

# **System Vs OS Virtualization**

**Student: Shuaiyu Wang**

## **Environment Setup**

Host System Configuration:

CPU: 11th Gen Intel(R) Core(TM) i7-11800H @ 2.30GHz

RAM: 8 GB Storage: 512MB

System Type: 64-bit operating system, x64-based processor

Primary OS: Windows 11

## **System Virtualization Setup**

### **QEMU Setup**

Below are the steps followed to install QEMU on Windows:

1. Downloaded ubuntu server ISO image from the following link:

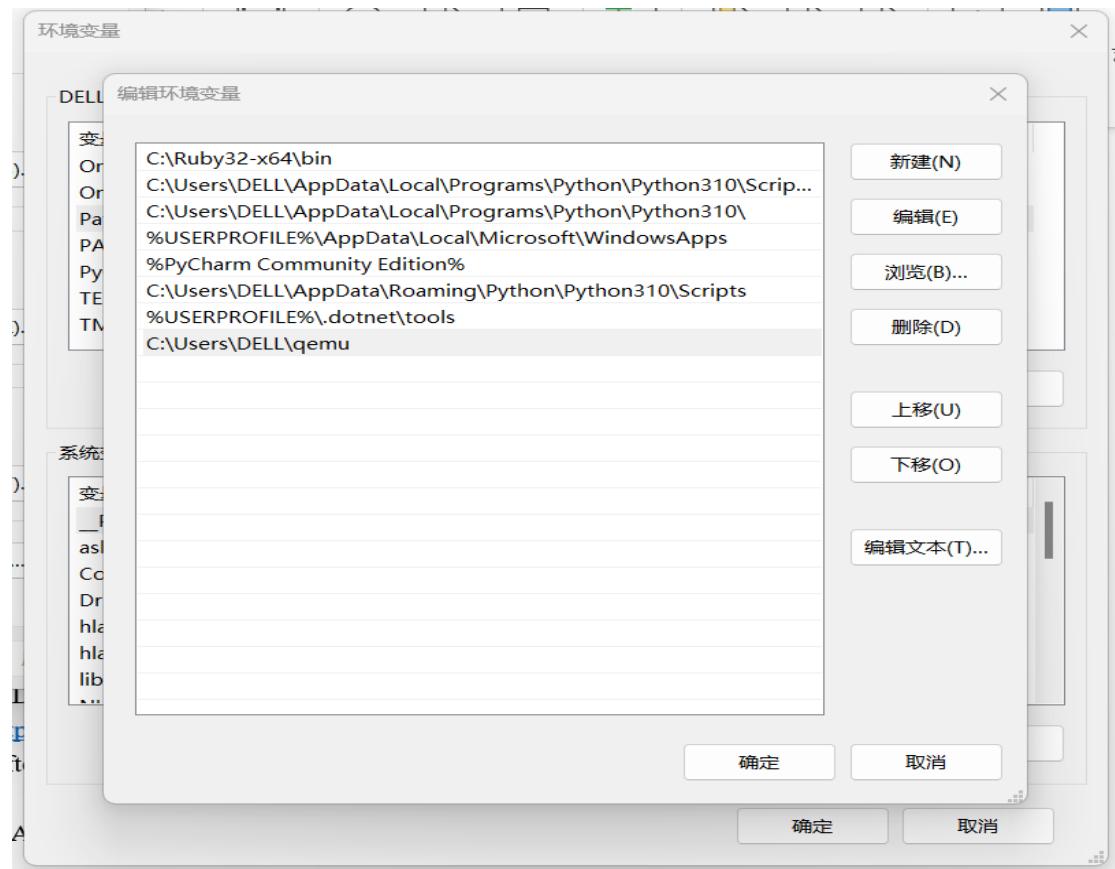
<https://releases.ubuntu.com/16.04/ubuntu-16.04.7-server-amd64.iso>

2. Downloaded QEMU for Windows(x64) from the following link:

<https://www.qemu.org/download/#windows>

After the download is complete, install it.

3. Add QEMU path into Environment Variables as shown in the image below:



4. Open the command Prompt/Powershell and execute the following command:

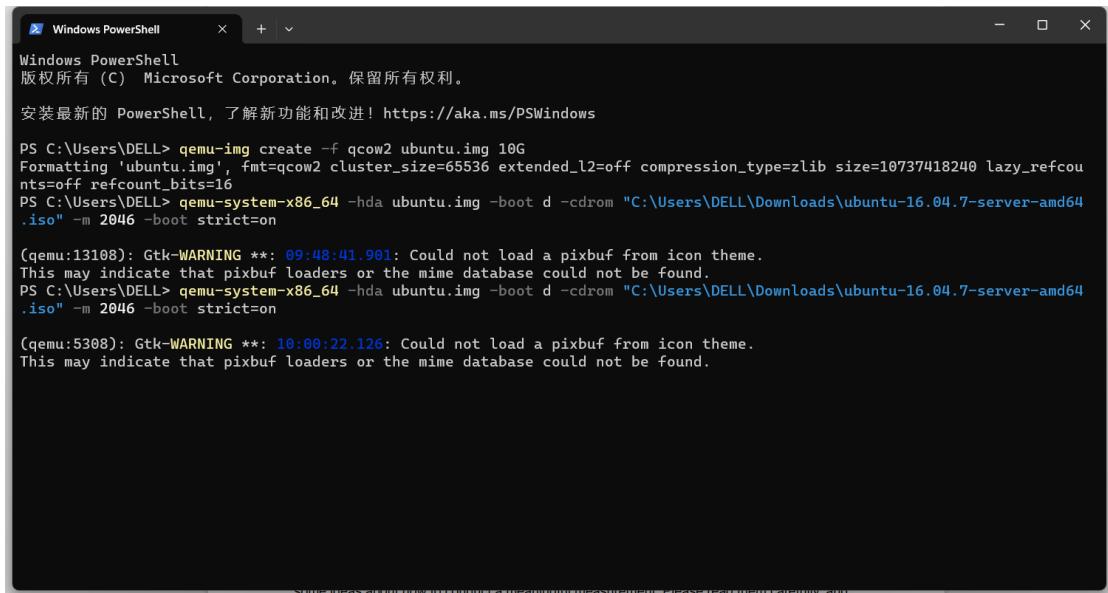
a.Create QEMU image of ubuntu in qcow2 file format using following command:

```
qemu-img create -f qcow2 ubuntu.img 10G
```

```
Windows PowerShell
版权所有 (C) Microsoft Corporation。保留所有权利。
4 安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows
PS C:\Users\DELL> qemu-img create -f qcow2 ubuntu.img 10G
Formatting 'ubuntu.img', fmt=qcow2 cluster_size=65536 extended_l2=off compression_type=zlib size=10737418240 lazy_refcounts=off refcount_bits=16
PS C:\Users\DELL>
```

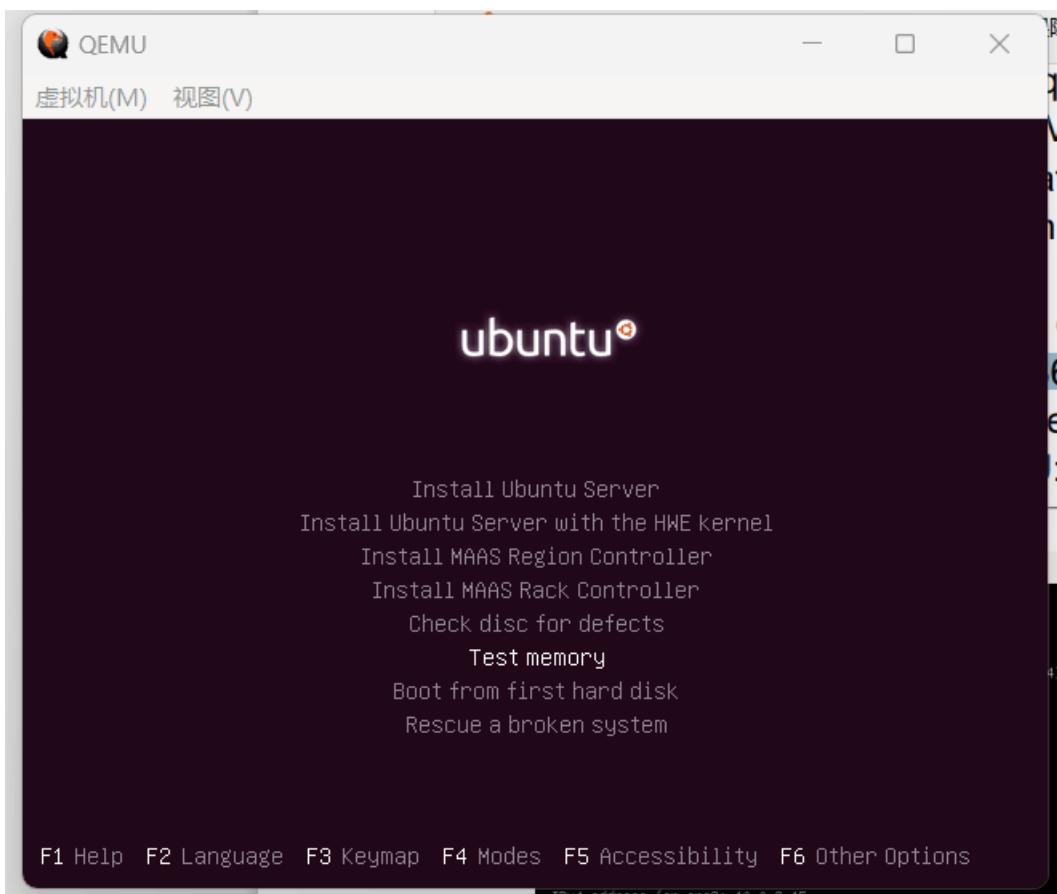
b. Boot iso file on QEMU with the following command:

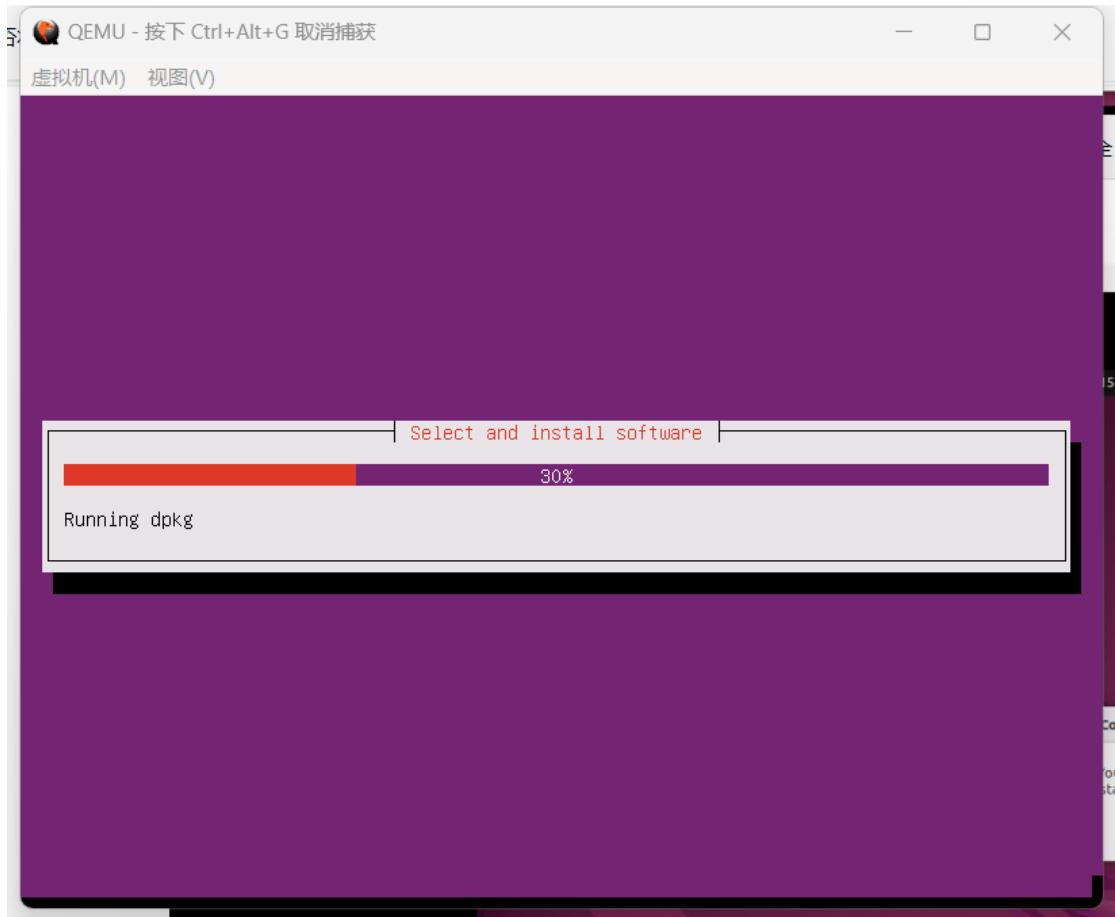
```
qemu-system-x86_64 -drive file=ubuntu.img, format=qcow2 -cdrom "C:\Users\DELL\Downloads\ubuntu-16.04.7-server-amd64.iso" -m 2048 -boot d
```



```
Windows PowerShell
版权所有 (C) Microsoft Corporation。保留所有权利。
安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows
PS C:\Users\DELL> qemu-img create -f qcow2 ubuntu.img 10G
Formatting 'ubuntu.img', fmt=qcow2 cluster_size=65536 extended_l2=off compression_type=zlib size=10737418240 lazy_refcou
nts=off refcount_bits=16
PS C:\Users\DELL> qemu-system-x86_64 -hda ubuntu.img -boot d -cdrom "C:\Users\DELL\Downloads\ubuntu-16.04.7-server-amd64
.iso" -m 2046 -boot strict=on
(qemu:13108): Gtk-WARNING **: 09:48:41.901: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
PS C:\Users\DELL> qemu-system-x86_64 -hda ubuntu.img -boot d -cdrom "C:\Users\DELL\Downloads\ubuntu-16.04.7-server-amd64
.iso" -m 2046 -boot strict=on
(qemu:5308): Gtk-WARNING **: 10:00:22.126: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

c. The ubuntu now boots up and we do the normal installation as shown in the following images:





d. Then we can create an image in raw format in a similar way:

```
Windows PowerShell
版权所有 (C) Microsoft Corporation。保留所有权利。
安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows
PS C:\Users\DELL> qemu-img create -f raw disk1.img 10G
Formatting 'disk1.img', fmt=raw size=10737418240
```

e. When starting the qemu VM, I used two different smp and two different m values:

```
(qemu:19212): Gtk-WARNING **: 18:22:45.467: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 2 -m 512
```

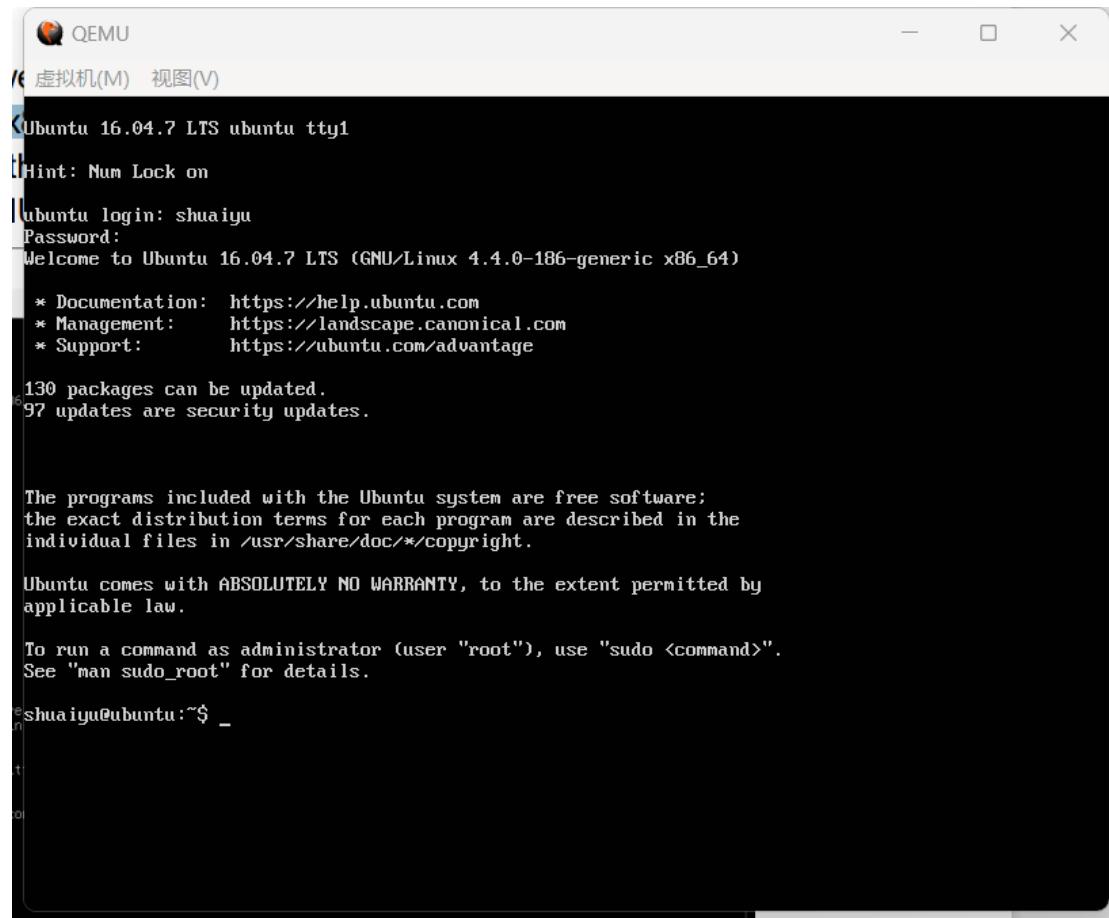
Use -smp 2 to simulate a dual-core processor, which is useful for scenarios where multi-core processing needs to be simulated, such as testing the behavior of software on multiple cores.

512MB of memory is allocated (via -m 512) in order to test the system's behavior in a resource-constrained environment.

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 2 -m 512
(qemu:15892): Gtk-WARNING **: 18:27:17.636: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 4 -m 4096
(qemu:17920): Gtk-WARNING **: 18:30:24.825: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

This time -smp 4 is used to simulate a quad-core processor, suitable for simulating more powerful

computing capabilities, such as running applications with higher memory or CPU requirements. Using -m 4096 allocates 4GB of memory to provide sufficient resources for running large applications or more complex operating systems.



The screenshot shows a QEMU terminal window titled "QEMU" with the sub-tab "虚拟机(M) 视图(V)". The terminal displays the following text:

```
Ubuntu 16.04.7 LTS ubuntu tty1
Hint: Num Lock on
ubuntu login: shuaiyu
Password:
Welcome to Ubuntu 16.04.7 LTS (GNU/Linux 4.4.0-186-generic x86_64)

 * Documentation: https://help.ubuntu.com
 * Management: https://landscape.canonical.com
 * Support: https://ubuntu.com/advantage

