by the I/O scheduler.

ticks  Number of ticks we kept the disk busy.

in_queue  Total time spent in the disk queue.

util  The disk utilization. A value of 100% means we kept the disk busy constantly, 50% would be a disk idling half of the time.

It is also possible to get fio to dump the current output while it is running, without terminating the job. To do that, send fio the USR1 signal. You can also get regularly timed dumps by using the --status-interval parameter, or by creating a file in /tmp named fio-dump-status. If fio sees this file, it will unlink it and dump the current output status.

### 1.15 Terse output

For scripted usage where you typically want to generate tables or graphs of the results, fio can output the results in a semicolon separated format. The format is one long line of values, such as:

```
2;card0:0;7139336;121836;60004;1;10109;27.932460;116.933948;220;126861;3495.446807;...
```

A description of this job goes here.

The job description (if provided) follows on a second line for terse v2. It appears on the same line for other terse versions.

To enable terse output, use the --minimal or --output-format=terse command line options. The first value is the version of the terse output format. If the output has to be changed for some reason, this number will be incremented by 1 to signify that change.

Split up, the format is as follows (comments in brackets denote when a field was introduced or whether it’s specific to some terse version):

```
terse version, fio version [v3], jobname, groupid, error

READ status:

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total IO (KiB), bandwidth (KiB/sec), IOPS, runtime (msec)</td>
<td></td>
</tr>
<tr>
<td>Submission latency:</td>
<td>min, max, mean, stdev (usec)</td>
</tr>
<tr>
<td>Completion latency:</td>
<td>min, max, mean, stdev (usec)</td>
</tr>
<tr>
<td>Completion latency percentiles:</td>
<td>20 fields (see below)</td>
</tr>
<tr>
<td>Total latency:</td>
<td>min, max, mean, stdev (usec)</td>
</tr>
<tr>
<td>Bw (KiB/s):</td>
<td>min, max, aggregate percentage of total, mean, stdev, number of samples [v5]</td>
</tr>
<tr>
<td>IOPS [v5]:</td>
<td>min, max, mean, stdev, number of samples</td>
</tr>
</tbody>
</table>

WRITE status:

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total IO (KiB), bandwidth (KiB/sec), IOPS, runtime (msec)</td>
<td></td>
</tr>
<tr>
<td>Submission latency:</td>
<td>min, max, mean, stdev (usec)</td>
</tr>
<tr>
<td>Completion latency:</td>
<td>min, max, mean, stdev (usec)</td>
</tr>
<tr>
<td>Completion latency percentiles:</td>
<td>20 fields (see below)</td>
</tr>
</tbody>
</table>
```

(continues on next page)
Total latency: min, max, mean, stdev (usec)
Bw (KiB/s): min, max, aggregate percentage of total, mean, stdev, number of...
IOPS [v5]: min, max, mean, stdev, number of samples

TRIM status [all but version 3]:
Fields are similar to READ/WRITE status.

CPU usage:
user, system, context switches, major faults, minor faults

I/O depths:
<=1, 2, 4, 8, 16, 32, >=64

I/O latencies microseconds:
<=2, 4, 10, 20, 50, 100, 250, 500, 750, 1000

I/O latencies milliseconds:
<=2, 4, 10, 20, 50, 100, 250, 500, 750, 1000, 2000, >=2000

Disk utilization [v3]:
disk name, read ios, write ios, read merges, write merges, read ticks, write...
time spent in queue, disk utilization percentage

Additional Info (dependent on continue_on_error, default off):
total # errors, first error code

Additional Info (dependent on description being set):
Text description

Completion latency percentiles can be a grouping of up to 20 sets, so for the terse output fio writes all of them. Each field will look like this:

1.00%=6112

which is the Xth percentile, and the usec latency associated with it.

For Disk utilization, all disks used by fio are shown. So for each disk there will be a disk utilization section.