130 packages can be updated.
97 updates are security updates.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

shuaiyu@ubuntu:~$ _
```

## 5. Following commands installs sysbench on QEMU

```
sudo apt-get update
sudo apt install sysbench
```

# Operating System Virtualization Setup

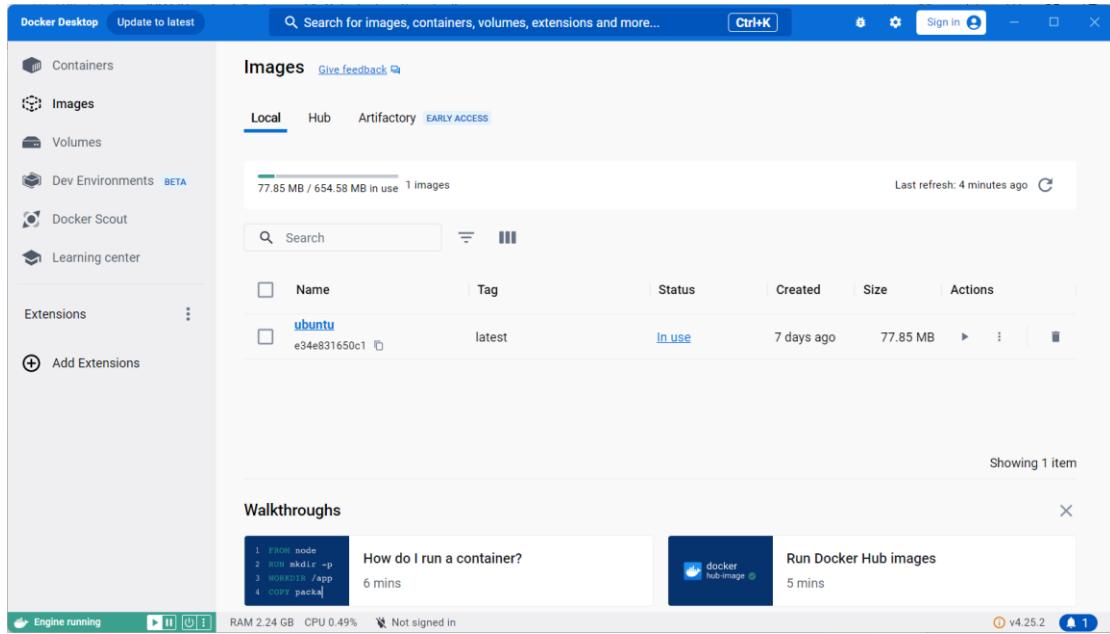
## Docker Setup:

- Create and start a new container based on Ubuntu image:

```
docker run ubuntu
```

- Start a bash shell in the Ubuntu container:

```
docker run -it ubuntu bash
```



The above screenshot shows the image id highlighted of the Ubuntu image that we created and started the bash script.

Image ID: e34e831650c1bb0be9b6f61c6755749cb8ea2053ba91c6cda27fded9e089811f

c. Now, to get the sudo command working we run the following commands:

apt-get update

apt-get -y install sudo

Following command installs sysbench:

sudo apt install -y sysbench

d. When starting a bash shell in the Ubuntu container, I used two different parameters for cpu and memory for experimentation

```

Windows PowerShell
版权所有 (C) Microsoft Corporation。保留所有权利。
安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows

PS C:\Users\DELL> docker run -it --cpus="0.5" --memory="1g" ubuntu bash
root@814dd772671:/# exit
exit
PS C:\Users\DELL> docker run -it --cpus="1" --memory="500m" ubuntu bash
root@c2b8eef74f74:/# exit
exit
PS C:\Users\DELL>

```

I used the `--cpus="0.5"` parameter to test the performance of the container when it was restricted to

using only half a CPU core. The reference group is also `--cpus="1"`, which is very useful for understanding how to allocate resources in a multi-tenant environment to ensure that no one container takes up too much CPU time and affects other containers.

In this experiment, I used the `--memory="500m"` parameter to limit the container's memory usage to 500M. At the same time, the reference group is `--memory="1g"`, which allows you to test the behavior of the container under memory-limited conditions and how it handles insufficient memory. This is very helpful for memory management optimization of applications.

## Proof of Experiment

Docker Running Environment:

1. PS C:\Users\DELL> docker run -it --cpus="1" --memory="500m" ubuntu bash
2. PS C:\Users\DELL> docker run -it --cpus="0.5" --memory="500m" ubuntu bash
3. PS C:\Users\DELL> docker run -it --cpus="0.5" --memory="1g" ubuntu bash
4. PS C:\Users\DELL> docker run -it --cpus="1" --memory="1g" ubuntu bash

## Experiment using sysbench

Environment 1:

1. CPU test:
  - a. Test 1:  
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run

```
root@262b5cba6fe8:/# Running the test with following options:
root@262b5cba6fe8:/# Number of threads: 1
root@262b5cba6fe8:/# Initializing random number generator from current time

root@262b5cba6fe8:/# Prime numbers limit: 10000
root@262b5cba6fe8:/# Initializing worker threads...
root@262b5cba6fe8:/# Threads started!
root@262b5cba6fe8:/# CPU speed:
root@262b5cba6fe8:/#   events per second: 1395.66
root@262b5cba6fe8:/# General statistics:
root@262b5cba6fe8:/#   total time:          10.0003s
root@262b5cba6fe8:/#   total number of events: 13959
root@262b5cba6fe8:/# Latency (ms):
root@262b5cba6fe8:/#   min:                      0.69
root@262b5cba6fe8:/#   avg:                      0.72
root@262b5cba6fe8:/#   max:                      1.59
root@262b5cba6fe8:/#   95th percentile:        0.80
root@262b5cba6fe8:/#   sum:                     9995.54
root@262b5cba6fe8:/# Threads fairness:
root@262b5cba6fe8:/#   events (avg/stddev):    13959.0000/0.00
root@262b5cba6fe8:/#   execution time (avg/stddev): 9.9955/0.00
root@262b5cba6fe8:/#
```

b. Test 2:

```
sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
```

```
root@262b5cba6fe8:/# sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 4
Initializing random number generator from current time

Prime numbers limit: 100000

Initializing worker threads...

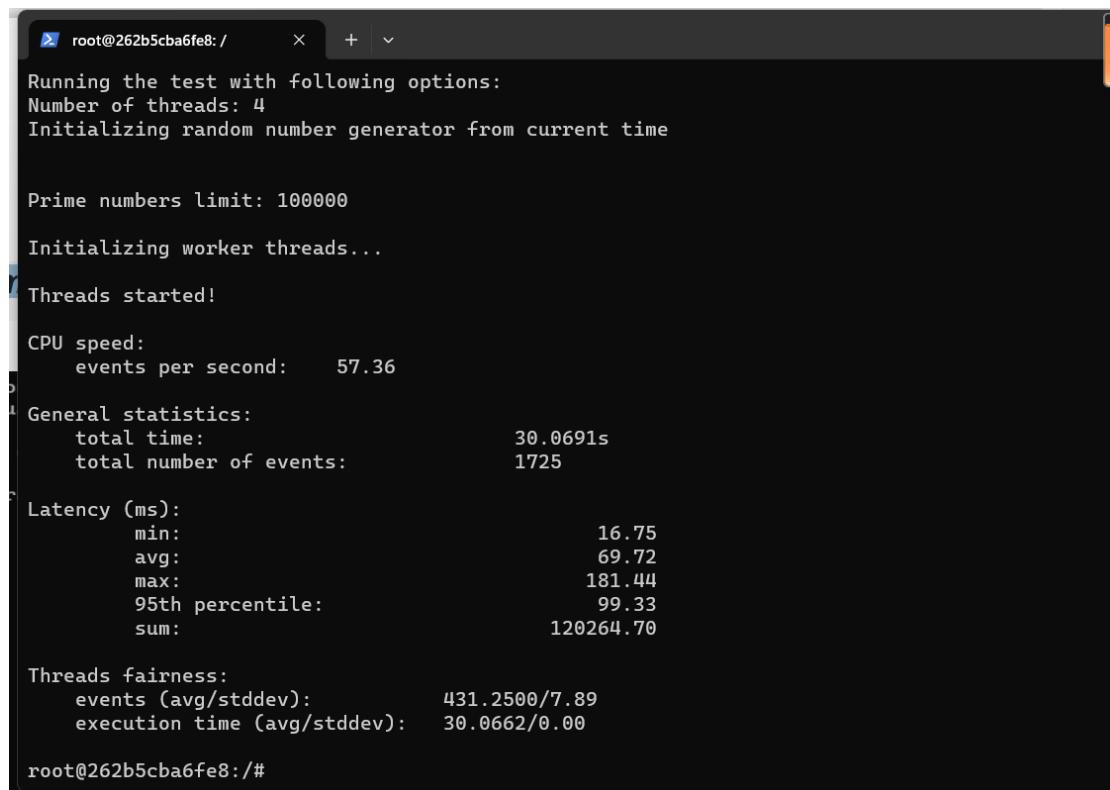
Threads started!

CPU speed:
  events per second: 57.36

General statistics:
  total time: 30.0691s
  total number of events: 1725

Latency (ms):
  min: 16.75
  avg: 69.72
  max: 181.44
  95th percentile: 99.33
  sum: 120264.70

Threads fairness:
  events (avg/stddev): 431.2500/7.89
```



```
root@262b5cba6fe8:/# sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 4
Initializing random number generator from current time

Prime numbers limit: 100000

Initializing worker threads...

Threads started!

CPU speed:
  events per second: 57.36

General statistics:
  total time: 30.0691s
  total number of events: 1725

Latency (ms):
  min: 16.75
  avg: 69.72
  max: 181.44
  95th percentile: 99.33
  sum: 120264.70

Threads fairness:
  events (avg/stddev): 431.2500/7.89
  execution time (avg/stddev): 30.0662/0.00

root@262b5cba6fe8:/#
```

2. FILE I/O test:

a. Test 1:

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare  
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run  
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```

The screenshot shows two terminal windows side-by-side. Both windows have a dark background and white text. The top window displays the initial configuration and start of the test. The bottom window displays the final results after the test has completed.

**Top Terminal Window (Test Start):**

```
root@75dad89fad92:/ ~ + ~  
2147483648 bytes written in 3.94 seconds (520.38 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Running the test with following options:  
Number of threads: 4  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 16MiB each  
2GiB total file size  
Block size 16KiB  
Number of IO requests: 0  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
    reads/s: 0.00  
    writes/s: 4981.42  
    fsyncs/s: 6414.87  
  
Throughput:  
    read, MiB/s: 0.00
```

**Bottom Terminal Window (Test Results):**

```
root@75dad89fad92:/ ~ + ~  
  
File operations:  
    reads/s: 0.00  
    writes/s: 4981.42  
    fsyncs/s: 6414.87  
  
Throughput:  
    read, MiB/s: 0.00  
    written, MiB/s: 77.83  
  
General statistics:  
    total time: 10.0361s  
    total number of events: 113876  
  
Latency (ms):  
    min: 0.00  
    avg: 0.35  
    max: 76.83  
    95th percentile: 0.39  
    sum: 39961.24  
  
Threads fairness:  
    events (avg/stddev): 28469.0000/217.92  
    execution time (avg/stddev): 9.9903/0.00  
  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Removing test files...  
root@75dad89fad92:/#
```

b. Test 2:

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr prepare
```

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr run  
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr cleanup
```

```
root@75dad89fad92:/ ~ + ~  
5368709120 bytes written in 6.87 seconds (745.71 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Running the test with following options:  
Number of threads: 8  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 40MiB each  
5GiB total file size  
Block size 16KiB  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing sequential write (creation) test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
  reads/s: 0.00  
  writes/s: 4978.78  
  fsyncs/s: 6470.40  
  
Throughput:  
  read, MiB/s: 0.00  
  written, MiB/s: 77.79
```

```
root@75dad89fad92:/ ~ + ~  
  
File operations:  
  reads/s: 0.00  
  writes/s: 4978.78  
  fsyncs/s: 6470.40  
  
Throughput:  
  read, MiB/s: 0.00  
  written, MiB/s: 77.79  
  
General statistics:  
  total time: 10.0483s  
  total number of events: 114034  
  
Latency (ms):  
  min: 0.01  
  avg: 0.70  
  max: 58.79  
  95th percentile: 5.57  
  sum: 79923.39  
  
Threads fairness:  
  events (avg/stddev): 14254.2500/178.59  
  execution time (avg/stddev): 9.9904/0.00  
  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Removing test files...  
root@75dad89fad92:/#
```

### 3. Memory test:

#### a. Test 1:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
root@75dad89fad92:/# sysbench memory --memory-block-size=1M --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 1024KiB
total size: 102400MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 102400 (22785.40 per second)
102400.00 MiB transferred (22785.40 MiB/sec)

General statistics:
    total time: 4.4926s
    total number of events: 102400

Latency (ms):
    min: 0.04
    avg: 0.04
    max: 0.35
    95th percentile: 0.05
    sum: 4469.74

Threads fairness:
    events (avg/stddev): 102400.0000/0.00
    execution time (avg/stddev): 4.4697/0.00

root@75dad89fad92:/#
```

b. Test 2:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
root@75dad89fad92:/# sysbench memory --memory-block-size=512K --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 512KiB
total size: 102400MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 204800 (45624.51 per second)
102400.00 MiB transferred (22812.26 MiB/sec)

General statistics:
    total time: 4.4873s
    total number of events: 204800

Latency (ms):
    min: 0.02
    avg: 0.02
    max: 0.29
    95th percentile: 0.02
    sum: 4450.69

Threads fairness:
    events (avg/stddev): 204800.0000/0.00
    execution time (avg/stddev): 4.4507/0.00

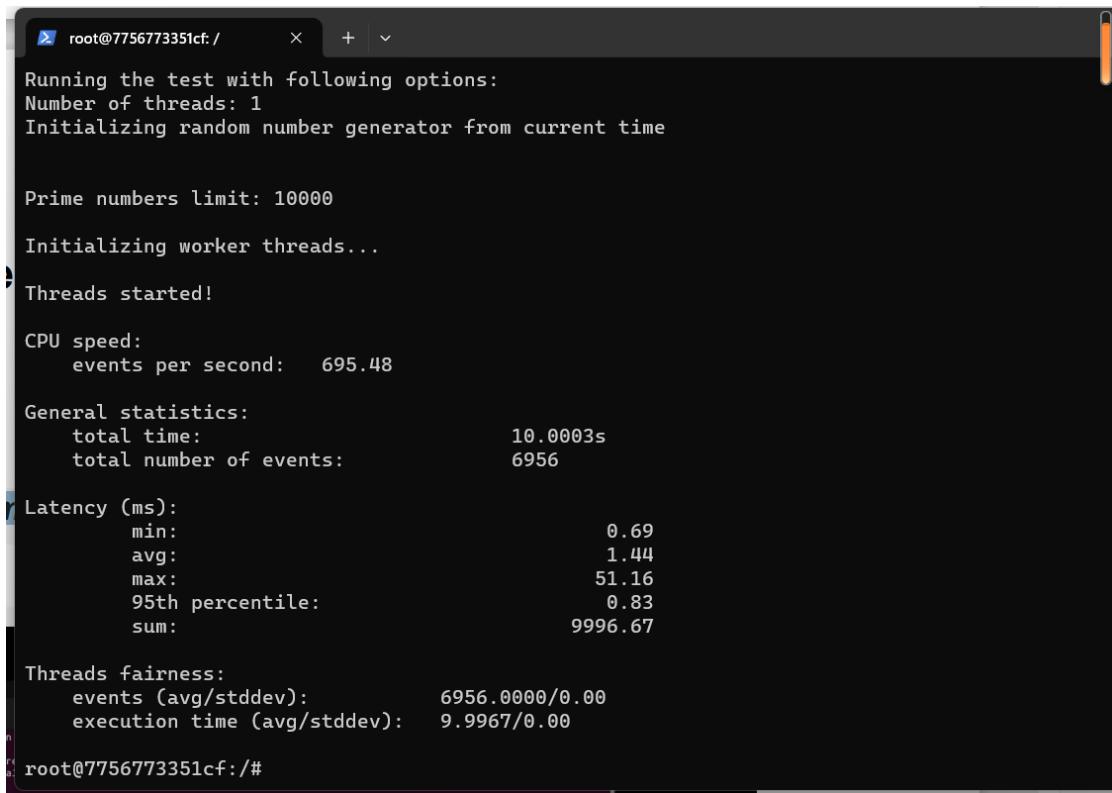
root@75dad89fad92:/#
```

## Environment 2:

### 1. CPU test:

#### a. Test 3:

```
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run
```



```
root@7756773351cf: ~ + ~
Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 10000
Initializing worker threads...
Threads started!
CPU speed:
events per second: 695.48

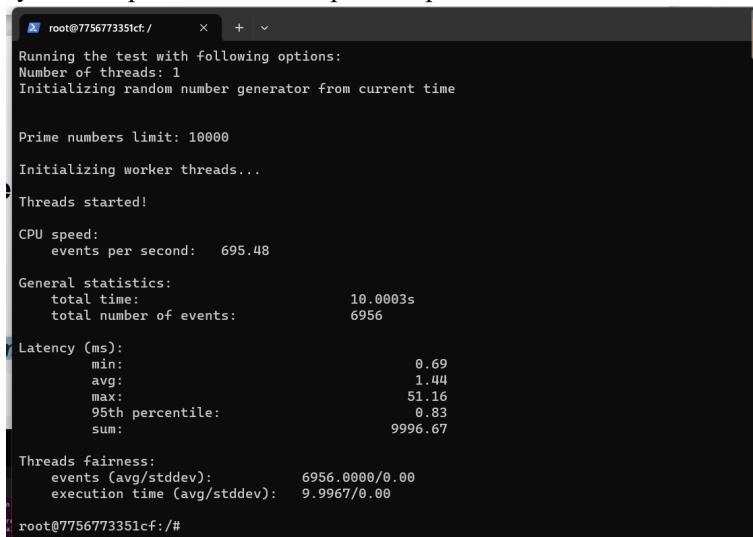
General statistics:
total time: 10.0003s
total number of events: 6956

Latency (ms):
min: 0.69
avg: 1.44
max: 51.16
95th percentile: 0.83
sum: 9996.67

Threads fairness:
events (avg/stddev): 6956.0000/0.00
execution time (avg/stddev): 9.9967/0.00
root@7756773351cf:/#
```

#### b. Test 4:

```
sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
```



```
root@7756773351cf: ~ + ~
Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 10000
Initializing worker threads...
Threads started!
CPU speed:
events per second: 695.48

General statistics:
total time: 10.0003s
total number of events: 6956

Latency (ms):
min: 0.69
avg: 1.44
max: 51.16
95th percentile: 0.83
sum: 9996.67

Threads fairness:
events (avg/stddev): 6956.0000/0.00
execution time (avg/stddev): 9.9967/0.00
root@7756773351cf:/#
```

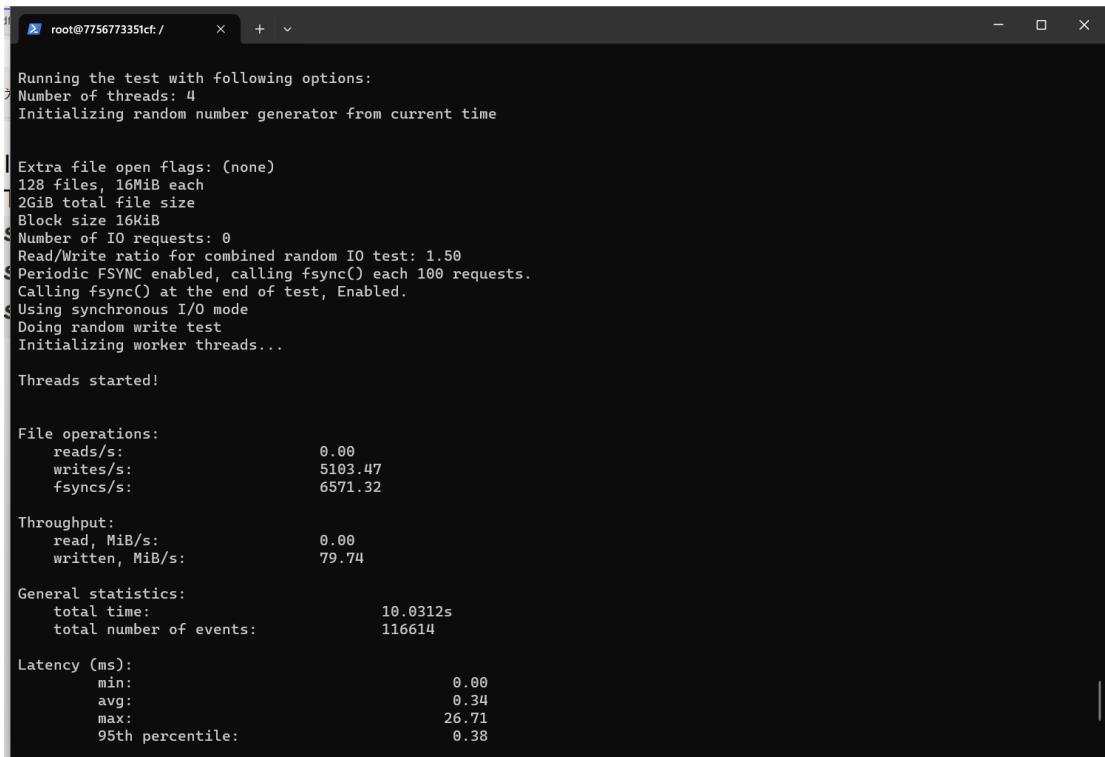
### 2. FILE I/O test:

#### a. Test 3:

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
```