Below is a single line containing short names for each of the fields in the minimal output v3, separated by semicolons:

terse_version_3;fio_version;jobname;groupid;error;read_kb;read_bandwidth_kb;read_iops;...
write_iops;write_runtime_ms;write_slat_min_us;write_slat_max_us;write_slat_mean_us;write_slat_dev_us;write_clat_min_us;write_clat_max_us;write_clat_mean_us;write_clat_dev_us;write_clat_pct01;write_clat_pct02;write_clat_pct03;write_clat_pct04;write_clat_pct05;write_clat_pct06;write_clat_pct07;write_clat_pct08;write_clat_pct09;write_clat_pct10;write_clat_pct11;write_clat_pct12;write_clat_pct13;write_clat_pct14;write_clat_pct15;write_clat_pct16;write_clat_pct17;write_clat_pct18;write_clat_pct19;write_clat_pct20;write_tlat_min_us;write_tlat_max_us;write_tlat_mean_us;write_tlat_dev_us;write_bw_min_kb;write_bw_max_kb;write_bw_agg_pct;write_bw_mean_kb;write_bw_dev_kb;cpu_user;cpu_sys;cpu_csw;cpu_mjf;iodepth_1;iodepth_2;iodepth_4;iodepth_8;iodepth_16;iodepth_32;iodepth_64;lat_2us;lat_4us;lat_10us;lat_20us;lat_50us;lat_100us;lat_250us;lat_500us;lat_750us;lat_1000us;lat_2000us;lat_over_2000us;disk_name;disk_read_iops;disk_write_iops;disk_read_merges;disk_write_merges;disk_read_ticks;write_ticks;disk_queue_time;disk_util...
In client/server mode terse output differs from what appears when jobs are run locally. Disk utilization data is omitted from the standard terse output and for v3 and later appears on its own separate line at the end of each terse reporting cycle.

### 1.16 JSON output

The `json` output format is intended to be both human readable and convenient for automated parsing. For the most part its sections mirror those of the `normal` output. The `runtime` value is reported in msec and the `bw` value is reported in 1024 bytes per second units.

### 1.17 JSON+ output

The `json+` output format is identical to the `json` output format except that it adds a full dump of the completion latency bins. Each `bins` object contains a set of (key, value) pairs where keys are latency durations and values count how many I/Os had completion latencies of the corresponding duration. For example, consider:

```json
  "bins" : { "87552" : 1, "89600" : 1, "94720" : 1, "97792" : 1, "99840" : 1, "100864" : 2, "103936" : 6, "104960" : 534, "105984" : 5995, "107008" : 7529, ... }
```

This data indicates that one I/O required 87,552ns to complete, two I/Os required 100,864ns to complete, and 7529 I/Os required 107,008ns to complete.

Also included with fio is a Python script `fio_jsonplus_clat2csv` that takes `json+` output and generates CSV-formatted latency data suitable for plotting.

The latency durations actually represent the midpoints of latency intervals. For details refer to `stat.h`.

### 1.18 Trace file format

There are two trace file format that you can encounter. The older (v1) format is unsupported since version 1.20-rc3 (March 2008). It will still be described below in case that you get an old trace and want to understand it.

In any case the trace is a simple text file with a single action per line.

#### 1.18.1 Trace file format v1

Each line represents a single I/O action in the following format:

```
  rw, offset, length
```

where `rw=0/1` for read/write, and the `offset` and `length` entries being in bytes.

This format is not supported in fio versions >= 1.20-rc3.
1.18.2 Trace file format v2

The second version of the trace file format was added in fio version 1.17. It allows to access more than one file per trace and has a bigger set of possible file actions.

The first line of the trace file has to be:

```
fio version 2 iolog
```

Following this can be lines in two different formats, which are described below.

The file management format:

```
filename action
```

The `filename` is given as an absolute path. The `action` can be one of these:

- **add**: Add the given `filename` to the trace.
- **open**: Open the file with the given `filename`. The `filename` has to have been added with the **add** action before.
- **close**: Close the file with the given `filename`. The file has to have been opened before.

The file I/O action format:

```
filename action offset length
```

The `filename` is given as an absolute path, and has to have been added and opened before it can be used with this format. The `offset` and `length` are given in bytes. The `action` can be one of these:

- **wait**: Wait for `offset` microseconds. Everything below 100 is discarded. The time is relative to the previous **wait** statement.
- **read**: Read `length` bytes beginning from `offset`.
- **write**: Write `length` bytes beginning from `offset`.
- **sync**: `fsync(2)` the file.
- **datasync**: `fdatasync(2)` the file.
- **trim**: Trim the given file from the given `offset` for `length` bytes.

1.19 I/O Replay - Merging Traces

Colocation is a common practice used to get the most out of a machine. Knowing which workloads play nicely with each other and which ones don’t is a much harder task. While fio can replay workloads concurrently via multiple jobs, it leaves some variability up to the scheduler making results harder to reproduce. Merging is a way to make the order of events consistent.