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
```

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



```
Running the test with following options:
Number of threads: 4
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

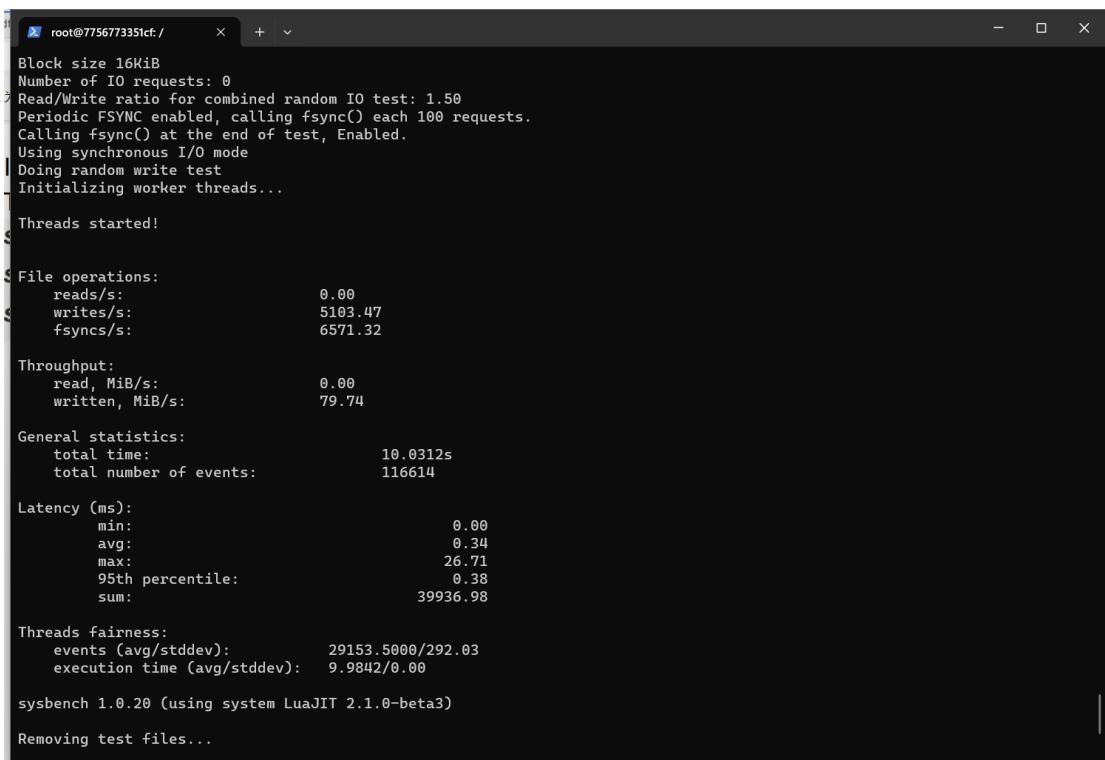
Threads started!

File operations:
  reads/s:          0.00
  writes/s:        5103.47
  fsyncs/s:        6571.32

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:   79.74

General statistics:
  total time:       10.0312s
  total number of events: 116614

Latency (ms):
  min:              0.00
  avg:              0.34
  max:             26.71
  95th percentile: 0.38
```



```
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:        5103.47
  fsyncs/s:        6571.32

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:   79.74

General statistics:
  total time:       10.0312s
  total number of events: 116614

Latency (ms):
  min:              0.00
  avg:              0.34
  max:             26.71
  95th percentile: 0.38
  sum:            39936.98

Threads fairness:
  events (avg/stddev):    29153.5000/292.03
  execution time (avg/stddev): 9.9842/0.00

sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Removing test files...
```

#### b. Test 4:

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr prepare
```

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr run
```

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr cleanup
```

```
root@7756773351cf:/home/centos/Downloads/ 5368709120 bytes written in 8.87 seconds (576.97 MiB/sec). sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 8 Initializing random number generator from current time Extra file open flags: (none) 128 files, 40MiB each 5GiB total file size Block size 16KiB Periodic FSYNC enabled, calling fsync() each 100 requests. Calling fsync() at the end of test, Enabled. Using synchronous I/O mode Doing sequential write (creation) test Initializing worker threads... Threads started! File operations: reads/s: 0.00 writes/s: 4246.06 fsyncs/s: 5528.71 Throughput: read, MiB/s: 0.00 written, MiB/s: 66.34 General statistics: total time: 10.0788s total number of events: 97505 Latency (ms): min: 0.01 avg: 0.82 max: 223.85 95th percentile: 5.47
```

```
root@7756773351cf:/home/centos/Downloads/ 5GiB total file size Block size 16KiB Periodic FSYNC enabled, calling fsync() each 100 requests. Calling fsync() at the end of test, Enabled. Using synchronous I/O mode Doing sequential write (creation) test Initializing worker threads... Threads started! File operations: reads/s: 0.00 writes/s: 4246.06 fsyncs/s: 5528.71 Throughput: read, MiB/s: 0.00 written, MiB/s: 66.34 General statistics: total time: 10.0788s total number of events: 97505 Latency (ms): min: 0.01 avg: 0.82 max: 223.85 95th percentile: 5.47 sum: 79950.62 Threads fairness: events (avg/stddev): 12188.1250/273.40 execution time (avg/stddev): 9.9938/0.00 sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3) Removing test files... root@7756773351cf:/#
```

### 3. Memory test:

#### c. Test 3:

sysbench memory --memory-block-size=1M --time=30 run

```
root@7756773351cf:/# sysbench memory --memory-block-size=1M --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 1024KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 102400 (11611.51 per second)
102400.00 MiB transferred (11611.51 MiB/sec)

General statistics:
  total time:           8.8176s
  total number of events: 102400

Latency (ms):
  min:                 0.04
  avg:                 0.09
  max:                50.37
  95th percentile:    0.04
  sum:                8791.37

Threads fairness:
  events (avg/stddev):   102400.0000/0.00
  execution time (avg/stddev):  8.7914/0.00

root@7756773351cf:/#
```

d. Test 4:

sysbench memory --memory-block-size=512K --time=30 run

```
root@7756773351cf:/# sysbench memory --memory-block-size=512K --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 512KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 204800 (23373.37 per second)
102400.00 MiB transferred (11686.69 MiB/sec)

General statistics:
  total time:           8.7606s
  total number of events: 204800

Latency (ms):
  min:                 0.02
  avg:                 0.04
  max:                50.33
  95th percentile:    0.02
  sum:                8720.85

Threads fairness:
  events (avg/stddev):   204800.0000/0.00
  execution time (avg/stddev):  8.7209/0.00

root@7756773351cf:/#
```

Environment 3:

1. CPU test:

a. Test 5:

sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run

```
root@231add996eb3:/# sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 10000
Initializing worker threads...
Threads started!

CPU speed:
events per second: 701.74

General statistics:
total time: 10.0367s
total number of events: 7044

Latency (ms):
min: 0.69
avg: 1.42
max: 51.29
95th percentile: 0.81
sum: 10033.01

Threads fairness:
events (avg/stddev): 7044.0000/0.00
execution time (avg/stddev): 10.0330/0.00
```

b. Test 6:

```
sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
```

```
root@231add996eb3:/# sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 4
Initializing random number generator from current time

Prime numbers limit: 100000
Initializing worker threads...
Threads started!

CPU speed:
events per second: 29.09

General statistics:
total time: 30.1840s
total number of events: 878

Latency (ms):
min: 16.75
avg: 137.17
max: 199.96
95th percentile: 196.89
sum: 120439.41

Threads fairness:
events (avg/stddev): 219.5000/2.29
execution time (avg/stddev): 30.1099/0.04
```

2. FILE I/O test:

a. Test 5:

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```

```
root@231add996eb3:/ 2147483648 bytes written in 4.18 seconds (490.01 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Running the test with following options:  
Number of threads: 4  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 16MiB each  
2GiB total file size  
Block size 16KiB  
Number of IO requests: 0  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
  reads/s:          0.00  
  writes/s:        5209.25  
  fsyncs/s:        6706.49  
  
Throughput:  
  read, MiB/s:      0.00  
  written, MiB/s:   81.39
```

```
Threads started!  
  
File operations:  
  reads/s:          0.00  
  writes/s:        5209.25  
  fsyncs/s:        6706.49  
  
Throughput:  
  read, MiB/s:      0.00  
  written, MiB/s:   81.39  
  
General statistics:  
  total time:           10.0387s  
  total number of events: 119120  
  
Latency (ms):  
  min:                 0.00  
  avg:                0.34  
  max:                24.47  
  95th percentile:     0.37  
  sum:               39961.20  
  
Threads fairness:  
  events (avg/stddev): 29780.0000/447.45  
  execution time (avg/stddev): 9.9903/0.00  
  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Removing test files...  
root@231add996eb3:/#
```

b. Test 6:

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr prepare  
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr run  
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr cleanup
```

```
root@231add996eb3:/ 5368709120 bytes written in 11.01 seconds (464.99 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Running the test with following options:  
Number of threads: 8  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 40MiB each  
5GiB total file size  
Block size 16KiB  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing sequential write (creation) test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
    reads/s:          0.00  
    writes/s:        3936.05  
    fsyncs/s:        5131.41  
  
Throughput:  
    read, MiB/s:      0.00  
    written, MiB/s:   61.50  
  
General statistics:  
    total time:       10.0342s
```

```
Threads started!  
  
File operations:  
    reads/s:          0.00  
    writes/s:        3936.05  
    fsyncs/s:        5131.41  
  
Throughput:  
    read, MiB/s:      0.00  
    written, MiB/s:   61.50  
  
General statistics:  
    total time:       10.0342s  
    total number of events: 89972  
  
Latency (ms):  
    min:              0.01  
    avg:             0.89  
    max:             99.64  
    95th percentile: 5.28  
    sum:            79923.64  
  
Threads fairness:  
    events (avg/stddev): 11246.5000/420.40  
    execution time (avg/stddev): 9.9905/0.01  
  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Removing test files...  
root@231add996eb3:/#
```

### 3. Memory test:

#### a. Test 5:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
root@231add996eb3:/# sysbench memory --memory-block-size=1M --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 1024KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 102400 (11467.23 per second)
102400.00 MiB transferred (11467.23 MiB/sec)

General statistics:
  total time: 8.9286s
  total number of events: 102400

Latency (ms):
  min: 0.04
  avg: 0.09
  max: 50.35
  95th percentile: 0.05
  sum: 8906.87

Threads fairness:
  events (avg/stddev): 102400.0000/0.00
  execution time (avg/stddev): 8.9069/0.00

root@231add996eb3:/#
```

b. Test 6:

sysbench memory --memory-block-size=512K --time=30 run

```
root@231add996eb3:/# execution time (avg/stddev): 8.9069/0.00
root@231add996eb3:/# sysbench memory --memory-block-size=512K --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 512KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 204800 (22827.02 per second)
102400.00 MiB transferred (11413.51 MiB/sec)

General statistics:
  total time: 8.9706s
  total number of events: 204800

Latency (ms):
  min: 0.02
  avg: 0.04
  max: 50.39
  95th percentile: 0.02
  sum: 8880.70

Threads fairness:
  events (avg/stddev): 204800.0000/0.00
  execution time (avg/stddev): 8.8807/0.00

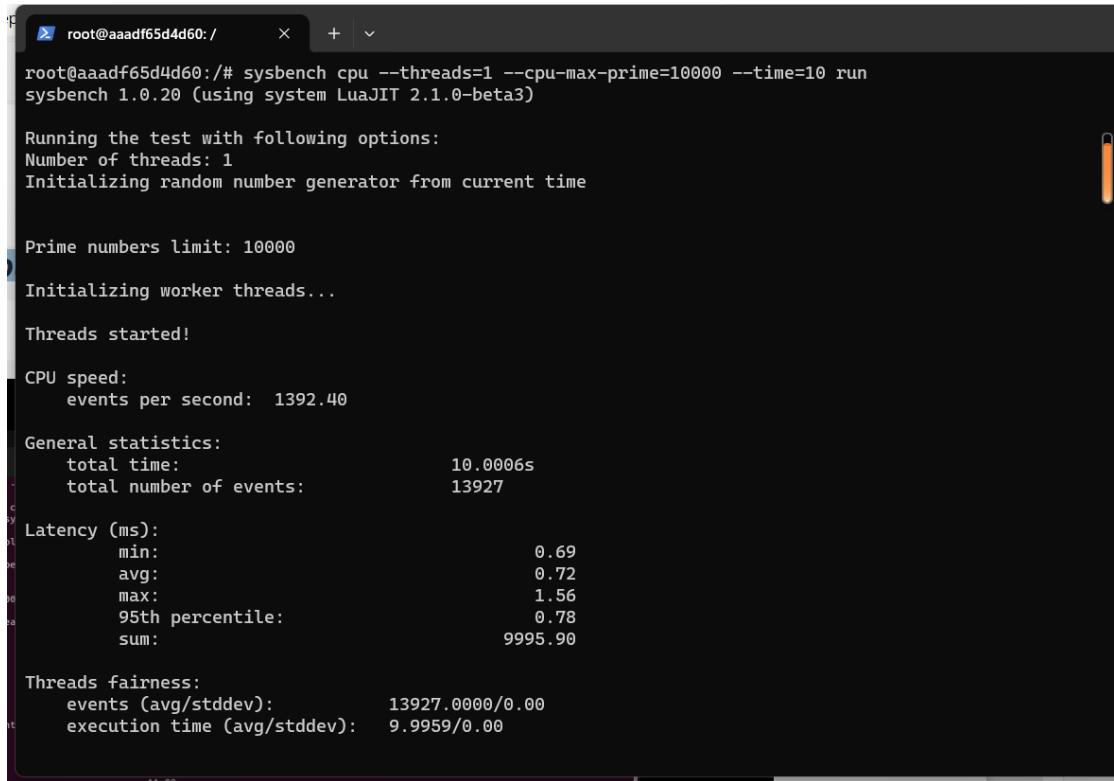
root@231add996eb3:/#
```

Environment 4:

1. CPU test:

a. Test 7:

```
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run
```



```
root@aaadf65d4d60:/# sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 10000

Initializing worker threads...

Threads started!

CPU speed:
events per second: 1392.40

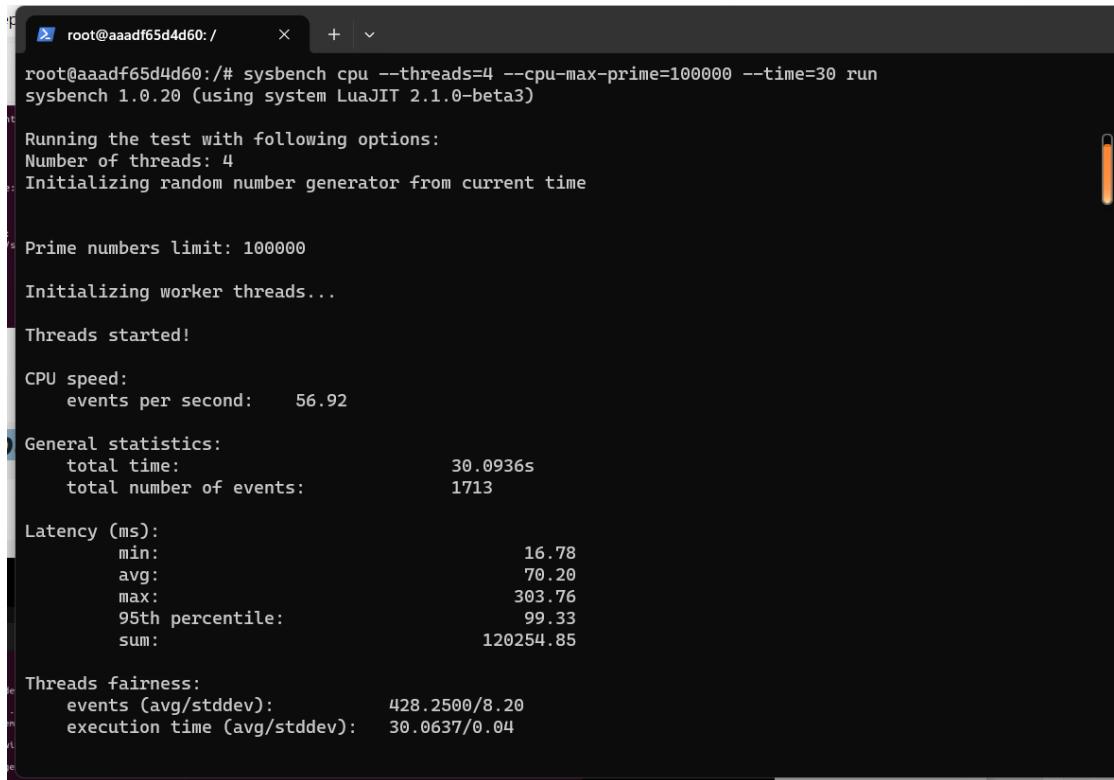
General statistics:
total time: 10.0006s
total number of events: 13927

Latency (ms):
min: 0.69
avg: 0.72
max: 1.56
95th percentile: 0.78
sum: 9995.90

Threads fairness:
events (avg/stddev): 13927.0000/0.00
execution time (avg/stddev): 9.9959/0.00
```

b. Test 8:

```
sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
```



```
root@aaadf65d4d60:/# sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 4
Initializing random number generator from current time

Prime numbers limit: 100000

Initializing worker threads...

Threads started!

CPU speed:
events per second: 56.92

General statistics:
total time: 30.0936s
total number of events: 1713

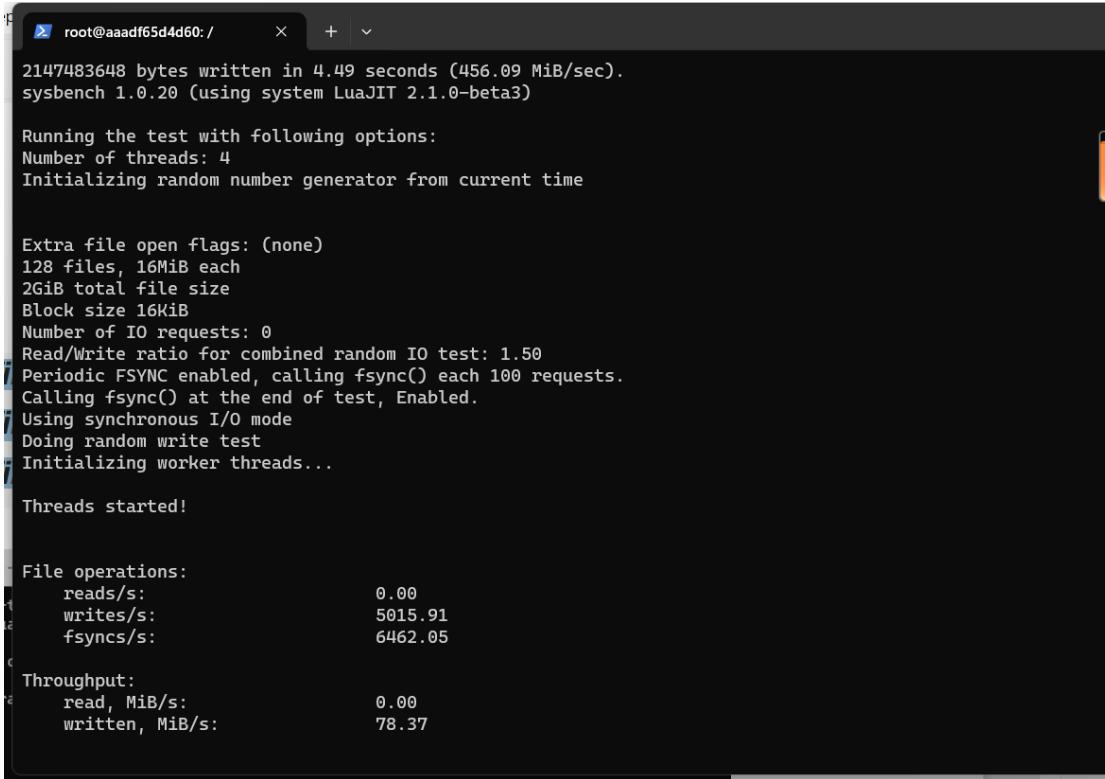
Latency (ms):
min: 16.78
avg: 70.20
max: 303.76
95th percentile: 99.33
sum: 120254.85

Threads fairness:
events (avg/stddev): 428.2500/8.20
execution time (avg/stddev): 30.0637/0.04
```

2. FILE I/O test:

a. Test 7:

```
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare  
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run  
sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



The screenshot shows a terminal window with the following output:

```
root@aaadf65d4d60:/ ~ + ~  
2147483648 bytes written in 4.49 seconds (456.09 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
  
Running the test with following options:  
Number of threads: 4  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 16MiB each  
2GiB total file size  
Block size 16KiB  
Number of IO requests: 0  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
  reads/s: 0.00  
  writes/s: 5015.91  
  fsyncs/s: 6462.05  
  
Throughput:  
  read, MiB/s: 0.00  
  written, MiB/s: 78.37
```

b. Test 8:

```
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr prepare  
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr run  
sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr cleanup
```

```
root@aaadf65d4d60:/ 5368709120 bytes written in 6.72 seconds (761.81 MiB/sec).  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
Running the test with following options:  
Number of threads: 8  
Initializing random number generator from current time  
  
Extra file open flags: (none)  
128 files, 40MiB each  
5GiB total file size  
Block size 16KiB  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing sequential write (creation) test  
Initializing worker threads...  
  
Threads started!  
  
File operations:  
    reads/s:          0.00  
    writes/s:         5334.13  
    fsyncs/s:         6920.71  
  
Throughput:  
    read, MiB/s:     0.00  
    written, MiB/s:  83.35  
  
General statistics:  
    total time:      10.0286s  
  
Threads started!  
  
File operations:  
    reads/s:          0.00  
    writes/s:         5334.13  
    fsyncs/s:         6920.71  
  
Throughput:  
    read, MiB/s:     0.00  
    written, MiB/s:  83.35  
  
General statistics:  
    total time:      10.0286s  
    total number of events: 121889  
  
Latency (ms):  
    min:              0.01  
    avg:              0.66  
    max:              54.70  
    95th percentile:  5.57  
    sum:              79958.95  
  
Threads fairness:  
    events (avg/stddev): 15236.1250/90.40  
    execution time (avg/stddev): 9.9949/0.00  
  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
Removing test files...  
root@aaadf65d4d60:/#
```

3. Memory test:

a. Test 7:

sysbench memory --memory-block-size=1M --time=30 run

```
root@aaadf65d4d60:/# sysbench memory --memory-block-size=1M --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 1024KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...
Threads started!

Total operations: 102400 (21874.04 per second)
102400.00 MiB transferred (21874.04 MiB/sec)

General statistics:
  total time: 4.6800s
  total number of events: 102400

  Latency (ms):
    min: 0.04
    avg: 0.05
    max: 0.35
    95th percentile: 0.05
    sum: 4658.56

  Threads fairness:
    events (avg/stddev): 102400.0000/0.00
    execution time (avg/stddev): 4.6586/0.00
```

c. Test 8:

sysbench memory --memory-block-size=512K --time=30 run

```
root@aaadf65d4d60:/# sysbench memory --memory-block-size=512K --time=30 run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 512KiB
  total size: 102400MiB
  operation: write
  scope: global

Initializing worker threads...
Threads started!

Total operations: 204800 (44954.10 per second)
102400.00 MiB transferred (22477.05 MiB/sec)

General statistics:
  total time: 4.5544s
  total number of events: 204800

  Latency (ms):
    min: 0.02
    avg: 0.02
    max: 0.34
    95th percentile: 0.02
    sum: 4515.84

  Threads fairness:
    events (avg/stddev): 204800.0000/0.00
    execution time (avg/stddev): 4.5158/0.00
```

QEMU VM Running Environment:

Image 1: ubuntu.image, format: qcow2

Environment 1:

```
Windows PowerShell + 
Windows PowerShell 版权所有 (C) Microsoft Corporation。保留所有权利。
安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 2 -m 512
(qemu:11104): Gtk-WARNING **: 06:45:41.141: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 2:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 2 -m 4096
(qemu:14160): Gtk-WARNING **: 07:24:07.396: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 3:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 4 -m 512
(qemu:13692): Gtk-WARNING **: 07:39:40.884: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 4:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=ubuntu.img,format=qcow2 -smp 4 -m 4096
(qemu:11248): Gtk-WARNING **: 07:58:30.131: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

## Experiment using sysbench

Environment 1:

1. CPU test:

a. Test 1:

```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
mutex - Mutex performance test
oltp - OLTP test

Commands: prepare run cleanup help version

See 'sysbench --test=<name> help' for a list of options for each test.

shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

Maximum prime number checked in CPU test: 10000

Test execution summary:
    total time:          10.0097s
    total number of events: 5854
    total time taken by event execution: 9.9703
    per-request statistics:
        min:                 1.58ms
        avg:                 1.70ms
        max:                12.74ms
        approx. 95 percentile: 1.83ms

Threads fairness:
    events (avg/stddev): 5854.0000/0.00
    execution time (avg/stddev): 9.9703/0.00

shuaigu@ubuntu:~$
```

b. Test 2:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
approx. 95 percentile:           1.83ms

Threads fairness:
    events (avg/stddev):      5854.0000/0.00
    execution time (avg/stddev): 9.9703/0.00

shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
    total time:          30.0463s
    total number of events: 1656
    total time taken by event execution: 120.0665
    per-request statistics:
        min:                 47.00ms
        avg:                 72.50ms
        max:                92.12ms
        approx. 95 percentile: 80.21ms

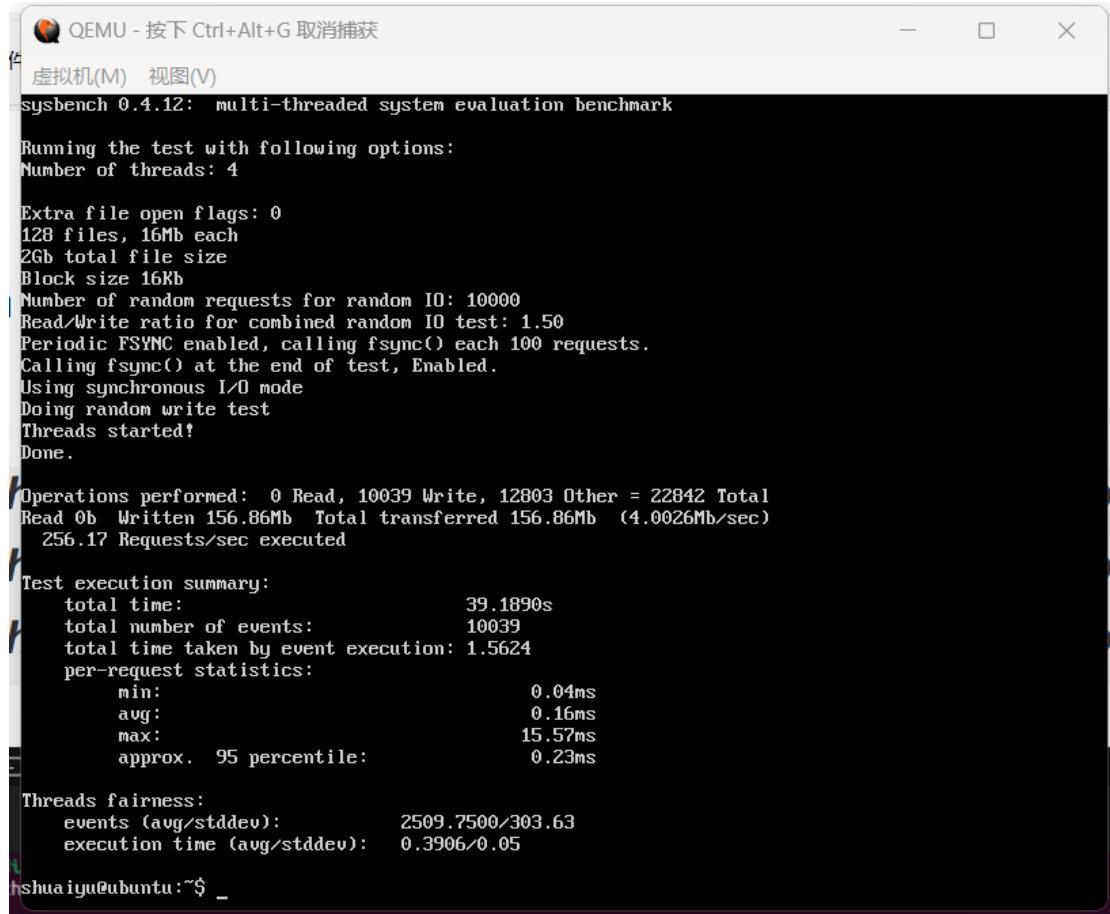
Threads fairness:
    events (avg/stddev): 414.0000/0.71
    execution time (avg/stddev): 30.0166/0.01

shuaigu@ubuntu:~$
```

## 2. FILE I/O test:

### a. Test 1:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare  
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run  
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



```
QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
Running the test with following options:  
Number of threads: 4  
  
Extra file open flags: 0  
128 files, 16Mb each  
2Gb total file size  
Block size 16Kb  
Number of random requests for random IO: 10000  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Threads started!  
Done.  
  
Operations performed: 0 Read, 10039 Write, 12803 Other = 22842 Total  
Read 0b Written 156.86Mb Total transferred 156.86Mb (4.0026Mb/sec)  
256.17 Requests/sec executed  
  
Test execution summary:  
total time: 39.1890s  
total number of events: 10039  
total time taken by event execution: 1.5624  
per-request statistics:  
    min: 0.04ms  
    avg: 0.16ms  
    max: 15.57ms  
    approx. 95 percentile: 0.23ms  
  
Threads fairness:  
events (avg/stddev): 2509.7500/303.63  
execution time (avg/stddev): 0.3906/0.05  
shuaiyu@ubuntu:~$
```

### b. Test 2:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)

128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10039 Write, 12803 Other = 22842 Total
Read 0b Written 156.86Mb Total transferred 156.86Mb (4.0026Mb/sec)
256.17 Requests/sec executed

Test execution summary:
    total time:                      39.1890s
    total number of events:           10039
    total time taken by event execution: 1.5624
    per-request statistics:
        min:                           0.04ms
        avg:                           0.16ms
        max:                           15.57ms
        approx. 95 percentile:          0.23ms

Threads fairness:
    events (avg/stddev):            2509.7500/303.63
    execution time (avg/stddev):     0.3906/0.05

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
prepare_
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)

sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10009 Write, 12803 Other = 22812 Total
Read 0b Written 156.39Mb Total transferred 156.39Mb (3.5724Mb/sec)
228.64 Requests/sec executed

Test execution summary:
    total time:                      43.7771s
    total number of events:           10009
    total time taken by event execution: 4.1684
    per-request statistics:
        min:                           0.05ms
        avg:                           0.42ms
        max:                           53.88ms
        approx. 95 percentile:          0.43ms

Threads fairness:
    events (avg/stddev):            1251.1250/153.08
    execution time (avg/stddev):     0.5211/0.07

shuaiyu@ubuntu:~$ _
```

### 3. Memory test:

#### a. Test 1:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 45647 ( 1521.24 ops/sec)

45647.00 MB transferred (1521.24 MB/sec)

Test execution summary:
  total time:                      30.0065s
  total number of events:          45647
  total time taken by event execution: 29.7676
  per-request statistics:
    min:                           0.61ms
    avg:                           0.65ms
    max:                           11.69ms
    approx. 95 percentile:          0.72ms

Threads fairness:
  events (avg/stddev):           45647.0000/0.00
  execution time (avg/stddev):   29.7676/0.00

shuaigu@ubuntu:~$
```

b. Test 2:

sysbench memory --memory-block-size=512K --time=30 run

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 91085 ( 3035.53 ops/sec)

45542.50 MB transferred (1517.76 MB/sec)

Test execution summary:
  total time:                      30.0063s
  total number of events:          91085
  total time taken by event execution: 29.5965
  per-request statistics:
    min:                           0.31ms
    avg:                           0.32ms
    max:                           4.24ms
    approx. 95 percentile:          0.37ms

Threads fairness:
  events (avg/stddev):           91085.0000/0.00
  execution time (avg/stddev):   29.5965/0.00

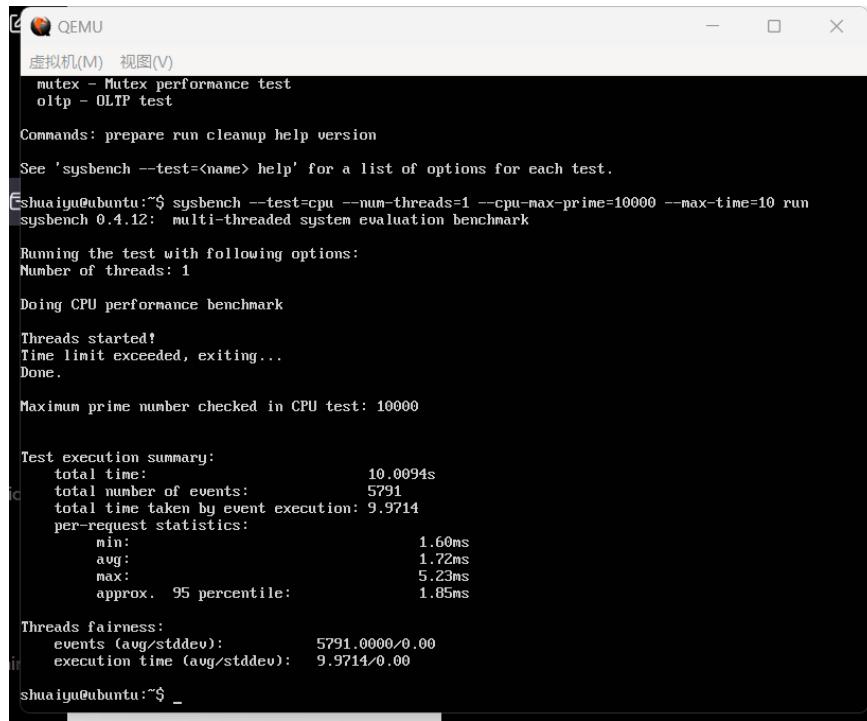
shuaigu@ubuntu:~$
```

Environment 2:

1. CPU test:

a. Test 3:

```
sysbench --test(cpu) --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



The screenshot shows a terminal window titled "QEMU" with the following content:

```
mutex - Mutex performance test
oltp - OLTP test

Commands: prepare run cleanup help version
See 'sysbench --test=<name> help' for a list of options for each test.

[shuaiyu@ubuntu:~$] sysbench --test(cpu) --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

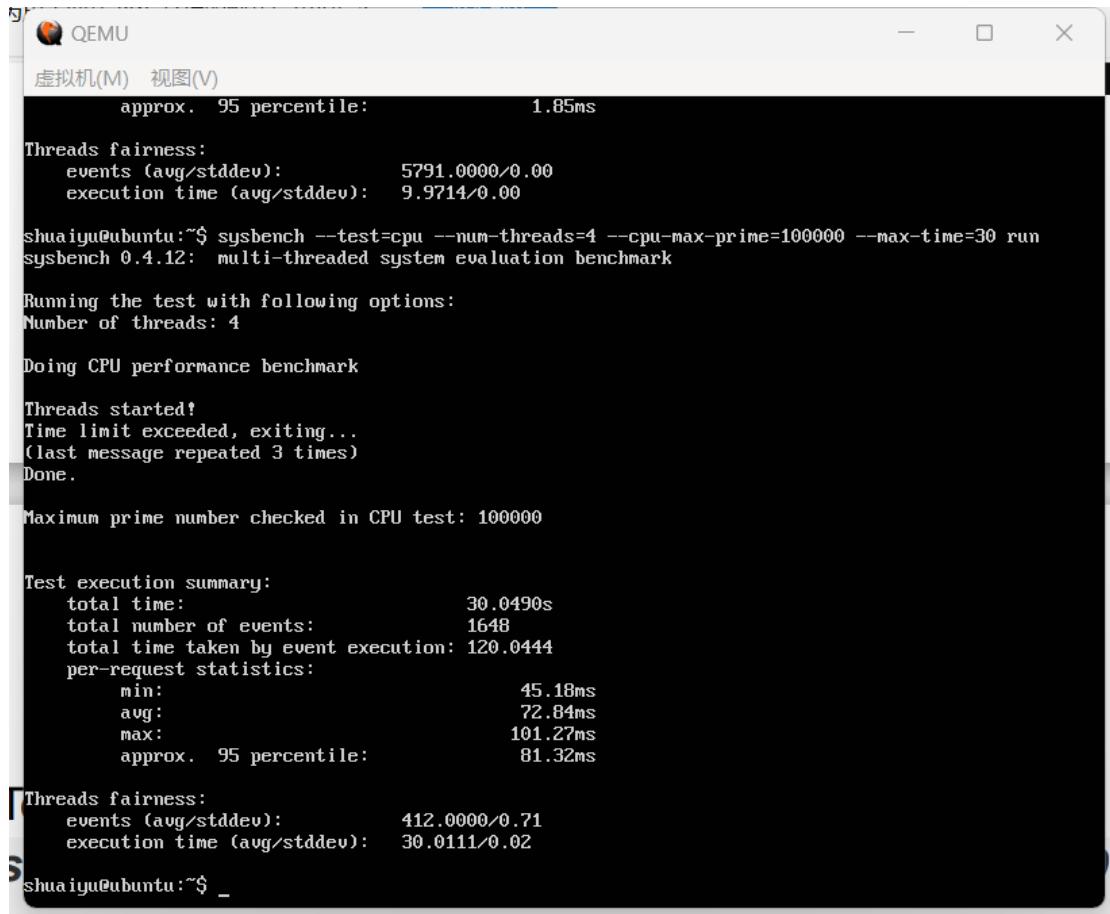
Maximum prime number checked in CPU test: 10000

Test execution summary:
  total time:          10.0094s
  total number of events:      5791
  total time taken by event execution: 9.9714
  per-request statistics:
    min:                 1.60ms
    avg:                 1.72ms
    max:                 5.23ms
    approx. 95 percentile: 1.85ms

Threads fairness:
  events (avg/stddev):   5791.0000/0.00
  execution time (avg/stddev): 9.9714/0.00
[shuaiyu@ubuntu:~$]
```

b. Test 4:

```
sysbench --test(cpu) --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



```
QEMU
虚拟机(M) 视图(V)

approx. 95 percentile: 1.85ms

Threads fairness:
events (avg/stddev): 5791.0000/0.00
execution time (avg/stddev): 9.9714/0.00

shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
total time: 30.0490s
total number of events: 1648
total time taken by event execution: 120.0444
per-request statistics:
    min: 45.18ms
    avg: 72.84ms
    max: 101.27ms
    approx. 95 percentile: 81.32ms

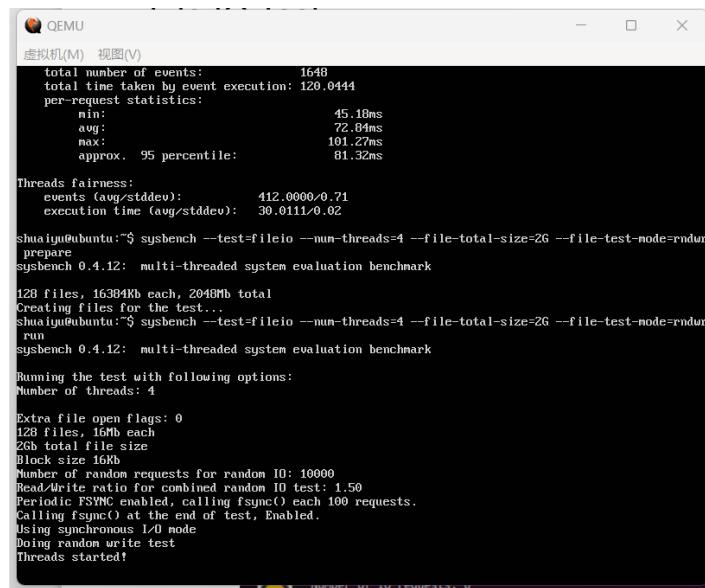
Threads fairness:
events (avg/stddev): 412.0000/0.71
execution time (avg/stddev): 30.0111/0.02

shuaigu@ubuntu:~$ _
```

## 2. FILE I/O test:

### a. Test 3:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



```
QEMU
虚拟机(M) 视图(V)

total number of events: 1648
total time taken by event execution: 120.0444
per-request statistics:
    min: 45.18ms
    avg: 72.84ms
    max: 101.27ms
    approx. 95 percentile: 81.32ms

Threads fairness:
events (avg/stddev): 412.0000/0.71
execution time (avg/stddev): 30.0111/0.02

shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 16384Kb each, 2048Mb total
Creating files for the test...
shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10114 Write, 12803 Other = 22917 Total
Read 0b Written 158.03Mb Total transferred 158.03Mb (3.5372Mb/sec)
226.38 Requests/sec executed

Test execution summary:
    total time:          44.6770s
    total number of events: 10114
    total time taken by event execution: 0.9640
    per-request statistics:
        min:           0.04ms
        avg:           0.10ms
        max:          22.44ms
        approx. 95 percentile: 0.12ms

Threads fairness:
    events (avg/stddev): 2528.5000/182.93
    execution time (avg/stddev): 0.2410/0.03

shuaiyu@ubuntu:~$
```

b. Test 4:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
max:          22.44ns
approx. 95 percentile: 0.12ns

Threads fairness:
events (avg/stddev): 2528.5000/182.93
execution time (avg/stddev): 0.2410/0.03

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndur
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndur
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 40960Kb each, 5120Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndur
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Threads started!
Done.