Merging is integrated into I/O replay and done when a merge_blktrace_file is specified. The list of files passed to read_iolog go through the merge process and output a single file stored to the specified file. The output file is passed on as if it were the only file passed to read_iolog. An example would look like:

```
$ fio --read_iolog="<file1>:<file2>" --merge_blktrace_file="<output_file>"
```

Creating only the merged file can be done by passing the command line argument --merge-blktrace-only.

Scaling traces can be done to see the relative impact of any particular trace being slowed down or sped up. merge_blktrace_scalars takes in a colon separated list of percentage scalars. It is index paired with the files passed to read_iolog.
With scaling, it may be desirable to match the running time of all traces. This can be done with `merge_blktrace_iters`. It is index paired with `read_iolog` just like `merge_blktrace_scalars`.

In an example, given two traces, A and B, each 60s long. If we want to see the impact of trace A issuing IOs twice as fast and repeat trace A over the runtime of trace B, the following can be done:

```bash
$ fio --read_iolog="$trace_a":$trace_b" --merge_blktrace_file"output_file" --merge_blktrace_scalars="50:100" --merge_blktrace_iters="2:1"
```

This runs trace A at 2x the speed twice for approximately the same runtime as a single run of trace B.

### 1.20 CPU idleness profiling

In some cases, we want to understand CPU overhead in a test. For example, we test patches for the specific goodness of whether they reduce CPU usage. Fio implements a balloon approach to create a thread per CPU that runs at idle priority, meaning that it only runs when nobody else needs the cpu. By measuring the amount of work completed by the thread, idleness of each CPU can be derived accordingly.

An unit work is defined as touching a full page of unsigned characters. Mean and standard deviation of time to complete an unit work is reported in “unit work” section. Options can be chosen to report detailed percpu idleness or overall system idleness by aggregating percpu stats.

### 1.21 Verification and triggers

Fio is usually run in one of two ways, when data verification is done. The first is a normal write job of some sort with verify enabled. When the write phase has completed, fio switches to reads and verifies everything it wrote. The second model is running just the write phase, and then later on running the same job (but with reads instead of writes) to repeat the same I/O patterns and verify the contents. Both of these methods depend on the write phase being completed, as fio otherwise has no idea how much data was written.

With verification triggers, fio supports dumping the current write state to local files. Then a subsequent read verify workload can load this state and know exactly where to stop. This is useful for testing cases where power is cut to a server in a managed fashion, for instance.

A verification trigger consists of two things:

1) Storing the write state of each job.

2) Executing a trigger command.

The write state is relatively small, on the order of hundreds of bytes to single kilobytes. It contains information on the number of completions done, the last X completions, etc.

A trigger is invoked either through creation (‘touch’) of a specified file in the system, or through a timeout setting. If fio is run with `--trigger-file= /tmp/trigger-file`, then it will continually check for the existence of `/tmp/trigger-file`. When it sees this file, it will fire off the trigger (thus saving state, and executing the trigger command).

For client/server runs, there’s both a local and remote trigger. If fio is running as a server backend, it will send the job states back to the client for safe storage, then execute the remote trigger, if specified. If a local trigger is specified, the server will still send back the write state, but the client will then execute the trigger.
1.21.1 Verification trigger example

Let’s say we want to run a powercut test on the remote Linux machine ‘server’. Our write workload is in `write-test.fio`. We want to cut power to ‘server’ at some point during the run, and we’ll run this test from the safety of our local machine, ‘localbox’. On the server, we’ll start the fio backend normally:

```
server# fio --server
```

and on the client, we’ll fire off the workload:

```
localbox$ fio --client=server --trigger-file=/tmp/my-trigger --trigger-remote="bash -c "echo b > /proc/sysrq-trigger""
```

We set `/tmp/my-trigger` as the trigger file, and we tell fio to execute:

```
echo b > /proc/sysrq-trigger
```

on the server once it has received the trigger and sent us the write state. This will work, but it’s not really cutting power to the server, it’s merely abruptly rebooting it. If we have a remote way of cutting power to the server through IPMI or similar, we could do that through a local trigger command instead. Let’s assume we have a script that does IPMI reboot of a given hostname, `ipmi-reboot`. On localbox, we could then have run fio with a local trigger instead:

```
localbox$ fio --client=server --trigger-file=/tmp/my-trigger --trigger="ipmi-reboot --server"
```

For this case, fio would wait for the server to send us the write state, then execute `ipmi-reboot server` when that happened.

1.21.2 Loading verify state

To load stored write state, a read verification job file must contain the `verify_state_load` option. If that is set, fio will load the previously stored state. For a local fio run this is done by loading the files directly, and on a client/server run, the server backend will ask the client to send the files over and load them from there.