Operations performed: 0 Read, 10015 Write, 12802 Other = 22817 Total
Read 0b Written 156.48Mb Total transferred 156.48Mb (4.3268Mb/sec)
276.92 Requests/sec executed

Test execution summary:
    total time:                      36.1663s
    total number of events:           10015
    total time taken by event execution: 3.7545
    per-request statistics:
        min:                           0.04ms
        avg:                           0.37ms
        max:                           54.08ms
        approx. 95 percentile:          0.47ms

Threads fairness:
    events (avg/stddev):            1251.8750/191.83
    execution time (avg/stddev):     0.4693/0.07

shuaiyu@ubuntu:~$ _
```

### 3. Memory test:

#### a. Test 3:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K
Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 41032 ( 1367.35 ops/sec)
41032.00 MB transferred (1367.35 MB/sec)

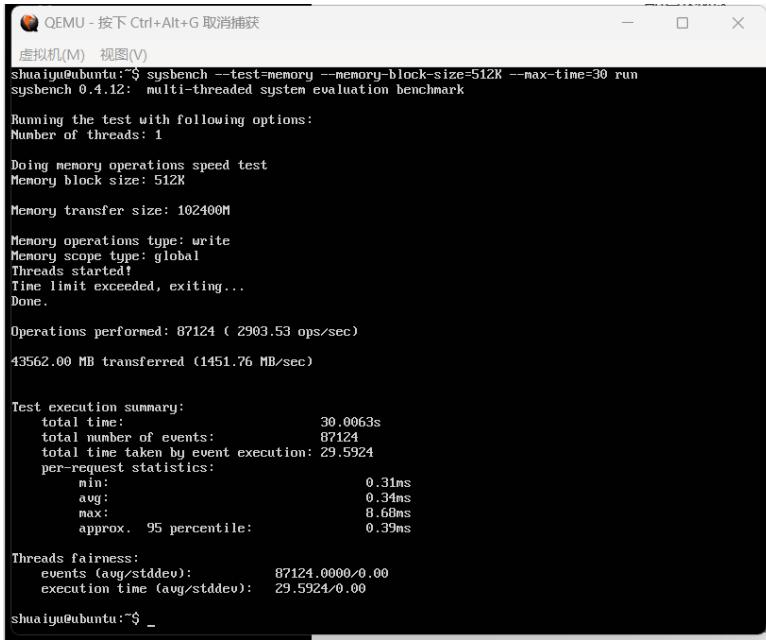
Test execution summary:
    total time:                      30.0004s
    total number of events:           41032
    total time taken by event execution: 29.8280
    per-request statistics:
        min:                           0.66ms
        avg:                           0.73ms
        max:                           13.32ms
        approx. 95 percentile:          0.82ms

Threads fairness:
    events (avg/stddev):            41032.0000/0.00
    execution time (avg/stddev):     29.8280/0.00

shuaiyu@ubuntu:~$ _
```

#### b. Test 4:

```
sysbench memory --memory-block-size=512K --time=30 run
```



```
QEMU - 按下 Ctrl+Alt+G 取取消操作
虚拟机(M) 视图(V)
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K
Memory transfer size: 102400M
Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 87124 (~ 2903.53 ops/sec)
43562.00 MB transferred (1451.76 MB/sec)

Test execution summary:
  total time:          30.0063s
  total number of events: 87124
  total time taken by event execution: 29.5924
  per-request statistics:
    min:                 0.31ms
    avg:                 0.34ms
    max:                 8.68ms
    approx. 95 percentile: 0.39ms

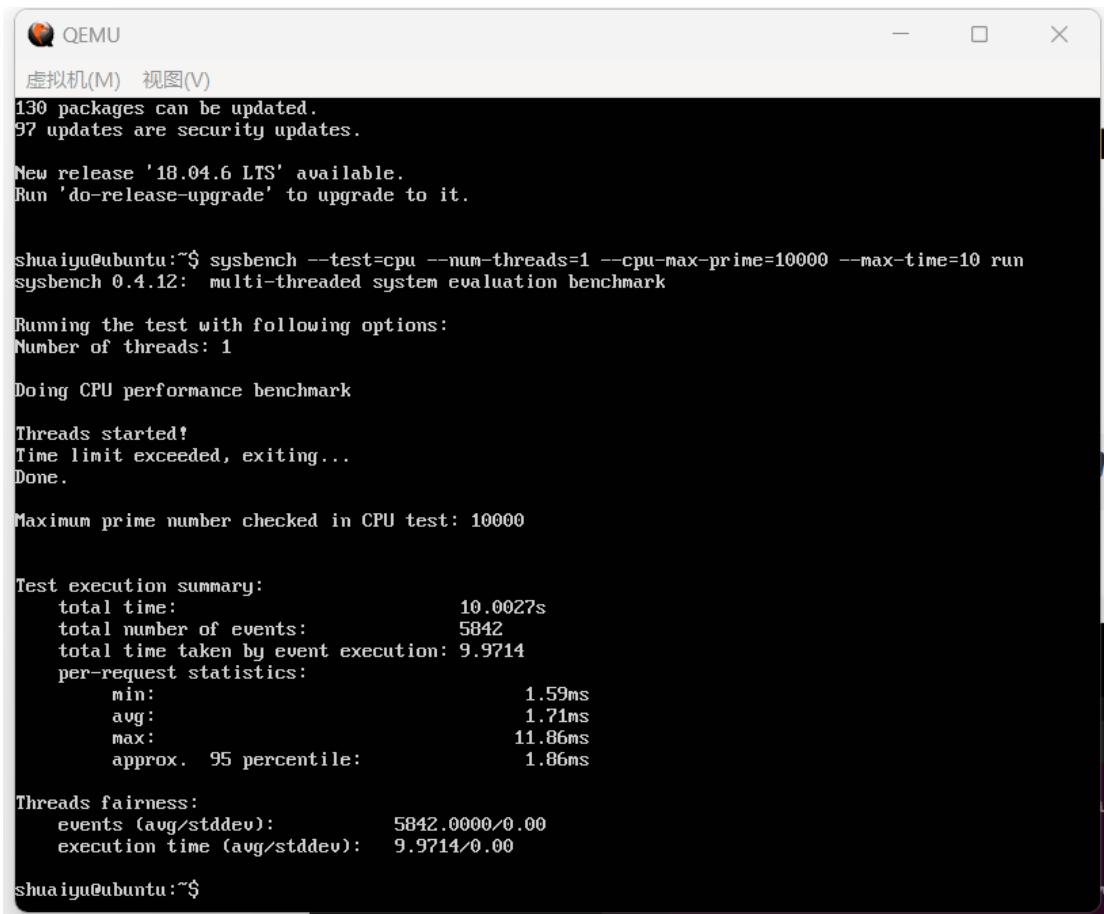
Threads fairness:
  events (avg/stddev): 87124.0000/0.00
  execution time (avg/stddev): 29.5924/0.00
shuaigu@ubuntu:~$
```

Environment 3:

1. CPU test:

a. Test 5:

```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



```
QEMU
虚拟机(M) 视图(V)
130 packages can be updated.
97 updates are security updates.

New release '18.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

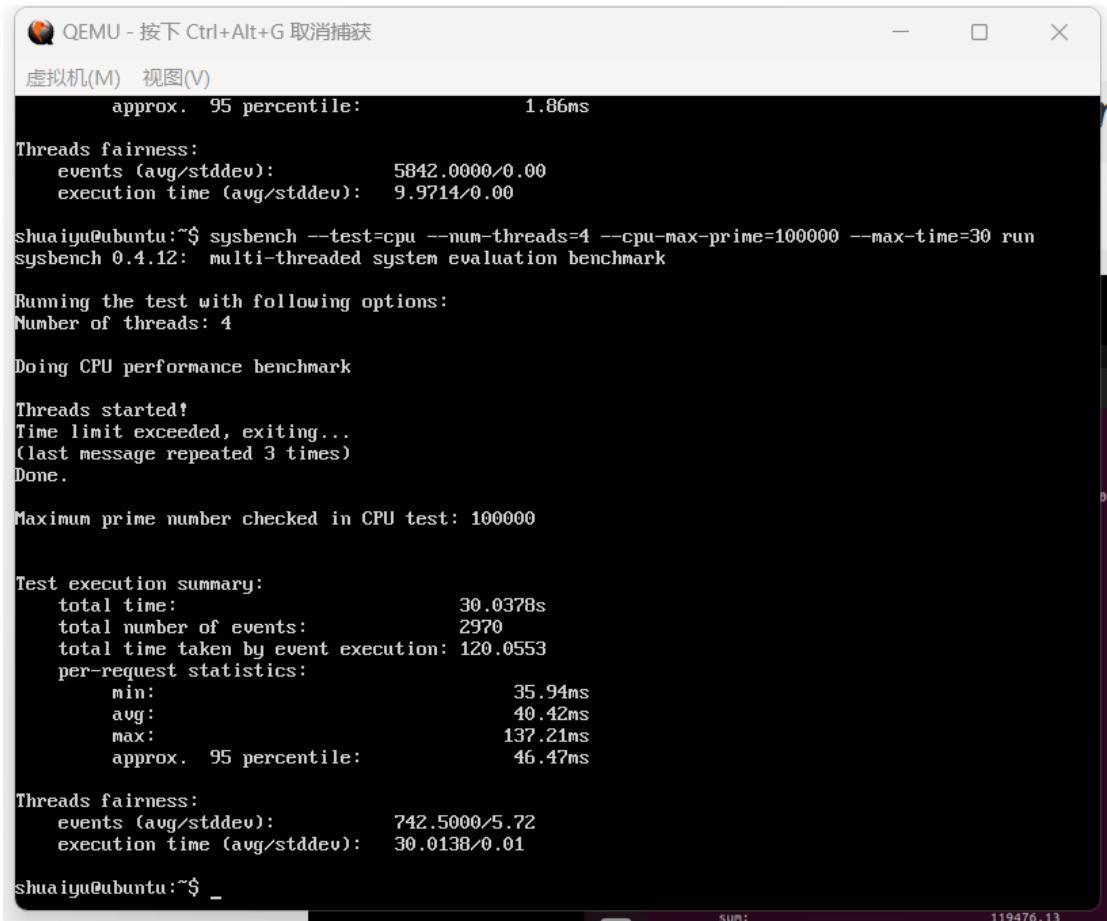
Maximum prime number checked in CPU test: 10000

Test execution summary:
  total time:          10.0027s
  total number of events: 5842
  total time taken by event execution: 9.9714
  per-request statistics:
    min:                 1.59ms
    avg:                 1.71ms
    max:                 11.86ms
    approx. 95 percentile: 1.86ms

Threads fairness:
  events (avg/stddev): 5842.0000/0.00
  execution time (avg/stddev): 9.9714/0.00
shuaigu@ubuntu:~$
```

b. Test 6:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



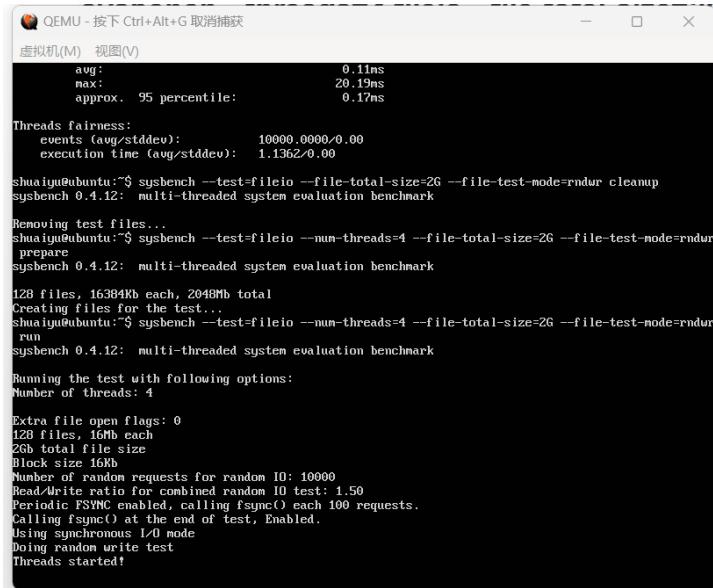
The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获" (QEMU - Press Ctrl+Alt+G to cancel screenshot). The window displays the output of a sysbench CPU test. Key statistics shown include:

- approx. 95 percentile: 1.86ms
- Threads fairness:
  - events (avg/stddev): 5842.0000/0.00
  - execution time (avg/stddev): 9.9714/0.00
- shuaiyu@ubuntu:~\$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- Running the test with following options:
- Number of threads: 4
- Doing CPU performance benchmark
- Threads started!
- Time limit exceeded, exiting...  
(last message repeated 3 times)
- Done.
- Maximum prime number checked in CPU test: 100000
- Test execution summary:
  - total time: 30.0378s
  - total number of events: 2970
  - total time taken by event execution: 120.0553
  - per-request statistics:
    - min: 35.94ms
    - avg: 40.42ms
    - max: 137.21ms
    - approx. 95 percentile: 46.47ms
- Threads fairness:
  - events (avg/stddev): 742.5000/5.72
  - execution time (avg/stddev): 30.0138/0.01
- shuaiyu@ubuntu:~\$ \_

## 2. FILE I/O test:

### a. Test 5:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获" (QEMU - Press Ctrl+Alt+G to cancel screenshot). The window displays the output of a sysbench FILE I/O test. Key statistics shown include:

- avg: 0.11ns
- max: 20.19ns
- approx. 95 percentile: 0.17ns
- Threads fairness:
  - events (avg/stddev): 10000.0000/0.00
  - execution time (avg/stddev): 1.1362/0.00
- shuaiyu@ubuntu:~\$ sysbench --test=fileio --file-total-size=2G --file-test-mode=rndwr cleanup
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- Removing test files...
- shuaiyu@ubuntu:~\$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr prepare
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- 128 files, 16384Kb each, 2048Mb total
- Creating files for the test...
- shuaiyu@ubuntu:~\$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr run
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- Running the test with following options:
- Number of threads: 4
- Extra file open flags: 0
- 128 files, 16Mb each
- 2Gb total file size
- Block size 16Kb
- Number of random requests for random IO: 10000
- Read/Write ratio for combined random IO test: 1.50
- Periodic FSYNC enabled, calling fsync() each 100 requests.
- Calling fsync() at the end of test, Enabled.
- Using synchronous I/O mode
- Doing random write test
- Threads started!

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10040 Write, 12810 Other = 22850 Total
Read 0b Written 156.88Mb Total transferred 156.88Mb (3.8273Mb/sec)
    244.94 Requests/sec executed

Test execution summary:
    total time:          40.9888s
    total number of events: 10040
    total time taken by event execution: 1.4986
    per-request statistics:
        min:                0.05ms
        avg:                0.15ms
        max:                10.15ms
        approx. 95 percentile: 0.25ms

Threads fairness:
    events (avg/stddev):   2510.0000/353.12
    execution time (avg/stddev):  0.3747/0.04

shuaiyu@ubuntu:~$ _
```

b. Test 6:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
execution time (avg/stddev): 0.3684/0.07
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 40960Kb each, 5120Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10027 Write, 12807 Other = 22834 Total
Read 0b Written 156.67Mb Total transferred 156.67Mb (3.9727Mb/sec)
254.25 Requests/sec executed

Test execution summary:
    total time:          39.4372s
    total number of events: 10027
    total time taken by event execution: 2.8746
    per-request statistics:
        min:                 0.05ms
        avg:                 0.29ms
        max:                45.46ms
        approx. 95 percentile: 0.26ms

Threads fairness:
    events (avg/stddev): 1253.3750/184.36
    execution time (avg/stddev): 0.3593/0.05

shuaiyu@ubuntu:~$
```

### 3. Memory test:

#### a. Test 5:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
QEMU
虚拟机(M) 视图(V)
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K
Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 45846 ( 1527.83 ops/sec)
45846.00 MB transferred (1527.83 MB/sec)

Test execution summary:
    total time:          30.0073s
    total number of events: 45846
    total time taken by event execution: 29.7320
    per-request statistics:
        min:                 0.61ms
        avg:                 0.65ms
        max:                15.38ms
        approx. 95 percentile: 0.72ms

Threads fairness:
    events (avg/stddev): 45846.0000/0.00
    execution time (avg/stddev): 29.7320/0.00

shuaiyu@ubuntu:~$
```

#### b. Test 6:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K
Memory transfer size: 102400M
Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 85786 ( 2858.92 ops/sec)
42893.00 MB transferred (1429.46 MB/sec)

Test execution summary:
total time: 30.0064s
total number of events: 85786
total time taken by event execution: 29.6245
per-request statistics:
    min: 0.30ms
    avg: 0.35ms
    max: 22.83ms
    approx. 95 percentile: 0.37ms

Threads fairness:
events (avg/stddev): 85786.0000/0.00
execution time (avg/stddev): 29.6245/0.00

shuaiyu@ubuntu:~$ _
```

#### Environment 4:

##### 1. CPU test:

###### a. Test 7:

```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
mutex - Mutex performance test
oltp - OLTP test

Commands: prepare run cleanup help version
See 'sysbench --test=<name> help' for a list of options for each test.

shuaiyu@ubuntu:~$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

Maximum prime number checked in CPU test: 10000

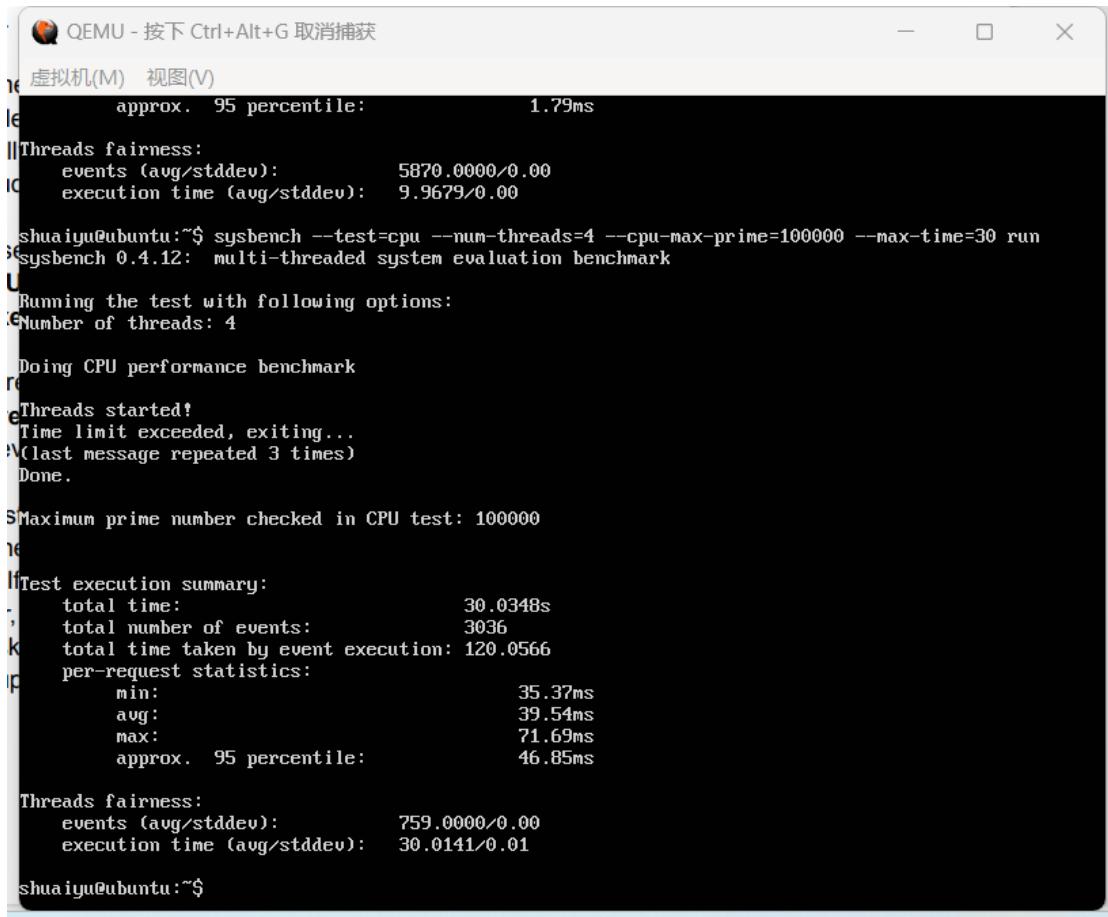
Test execution summary:
total time: 10.0097s
total number of events: 5870
total time taken by event execution: 9.9679
per-request statistics:
    min: 1.59ms
    avg: 1.70ms
    max: 5.06ms
    approx. 95 percentile: 1.79ms

Threads fairness:
events (avg/stddev): 5870.0000/0.00
execution time (avg/stddev): 9.9679/0.00

shuaiyu@ubuntu:~$ _
```

b. Test 8:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获" (QEMU - Press Ctrl+Alt+G to cancel capture). The window displays the output of a sysbench CPU test. The test was run with 4 threads, a maximum prime number of 100000, and a maximum time of 30 seconds. The output includes performance metrics like execution times and fairness statistics, along with a summary of the test execution.

```
shuaiyu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
total time: 30.0348s
total number of events: 3036
total time taken by event execution: 120.0566
per-request statistics:
    min: 35.37ms
    avg: 39.54ms
    max: 71.69ms
    approx. 95 percentile: 46.85ms

Threads fairness:
events (avg/stddev): 759.0000/0.00
execution time (avg/stddev): 30.0141/0.01

shuaiyu@ubuntu:~$
```

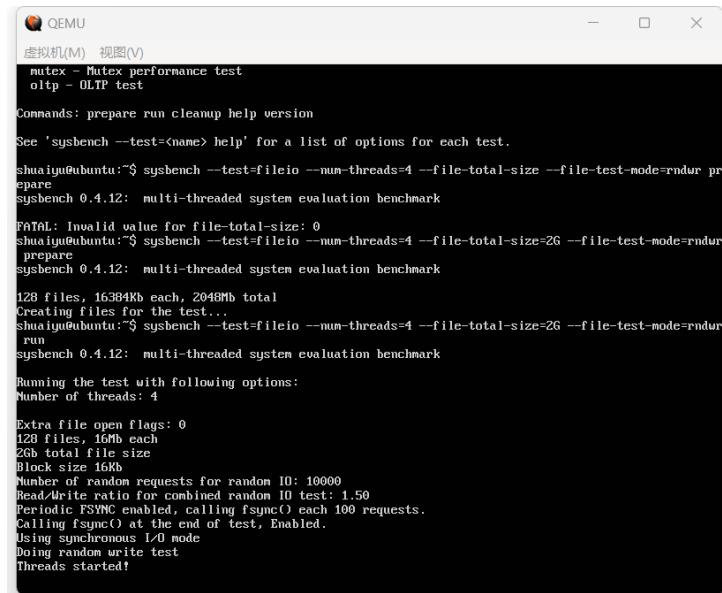
2. FILE I/O test:

a. Test 7:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



The screenshot shows a terminal window titled "QEMU" with a sub-tab "虚拟机(M) 视图(V)". The window displays the output of a sysbench FILE I/O test. The test was run with 4 threads, a total file size of 2GB, and a random write mode. The output includes details about the files created, the test setup, and the test execution.

```
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

FATAL: Invalid value for file-total-size: 0
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10025 Write, 12810 Other = 22835 Total
Read 0b Written 156.64Mb Total transferred 156.64Mb (3.6979Mb/sec)
236.66 Requests/sec executed

Test execution summary:
total time: 42.3598s
total number of events: 10025
total time taken by event execution: 0.8529
per-request statistics:
    min: 0.04ms
    avg: 0.09ms
    max: 9.26ms
    approx. 95 percentile: 0.13ms

Threads fairness:
events (avg/stddev): 2506.2500/158.11
execution time (avg/stddev): 0.2132/0.02

shuaiyu@ubuntu:~$ _
```

b. Test 8:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

```
QEMU
虚拟机(M) 视图(V)
max: 9.26ms
approx. 95 percentile: 0.13ms

Threads fairness:
events (avg/stddev): 2506.2500/158.11
execution time (avg/stddev): 0.2132/0.02

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
^[[Ashuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 40960Kb each, 5120Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
Running the test with following options:  
Number of threads: 8  
Extra file open flags: 0  
128 files, 40Mb each  
5Gb total file size  
Block size 16Kb  
Number of random requests for random IO: 10000  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Threads started!  
Done.  
Operations performed: 0 Read, 10051 Write, 12815 Other = 22866 Total  
Read 0b Written 157.05Mb Total transferred 157.05Mb (3.844Mb/sec)  
246.02 Requests/sec executed  
Test execution summary:  
total time: 40.8552s  
total number of events: 10051  
total time taken by event execution: 3.4597  
per-request statistics:  
min: 0.04ms  
avg: 0.34ms  
max: 50.07ms  
approx. 95 percentile: 0.27ms  
Threads fairness:  
events (avg/stddev): 1256.3750/221.13  
execution time (avg/stddev): 0.4325/0.04  
shuaiyu@ubuntu:~\$ \_

### 3. Memory test:

#### a. Test 7:

```
sysbench memory --memory-block-size=1M --time=30 run
```

QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)  
shuaiyu@ubuntu:~\$ sysbench --test=memory --memory-block-size=1M --max-time=30 run  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
Running the test with following options:  
Number of threads: 1  
Doing memory operations speed test  
Memory block size: 1024K  
Memory transfer size: 102400M  
Memory operations type: write  
Memory scope type: global  
Threads started!  
Time limit exceeded, exiting...  
Done.  
Operations performed: 41246 ( 1374.52 ops/sec)  
341246.00 MB transferred (1374.52 MB/sec)  
Test execution summary:  
total time: 30.0075s  
total number of events: 41246  
total time taken by event execution: 29.7713  
per-request statistics:  
min: 0.67ms  
avg: 0.72ms  
max: 75.47ms  
approx. 95 percentile: 0.81ms  
Threads fairness:  
events (avg/stddev): 41246.0000/0.00  
execution time (avg/stddev): 29.7713/0.00  
shuaiyu@ubuntu:~\$

#### b. Test 8:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 89303 ( 2976.03 ops/sec)

344651.50 MB transferred (1488.02 MB/sec)

Test execution summary:
  total time: 30.0074s
  total number of events: 89303
  total time taken by event execution: 29.5813
  per-request statistics:
    min: 0.31ms
    avg: 0.33ms
    max: 13.62ms
    approx. 95 percentile: 0.37ms

  Threads fairness:
    events (avg/stddev): 89303.0000/0.00
    execution time (avg/stddev): 29.5813/0.00

shuaigu@ubuntu:~$ _
```

Image 2: disk.img format=raw

Environment 1:

```
Windows PowerShell
版权所有 (C) Microsoft Corporation。保留所有权利。

安装最新的 PowerShell，了解新功能和改进！https://aka.ms/PSWindows

PS C:\Users\DELL> qemu-system-x86_64 -drive file=disk1.img,format=raw -smp 2 -m 512
(qemu:22712): Gtk-WARNING **: 13:10:19.572: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 2:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=disk1.img,format=raw -smp 2 -m 4096
(qemu:1652): Gtk-WARNING **: 13:37:36.308: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 3:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=disk1.img,format=raw -smp 4 -m 512
(qemu:8164): Gtk-WARNING **: 14:10:31.480: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

Environment 4:

```
PS C:\Users\DELL> qemu-system-x86_64 -drive file=disk1.img,format=raw -smp 4 -m 4096  
(qemu:5336): Gtk-WARNING **: 14:24:01.765: Could not load a pixbuf from icon theme.  
This may indicate that pixbuf loaders or the mime database could not be found.
```

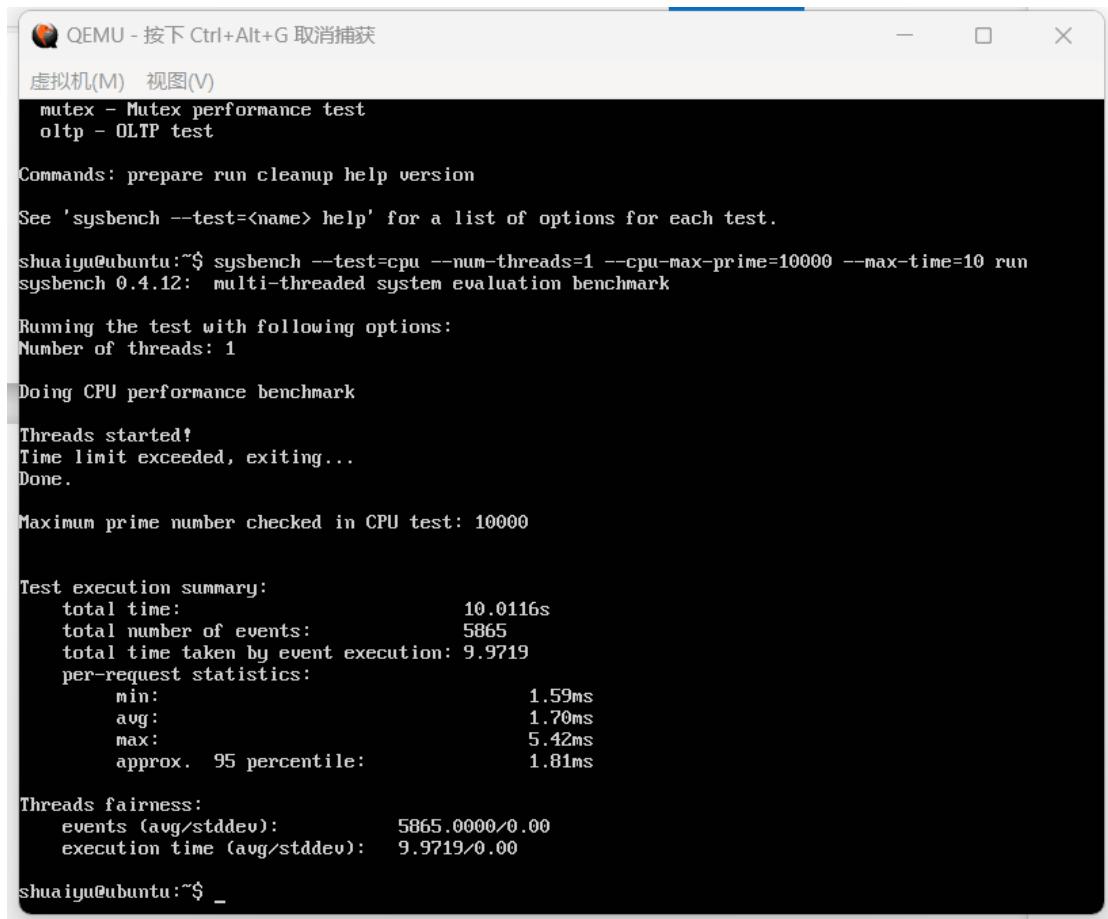
## Experiment using sysbench

Environment 1:

1. CPU test:

a. Test 1:

```
sysbench --test(cpu) --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获". The window contains the following text:

```
虚拟机(M) 视图(V)  
mutex - Mutex performance test  
oltp - OLTP test  
  
Commands: prepare run cleanup help version  
  
See 'sysbench --test=<name> help' for a list of options for each test.  
  
shuaiyu@ubuntu:~$ sysbench --test(cpu) --num-threads=1 --cpu-max-prime=10000 --max-time=10 run  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
  
Running the test with following options:  
Number of threads: 1  
  
Doing CPU performance benchmark  
  
Threads started!  
Time limit exceeded, exiting...  
Done.  
  
Maximum prime number checked in CPU test: 10000  
  
Test execution summary:  
total time: 10.0116s  
total number of events: 5865  
total time taken by event execution: 9.9719  
per-request statistics:  
    min: 1.59ms  
    avg: 1.70ms  
    max: 5.42ms  
    approx. 95 percentile: 1.81ms  
  
Threads fairness:  
    events (avg/stddev): 5865.0000/0.00  
    execution time (avg/stddev): 9.9719/0.00  
  
shuaiyu@ubuntu:~$ _
```

b. Test 2:

```
sysbench --test(cpu) --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
approx. 95 percentile: 1.81ms

Threads fairness:
events (avg/stddev): 5865.0000/0.00
execution time (avg/stddev): 9.9719/0.00

shuaiyu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
total time: 30.0525s
total number of events: 1632
total time taken by event execution: 120.0404
per-request statistics:
min: 47.25ms
avg: 73.55ms
max: 100.15ms
approx. 95 percentile: 81.95ms

Threads fairness:
events (avg/stddev): 408.0000/0.71
execution time (avg/stddev): 30.0101/0.02

shuaiyu@ubuntu:~$ _
```

## 2. FILE I/O test:

### a. Test 1:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10009 Write, 12802 Other = 22811 Total
Read 0b Written 156.39Mb Total transferred 156.39Mb (3.9470Mb/sec)
252.66 Requests/sec executed

Test execution summary:
total time: 39.6146s
total number of events: 10009
total time taken by event execution: 1.8523
per-request statistics:
min: 0.04ns
avg: 0.19ns
max: 38.18ns
approx. 95 percentile: 0.25ns

Threads fairness:
events (avg/stddev): 2502.2500/138.27
execution time (avg/stddev): 0.4631/0.03

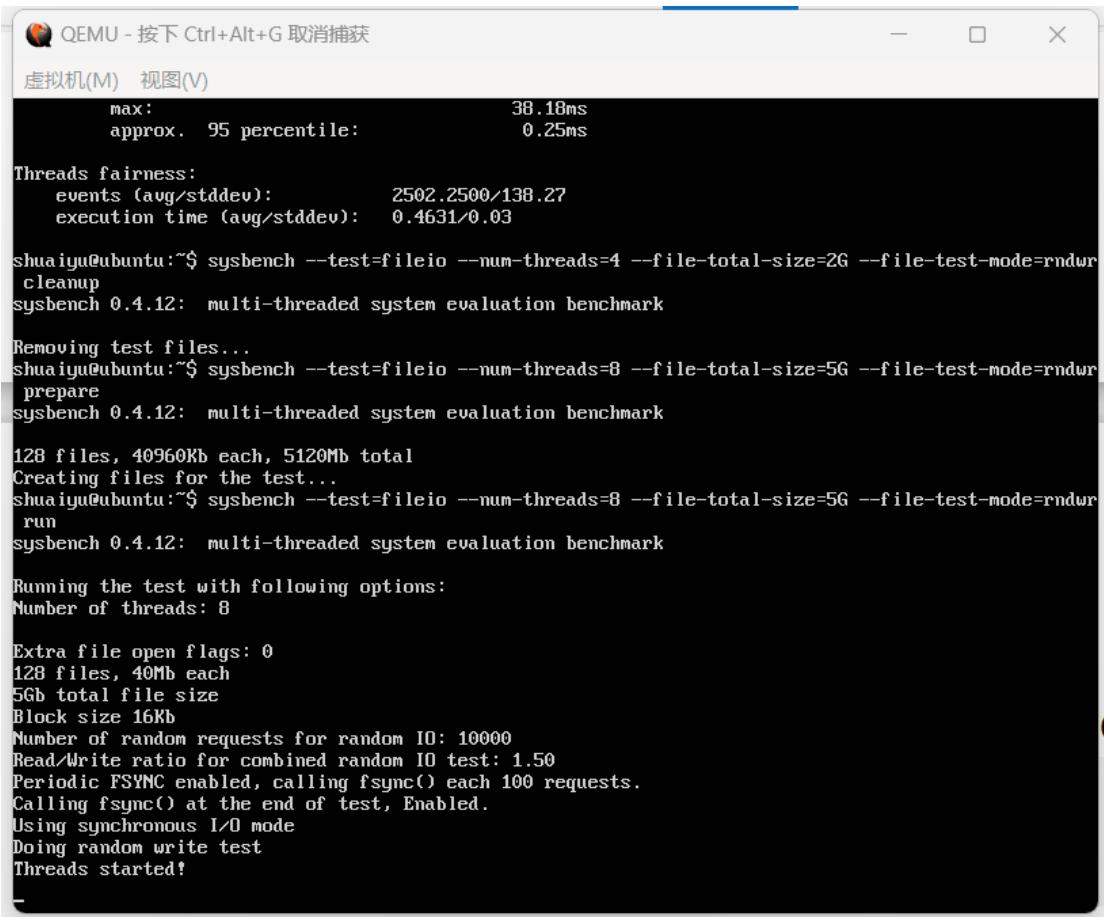
shuaiyu@ubuntu:~$ _
```

b. Test 2:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare
```

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run
```