1.22 Log File Formats

Fio supports a variety of log file formats, for logging latencies, bandwidth, and IOPS. The logs share a common format, which looks like this:

```
time (msec), value, data direction, block size (bytes), offset (bytes), command priority
```

Time for the log entry is always in milliseconds. The value logged depends on the type of log, it will be one of the following:

- **Latency log** Value is latency in nsecs
- **Bandwidth log** Value is in KiB/sec
- **IOPS log** Value is IOPS

Data direction is one of the following:

- 0 I/O is a READ
- 1 I/O is a WRITE
- 2 I/O is a TRIM
The entry’s block size is always in bytes. The offset is the position in bytes from the start of the file for that particular I/O. The logging of the offset can be toggled with log_offset.

Command priority is 0 for normal priority and 1 for high priority. This is controlled by the ioengine specific cmdprio_percentage.

Fio defaults to logging every individual I/O but when windowed logging is set through log_avg_msec, either the average (by default) or the maximum (log_max_value is set) value seen over the specified period of time is recorded. Each data direction seen within the window period will aggregate its values in a separate row. Further, when using windowed logging the block size and offset entries will always contain 0.

### 1.23 Client/Server

Normally fio is invoked as a stand-alone application on the machine where the I/O workload should be generated. However, the backend and frontend of fio can be run separately i.e., the fio server can generate an I/O workload on the “Device Under Test” while being controlled by a client on another machine.

Start the server on the machine which has access to the storage DUT:

```
$ fio --server=--server=--server=--server=--server=--server=--server=--server=
```

where args defines what fio listens to. The arguments are of the form type,hostname or IP, port. type is either ip (or ip4) for TCP/IP v4, ip6 for TCP/IP v6, or sock for a local unix domain socket. hostname is either a hostname or IP address, and port is the port to listen to (only valid for TCP/IP, not a local socket). Some examples:

1) fio --server
   Start a fio server, listening on all interfaces on the default port (8765).
2) fio --server=ip:hostname,4444
   Start a fio server, listening on IP belonging to hostname and on port 4444.
3) fio --server=ip6::1,4444
   Start a fio server, listening on IPv6 localhost ::1 and on port 4444.
4) fio --server=,4444
   Start a fio server, listening on all interfaces on port 4444.
5) fio --server=1.2.3.4
   Start a fio server, listening on IP 1.2.3.4 on the default port.
6) fio --server=sock:/tmp/fio.sock
   Start a fio server, listening on the local socket /tmp/fio.sock.

Once a server is running, a “client” can connect to the fio server with:

```
fio <local-args> --client=<server> <remote-args> <job file(s)>
```

where local-args are arguments for the client where it is running, server is the connect string, and remote-args and job file(s) are sent to the server. The server string follows the same format as it does on the server side, to allow IP/hostname/socket and port strings.

Fio can connect to multiple servers this way:

```
fio --client=<server1> <job file(s)> --client=<server2> <job file(s)>
```
If the job file is located on the fio server, then you can tell the server to load a local file as well. This is done by using `--remote-config`

```
fio --client=server --remote-config /path/to/file.fio
```

Then fio will open this local (to the server) job file instead of being passed one from the client.

If you have many servers (example: 100 VMs/containers), you can input a pathname of a file containing host IPs/names as the parameter value for the `--client` option. For example, here is an example `host.list` file containing 2 hostnames:

```
host1.your.dns.domain
host2.your.dns.domain
```

The fio command would then be:

```
fio --client=host.list <job file(s)>
```

In this mode, you cannot input server-specific parameters or job files – all servers receive the same job file.

In order to let fio `--client` runs use a shared filesystem from multiple hosts, fio `--client` now prepends the IP address of the server to the filename. For example, if fio is using the directory `/mnt/nfs/fio` and is writing filename `fileio.tmp`, with a `--client hostfile` containing two hostnames h1 and h2 with IP addresses 192.168.10.120 and 192.168.10.121, then fio will create two files:

```
/mnt/nfs/fio/192.168.10.120.fileio.tmp
/mnt/nfs/fio/192.168.10.121.fileio.tmp
```

Terse output in client/server mode will differ slightly from what is produced when fio is run in stand-alone mode. See the terse output section for details.
Some job file examples.