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```



QEMU - 按下 Ctrl+Alt+G 取消捕获

虚拟机(M) 视图(V)

```
max: 38.18ms
approx. 95 percentile: 0.25ms

Threads fairness:
events (avg/stddev): 2502.2500/138.27
execution time (avg/stddev): 0.4631/0.03

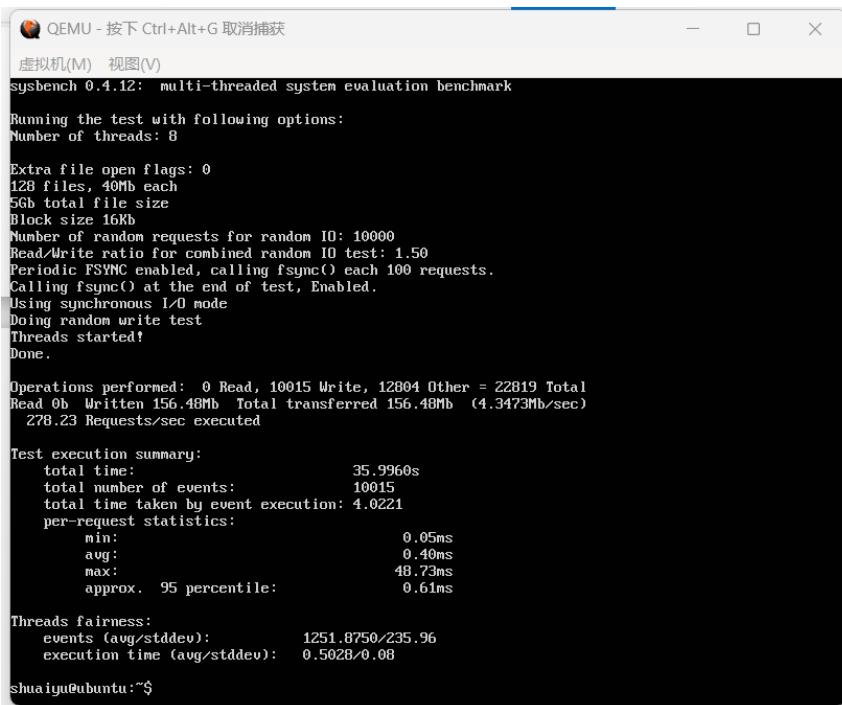
shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 40960Kb each, 5120Mb total
Creating files for the test...
shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```



QEMU - 按下 Ctrl+Alt+G 取消捕获

虚拟机(M) 视图(V)

```
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10015 Write, 12804 Other = 22819 Total
Read 0b Written 156.48Mb Total transferred 156.48Mb (4.347Mb/sec)
278.23 Requests/sec executed

Test execution summary:
total time: 35.9960s
total number of events: 10015
total time taken by event execution: 4.0221
per-request statistics:
min: 0.05ms
avg: 0.40ms
max: 48.73ms
approx. 95 percentile: 0.61ms

Threads fairness:
events (avg/stddev): 1251.8750/235.96
execution time (avg/stddev): 0.5028/0.08

shuaigu@ubuntu:~$
```

### 3. Memory test:

#### a. Test 1:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 44124 ( 1470.41 ops/sec)
44124.00 MB transferred (1470.41 MB/sec)

Test execution summary:
  total time:                      30.0081s
  total number of events:          44124
  total time taken by event execution: 29.8140
  per-request statistics:
    min:                            0.61ms
    avg:                            0.68ms
    max:                            232.48ms
    approx. 95 percentile:          0.76ms

Threads fairness:
  events (avg/stddev):           44124.0000/0.00
  execution time (avg/stddev):   29.8140/0.00

shuaiyu@ubuntu:~$ _
```

#### b. Test 2:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 87037 ( 2900.60 ops/sec)
43518.50 MB transferred (1450.30 MB/sec)

Test execution summary:
  total time:                      30.0065s
  total number of events:          87037
  total time taken by event execution: 29.6012
  per-request statistics:
    min:                            0.31ms
    avg:                            0.34ms
    max:                            7.02ms
    approx. 95 percentile:          0.41ms

Threads fairness:
  events (avg/stddev):           87037.0000/0.00
  execution time (avg/stddev):   29.6012/0.00

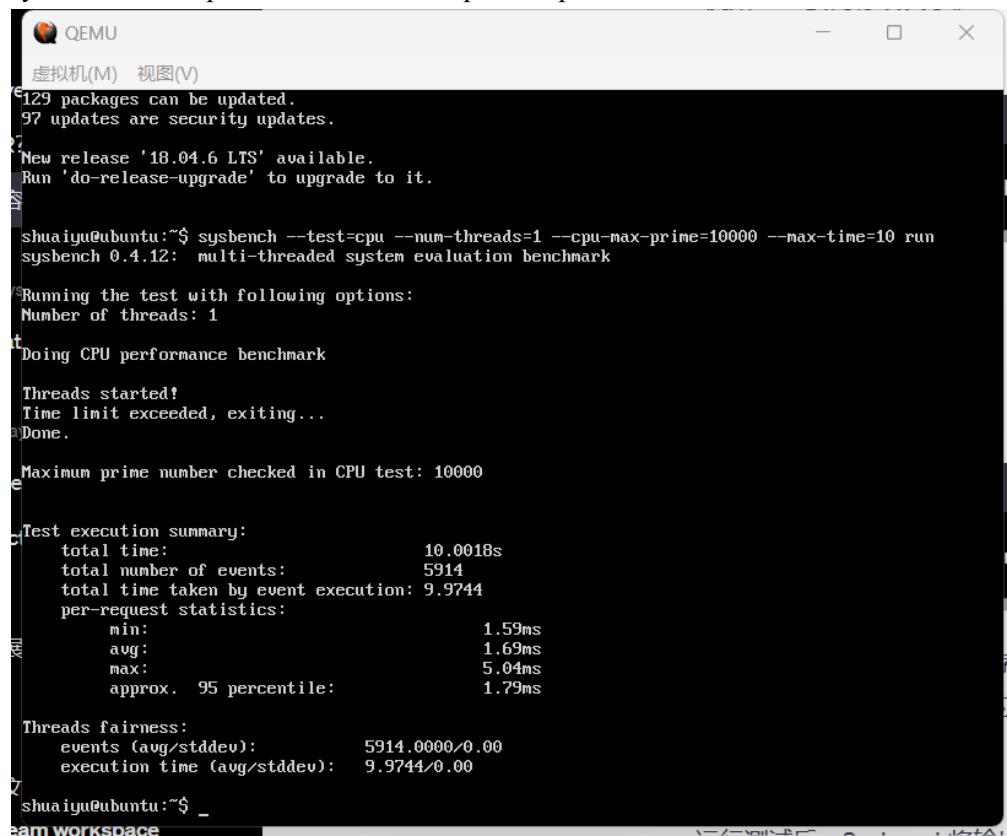
shuaiyu@ubuntu:~$ _
```

## Environment 2:

1. CPU test:

a. Test 3:

```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



```
QEMU
虚拟机(M) 视图(V)
129 packages can be updated.
97 updates are security updates.

New release '18.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

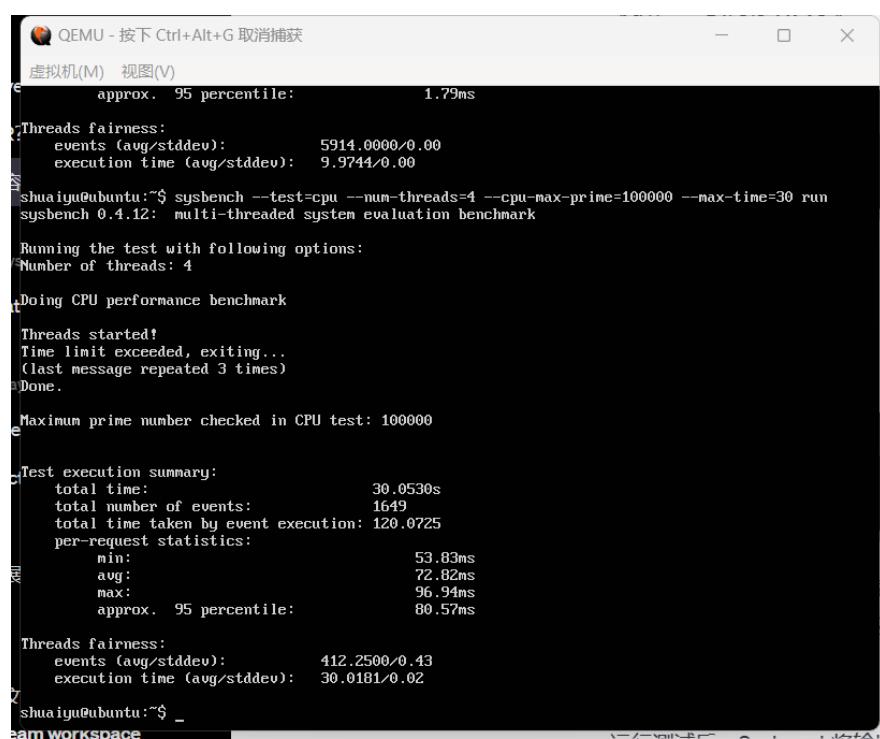
Maximum prime number checked in CPU test: 10000

Test execution summary:
total time: 10.0018s
total number of events: 5914
total time taken by event execution: 9.9744
per-request statistics:
    min: 1.59ms
    avg: 1.69ms
    max: 5.04ms
    approx. 95 percentile: 1.79ms

Threads fairness:
events (avg/stddev): 5914.0000/0.00
execution time (avg/stddev): 9.9744/0.00
shuaigu@ubuntu:~$ _
```

b. Test 4:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
approx. 95 percentile: 1.79ms

Threads fairness:
events (avg/stddev): 5914.0000/0.00
execution time (avg/stddev): 9.9744/0.00
shuaigu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
total time: 30.0530s
total number of events: 1649
total time taken by event execution: 120.0225
per-request statistics:
    min: 53.83ms
    avg: 72.82ms
    max: 96.94ms
    approx. 95 percentile: 80.57ms

Threads fairness:
events (avg/stddev): 412.2500/0.43
execution time (avg/stddev): 30.0181/0.02
shuaigu@ubuntu:~$ _
```

## 2. FILE I/O test:

a. Test 3:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare  
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run  
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
total number of events: 1649
total time taken by event execution: 120.0725
per-request statistics:
    min:                      53.83ms
    avg:                      72.82ms
    max:                      96.94ms
    approx. 95 percentile:    80.57ms

Threads fairness:
  events (avg/stddev):     412.2500/0.43
  execution time (avg/stddev): 30.0181/0.02

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndrw
  prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 16384Kb each, 2048Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndrw
  run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10038 Write, 12802 Other = 22840 Total
Read 0b Written 156.84Mb Total transferred 156.84Mb (3.7226Mb/sec)
238.25 Requests/sec executed

Test execution summary:
total time: 42.1330s
total number of events: 10038
total time taken by event execution: 0.9714
per-request statistics:
    min: 0.04ms
    avg: 0.10ms
    max: 22.13ms
    approx. 95 percentile: 0.12ms

Threads fairness:
events (avg/stddev): 2509.5000/187.06
execution time (avg/stddev): 0.2428/0.01

shuaigu@ubuntu:~$
```

b. Test 4;

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run
```

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
max: 22.13ms
approx. 95 percentile: 0.12ms

Threads fairness:
events (avg/stddev): 2509.5000/187.06
execution time (avg/stddev): 0.2428/0.01

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
cleanup
sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 40960Kb each, 5120Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 8

Extra file open flags: 0
128 files, 40Mb each
5Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10050 Write, 12804 Other = 22854 Total
Read 0b Written 157.03Mb Total transferred 157.03Mb (4.1042Mb/sec)
262.67 Requests/sec executed

Test execution summary:
total time: 38.2613s
total number of events: 10050
total time taken by event execution: 2.9469
per-request statistics:
min: 0.04ms
avg: 0.29ms
max: 34.14ms
approx. 95 percentile: 0.34ms

Threads fairness:
events (avg/stddev): 1256.2500/208.63
execution time (avg/stddev): 0.3684/0.03

shuaiyu@ubuntu:~$
```

### 3. Memory test:

#### a. Test 3:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 41493 ( 1382.14 ops/sec)

41493.00 MB transferred (1382.14 MB/sec)

Test execution summary:
total time: 30.0209s
total number of events: 41493
total time taken by event execution: 29.7930
per-request statistics:
    min: 0.67ms
    avg: 0.72ms
    max: 13.89ms
    approx. 95 percentile: 0.80ms

Threads fairness:
events (avg/stddev): 41493.0000/0.00
execution time (avg/stddev): 29.7930/0.00

shuaiyu@ubuntu:~$
```

b. Test 4:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 85841 ( 2860.75 ops/sec)

42920.50 MB transferred (1430.37 MB/sec)

Test execution summary:
total time: 30.0065s
total number of events: 85841
total time taken by event execution: 29.6265
per-request statistics:
    min: 0.31ms
    avg: 0.35ms
    max: 21.89ms
    approx. 95 percentile: 0.37ms

Threads fairness:
events (avg/stddev): 85841.0000/0.00
execution time (avg/stddev): 29.6265/0.00

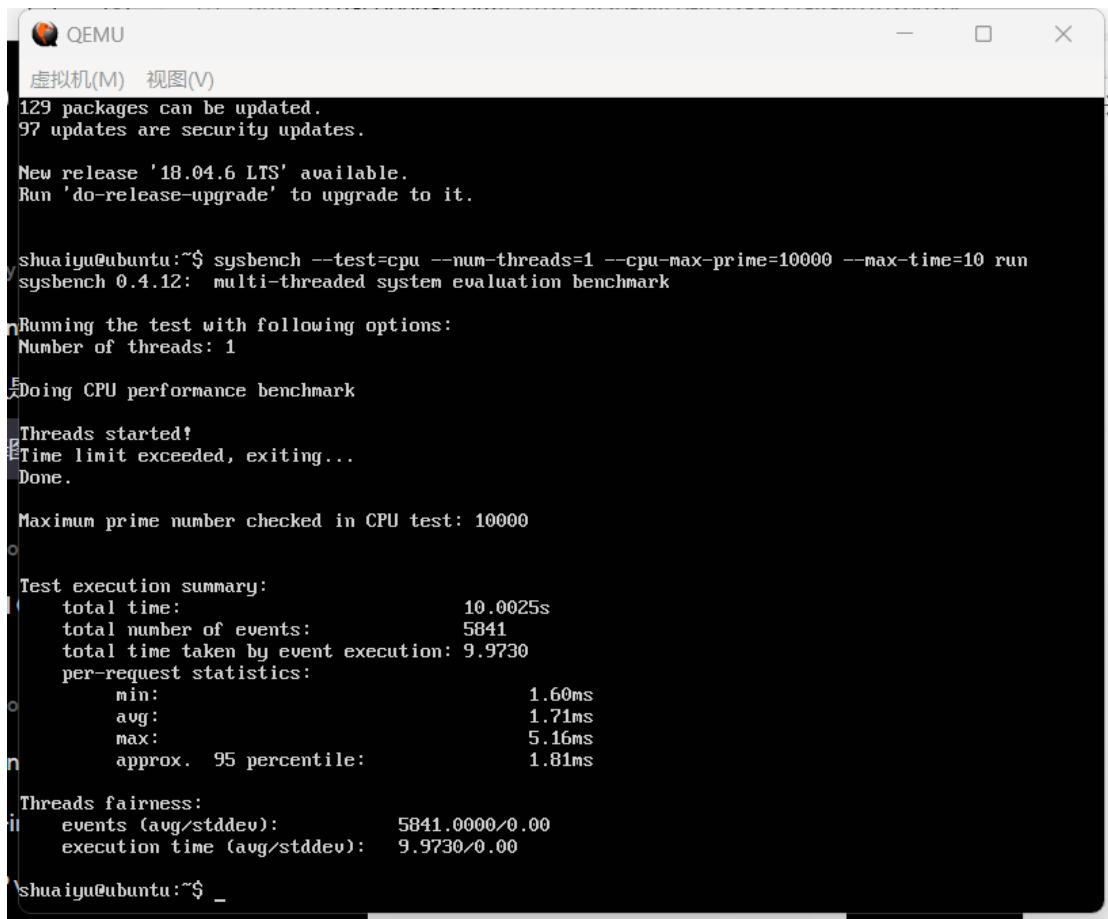
shuaiyu@ubuntu:~$
```

### Environment 3:

#### 1. CPU test:

##### a. Test 5:

```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



```
QEMU
虚拟机(M) 视图(V)
129 packages can be updated.
97 updates are security updates.

New release '18.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

shuaiyu@ubuntu:~$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Time limit exceeded, exiting...
Done.

Maximum prime number checked in CPU test: 10000

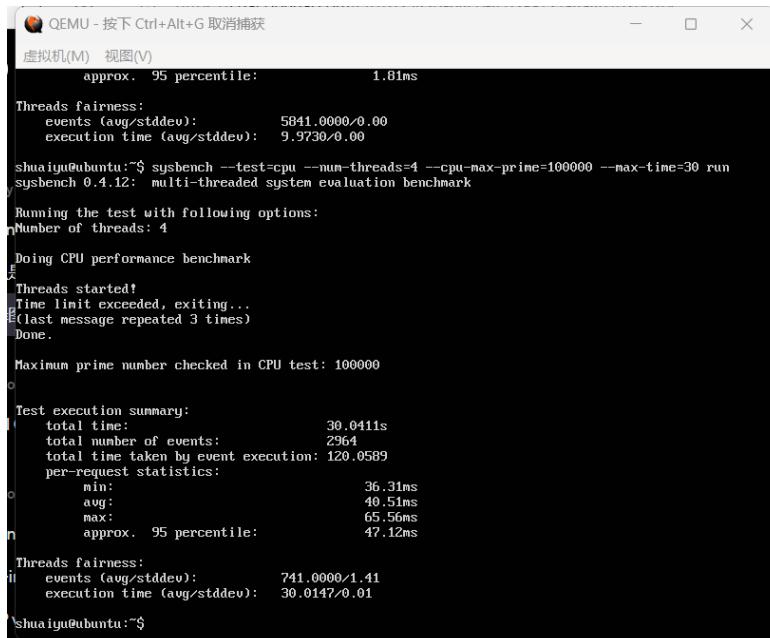
Test execution summary:
total time: 10.0025s
total number of events: 5841
total time taken by event execution: 9.9730
per-request statistics:
    min: 1.60ms
    avg: 1.71ms
    max: 5.16ms
approx. 95 percentile: 1.81ms

Threads fairness:
events (avg/stddev): 5841.0000/0.00
execution time (avg/stddev): 9.9730/0.00

shuaiyu@ubuntu:~$ _
```

##### b. Test 6:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



```
QEMU - 按下 Ctrl+Alt+G 取取消捕获
虚拟机(M) 视图(V)
approx. 95 percentile: 1.81ms

Threads fairness:
events (avg/stddev): 5841.0000/0.00
execution time (avg/stddev): 9.9730/0.00

shuaiyu@ubuntu:~$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark
Threads started!
Time limit exceeded, exiting...
(last message repeated 3 times)
Done.