### 2.1 Poisson request flow

Download poisson-rate-submission.fio

```fio
[poisson-rate-submit]
size=128m
rw=randread
ioengine=libaio
iodepth=32
direct=1
# by setting the submit mode to offload, we can guarantee a fixed rate of
# submission regardless of what the device completion rate is.
io_submit_mode=offload
rate_iops=50
# Real world random request flow follows Poisson process. To give better
# insight on latency distribution, we simulate request flow under Poisson
# process.
rate_process=poisson
```

### 2.2 Latency profile

Download latency-profile.fio

```fio
# Test job that demonstrates how to use the latency target
# profiling. Fio will find the queue depth between 1..128
# that fits within the latency constraints of this 4k random
# read workload.
```

(continues on next page)
2.3 Read 4 files with aio at different depths

Download aio-read.fio

```plaintext
# Read 4 files with aio at different depths
[global]
ioengine=libaio
buffered=0
rw=randread
bs=128k
size=512m
directory=/data1

[file1]
iodepth=4

[file2]
iodepth=32

[file3]
iodepth=8

[file4]
iodepth=16
```

2.4 Read backwards in a file

Download backwards-read.fio

```plaintext
# Demonstrates how to read backwards in a file.
[backwards-read]
bs=4k
# seek -8k back for every IO
rw=read:-8k
```
2.5 Basic verification

Download basic-verify.fio

```
filename=128m
size=128m

[write-and-verify]
rw=randwrite
bs=4k
direct=1
ioengine=libaio
iodepth=16
verify=crc32c

# Use /dev/XXX. For running this on a file instead, remove the filename
# option and add a size=32G (or whatever file size you want) instead.
filename=/dev/XXX
```

2.6 Fixed rate submission

Download fixed-rate-submission.fio

```
[size=128m
rw=read
ioengine=libaio
iodepth=32
direct=1

# by setting the submit mode to offload, we can guarantee a fixed rate of
# submission regardless of what the device completion rate is.
io_submit_mode=offload
rate_iops=1000
```

2.7 Butterfly seek pattern

Download butterfly.fio

```
filename=/tmp/testfile
bs=4k
direct=1

[forward]
rw=read
```

(continues on next page)
flow=2
# Uncomment the size= and offset= lines to prevent each direction going past
# the middle of the file
#size=50%

[backward]
:rw=read:-8k
flow=2
offset=50%
3.1 GFIO TODO

In no particular order:

- Ability to save job files. Probably in an extended gfio format, so we can include options/settings outside of a fio job file.

- End view improvements:
  - Cleanup the layout
  - Add ability to save the results
  - Add ability to load end-results as well
  - Add ability to request graphs of whatever graphing options the fio job included.
  - Add ability to graph completion latencies, percentiles, etc.

- Add ability to edit job options:
  - We need an options view after sending a job, that allows us to visually see what was parsed, make changes, resubmit.
  - Job options are already converted across the network and are available in gfio_client->o for view/edit. We’ll need a FIO_NET_CMD_UPDATE_OPTIONS command to send them back, and backend support for updating an existing set of options.

- Add support for printing end results, graphs, etc.

- Improve the auto-start backend functionality, it’s quite buggy.

- Ensure that it works on OSX and Windows. We’ll need a bit of porting work there.

- Persistent store of preferences set. This will need a per-OS bit as well, using gfonf on Linux, registry on Windows, ?? on OSX.

- Ensure that local errors go to our log, instead of being displayed on the console.
• Ensure that the whole connect/send/start button logic is sane. Right now it works when you perform the right sequence, but if you connect and disconnect, things can get confused. We’ll need to improve how we store and send job files. Right now they are in `ge->job_files[]` and are always emptied on send. Keep them around?

• Commit rate display is not enabled.

• Group status reporting is not enabled.

• Split `gfio.c` a bit. Add `gfio/` sub directory, and split it into files based on functionality. It’s already ~3000 lines long.

• Attempt to ensure that we work with `gtk 2.10` and newer. Right now the required version is ~2.18 (not quite known).

### 3.2 Server TODO

• Collate ETA output from multiple connections into 1

• If `group_reporting` is set, collate final output from multiple connections

### 3.3 Steady State TODO

Known issues/TODO (for steady-state)

• Allow user to specify the frequency of measurements

• Better documentation for output

• Report read, write, trim IOPS/BW separately

• Semantics for the ring buffer `ss->head` are confusing. `ss->head` points to the beginning of the buffer up through the point where the buffer is filled for the first time. Afterwards, when a new element is added, `ss->head` is advanced to point to the second element in the buffer. If steady state is attained upon adding a new element, `ss->head` is not advanced so it actually does point to the head of the buffer.
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