Maximum prime number checked in CPU test: 100000

Test execution summary:
total time: 30.0411s
total number of events: 2964
total time taken by event execution: 120.0589
per-request statistics:
    min: 36.31ms
    avg: 40.51ms
    max: 65.56ms
approx. 95 percentile: 47.12ms

Threads fairness:
events (avg/stddev): 741.0000/1.41
execution time (avg/stddev): 30.0147/0.01

shuaiyu@ubuntu:~$ _
```

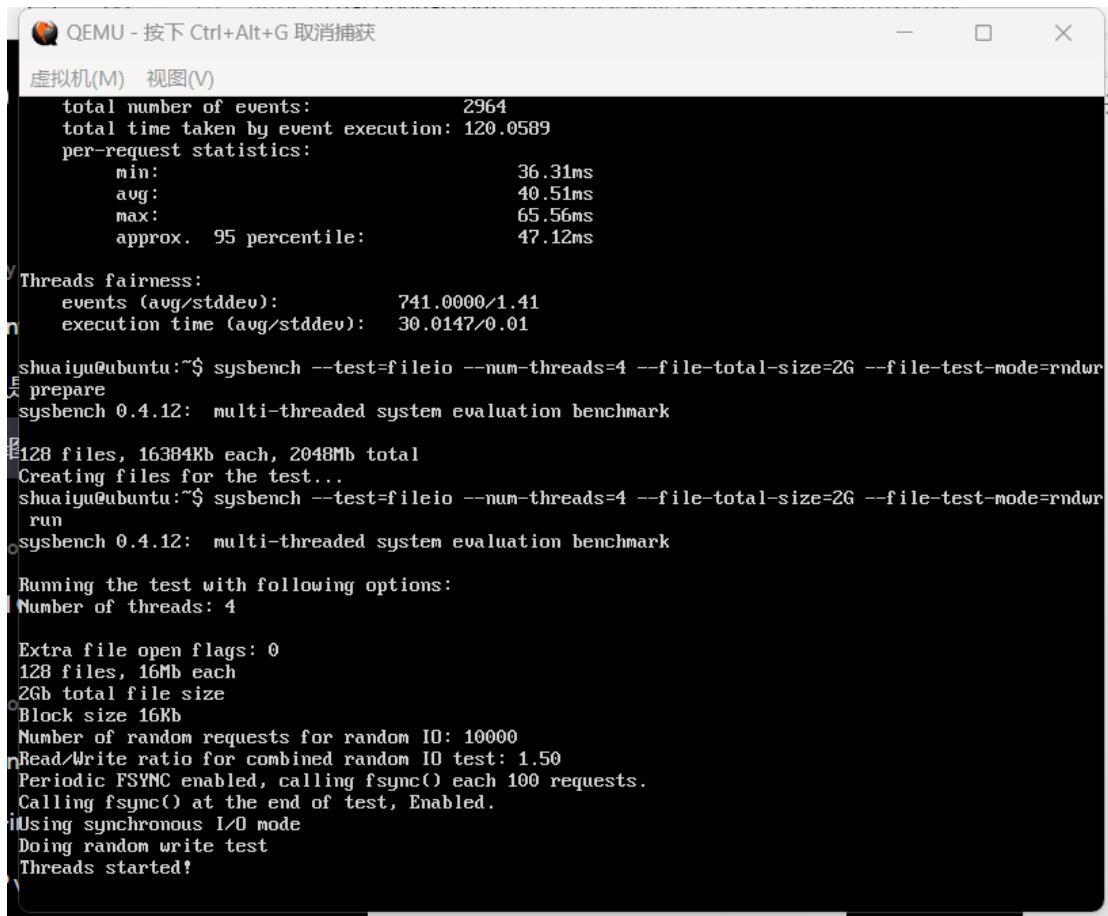
## 2. FILE I/O test:

### a. Test 5:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
total number of events: 2964
total time taken by event execution: 120.0589
per-request statistics:
    min: 36.31ms
    avg: 40.51ms
    max: 65.56ms
    approx. 95 percentile: 47.12ms

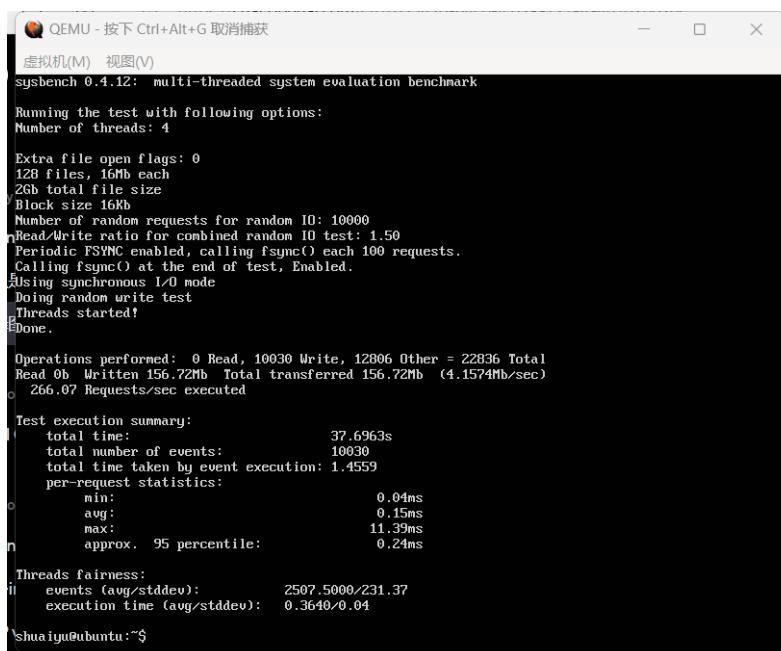
Threads fairness:
    events (avg/stddev): 741.0000/1.41
    execution time (avg/stddev): 30.0147/0.01

shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
准备
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 16384Kb each, 2048Mb total
Creating files for the test...
shuaiyu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
运行
sysbench 0.4.12: multi-threaded system evaluation benchmark

运行测试，以下选项：
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
ReadWrite ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```



```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
sysbench 0.4.12: multi-threaded system evaluation benchmark

运行测试，以下选项：
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
ReadWrite ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10030 Write, 12806 Other = 22836 Total
Read 0b Written 156.72Mb Total transferred 156.72Mb (4.1574mb/sec)
266.07 Requests/sec executed

Test execution summary:
    total time: 37.6963s
    total number of events: 10030
    total time taken by event execution: 1.4559
    per-request statistics:
        min: 0.04ms
        avg: 0.15ms
        max: 11.39ms
    approx. 95 percentile: 0.24ms

Threads fairness:
    events (avg/stddev): 2507.5000/231.37
    execution time (avg/stddev): 0.3640/0.04

shuaiyu@ubuntu:~$
```

b. Test 6:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获". The window contains the output of a sysbench fileio test. Key statistics shown include:

- max: 11.39ms
- approx. 95 percentile: 0.24ms

Threads fairness:

- events (avg/stddev): 2507.5000/231.37
- execution time (avg/stddev): 0.3640/0.04

Test configuration:

- shuaiyu@ubuntu:~\$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr cleanup
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- Removing test files...
- shuaiyu@ubuntu:~\$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr prepare
- sysbench 0.4.12: multi-threaded system evaluation benchmark
- 128 files, 40960Kb each, 5120Mb total
- Creating files for the test...
- shuaiyu@ubuntu:~\$ sysbench --test=fileio --num-threads=8 --file-total-size=5G --file-test-mode=rndwr run
- sysbench 0.4.12: multi-threaded system evaluation benchmark

Test options and setup:

- Running the test with following options:
- Number of threads: 8
- Extra file open flags: 0
- 128 files, 40Mb each
- 5Gb total file size
- Block size 16Kb
- Number of random requests for random IO: 10000
- Read/Write ratio for combined random IO test: 1.50
- Periodic FSYNC enabled, calling fsync() each 100 requests.
- Calling fsync() at the end of test, Enabled.
- Using synchronous I/O mode
- Doing random write test
- Threads started!

The screenshot shows a terminal window titled "QEMU - 按下 Ctrl+Alt+G 取消捕获". The window contains the final results of the sysbench fileio test. Key statistics shown include:

- Operations performed: 0 Read, 10023 Write, 12805 Other = 22828 Total
- Read 0b Written 156.61Mb Total transferred 156.61Mb (4.2594Mb/sec)
- 272.60 Requests/sec executed

Test execution summary:

- total time: 36.7680s
- total number of events: 10023
- total time taken by event execution: 2.7923
- per-request statistics:

  - min: 0.05ms
  - avg: 0.28ms
  - max: 46.01ms
  - approx. 95 percentile: 0.28ms

Threads fairness:

- events (avg/stddev): 1252.8750/175.02
- execution time (avg/stddev): 0.3490/0.02

3. Memory test:

a. Test 5:

```
sysbench memory --memory-block-size=1M --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1024K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 41788 ( 1392.59 ops/sec)
41788.00 MB transferred (1392.59 MB/sec)

Test execution summary:
  total time:          30.0074s
  total number of events:    41788
  total time taken by event execution: 29.7837
  per-request statistics:
    min:                  0.67ms
    avg:                  0.71ms
    max:                  4.66ms
    approx. 95 percentile: 0.78ms

Threads fairness:
  events (avg/stddev):   41788.0000/0.00
  execution time (avg/stddev): 29.7837/0.00

shuaiyu@ubuntu:~$
```

b. Test 6:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
shuaiyu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 79445 ( 2647.59 ops/sec)
39722.50 MB transferred (1323.80 MB/sec)

Test execution summary:
  total time:          30.0065s
  total number of events:    79445
  total time taken by event execution: 29.5355
  per-request statistics:
    min:                  0.34ms
    avg:                  0.37ms
    max:                  6.47ms
    approx. 95 percentile: 0.43ms

Threads fairness:
  events (avg/stddev):   79445.0000/0.00
  execution time (avg/stddev): 29.5355/0.00

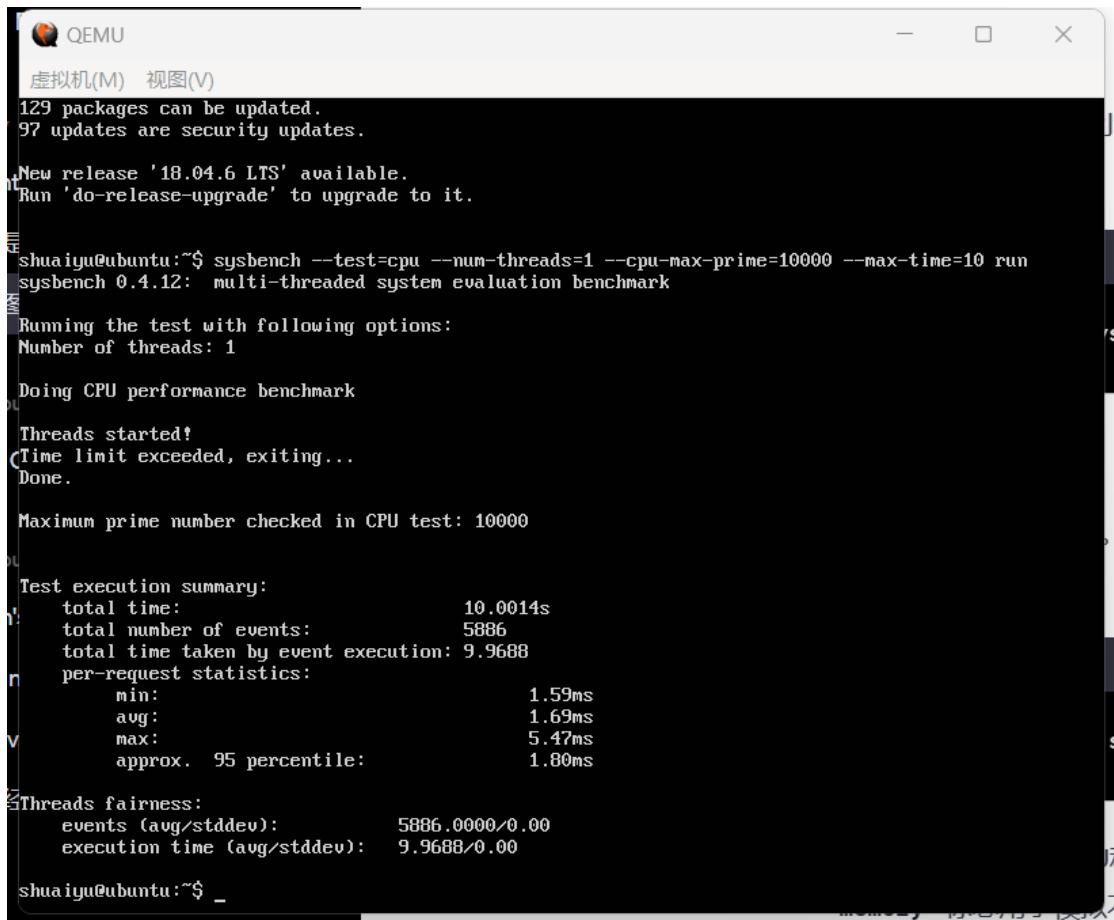
shuaiyu@ubuntu:~$
```

Environment 4:

1. CPU test:

a. Test 7:

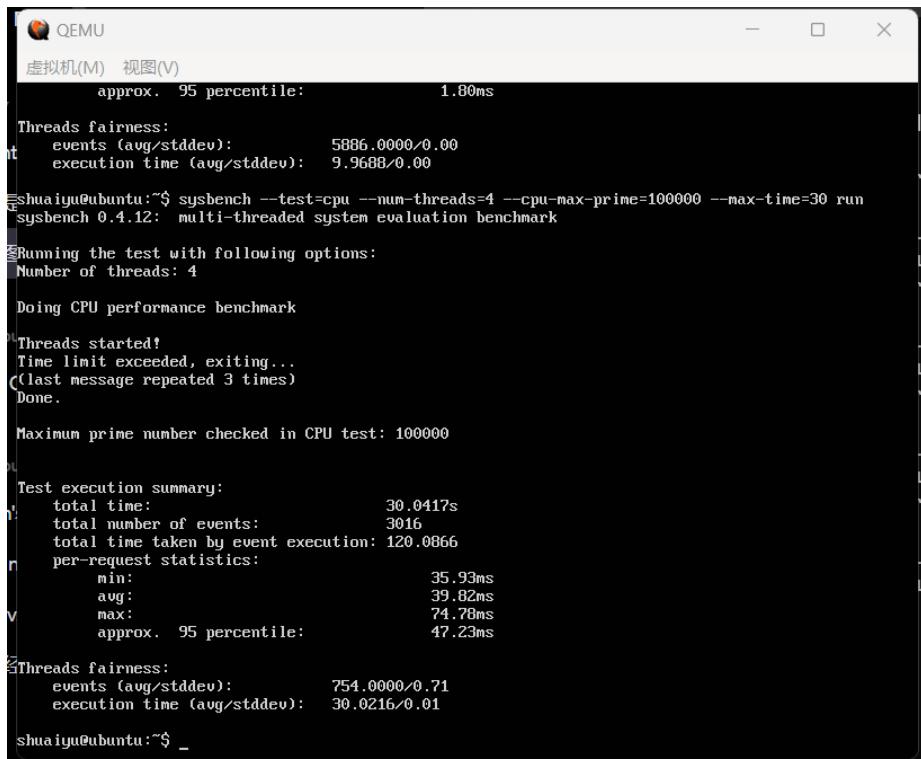
```
sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run
```



QEMU  
虚拟机(M) 视图(V)  
129 packages can be updated.  
97 updates are security updates.  
New release '18.04.6 LTS' available.  
Run 'do-release-upgrade' to upgrade to it.  
  
shuaiyu@ubuntu:~\$ sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 --max-time=10 run  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
  
Running the test with following options:  
Number of threads: 1  
  
Doing CPU performance benchmark  
  
Threads started!  
Time limit exceeded, exiting...  
Done.  
  
Maximum prime number checked in CPU test: 10000  
  
Test execution summary:  
total time: 10.0014s  
total number of events: 5886  
total time taken by event execution: 9.9688  
per-request statistics:  
min: 1.59ms  
avg: 1.69ms  
max: 5.47ms  
approx. 95 percentile: 1.80ms  
  
Threads fairness:  
events (avg/stddev): 5886.0000/0.00  
execution time (avg/stddev): 9.9688/0.00  
  
shuaiyu@ubuntu:~\$ \_

b. Test 8:

```
sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run
```



QEMU  
虚拟机(M) 视图(V)  
approx. 95 percentile: 1.80ms  
  
Threads fairness:  
events (avg/stddev): 5886.0000/0.00  
execution time (avg/stddev): 9.9688/0.00  
  
shuaiyu@ubuntu:~\$ sysbench --test=cpu --num-threads=4 --cpu-max-prime=100000 --max-time=30 run  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
  
Running the test with following options:  
Number of threads: 4  
  
Doing CPU performance benchmark  
  
Threads started!  
Time limit exceeded, exiting...  
(last message repeated 3 times)  
Done.  
  
Maximum prime number checked in CPU test: 100000  
  
Test execution summary:  
total time: 30.0417s  
total number of events: 3016  
total time taken by event execution: 120.0866  
per-request statistics:  
min: 35.93ms  
avg: 39.82ms  
max: 74.78ms  
approx. 95 percentile: 47.23ms  
  
Threads fairness:  
events (avg/stddev): 754.0000/0.71  
execution time (avg/stddev): 30.0216/0.01  
  
shuaiyu@ubuntu:~\$ \_

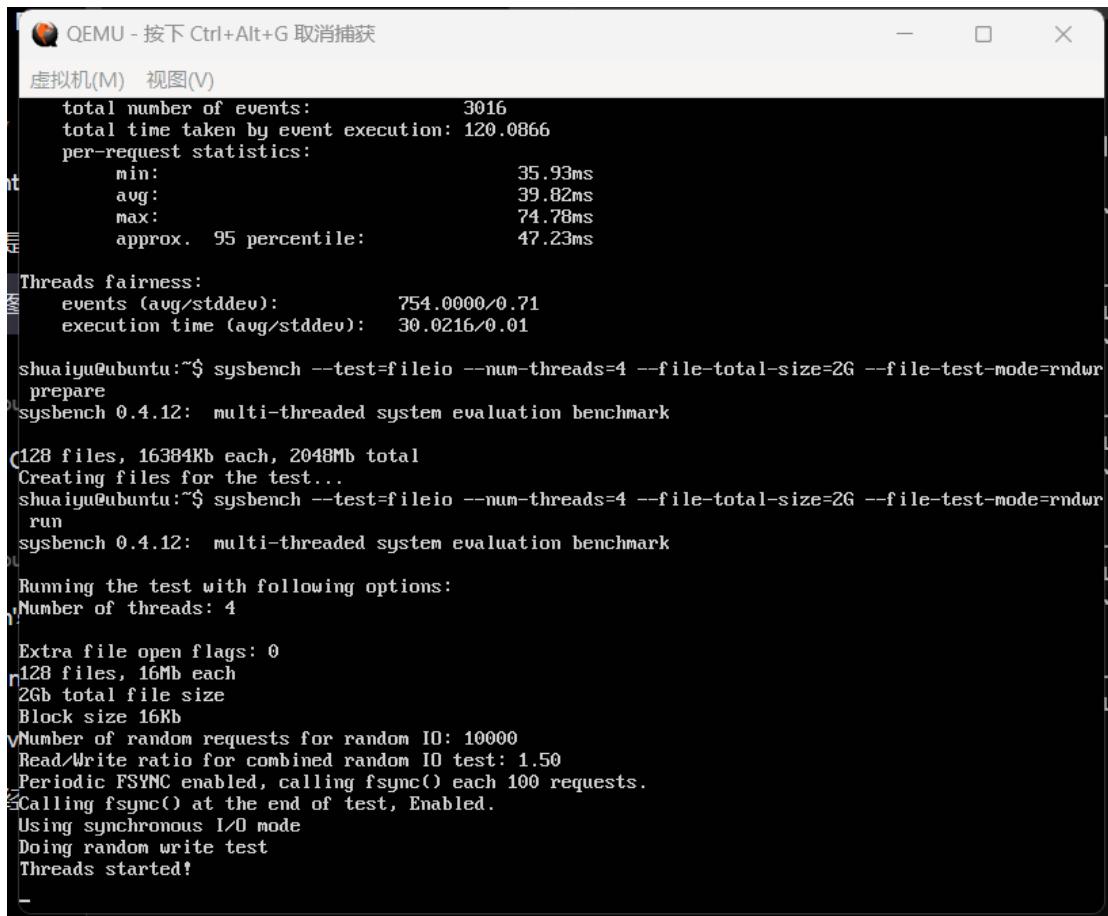
## 2. FILE I/O test:

### a. Test 7:

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr prepare
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run
```

```
sysbench --num-threads=4 fileio --file-total-size=2G --file-test-mode=rndwr cleanup
```



QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)

```
total number of events: 3016
total time taken by event execution: 120.0866
per-request statistics:
    min: 35.93ms
    avg: 39.82ms
    max: 74.78ms
    approx. 95 percentile: 47.23ms

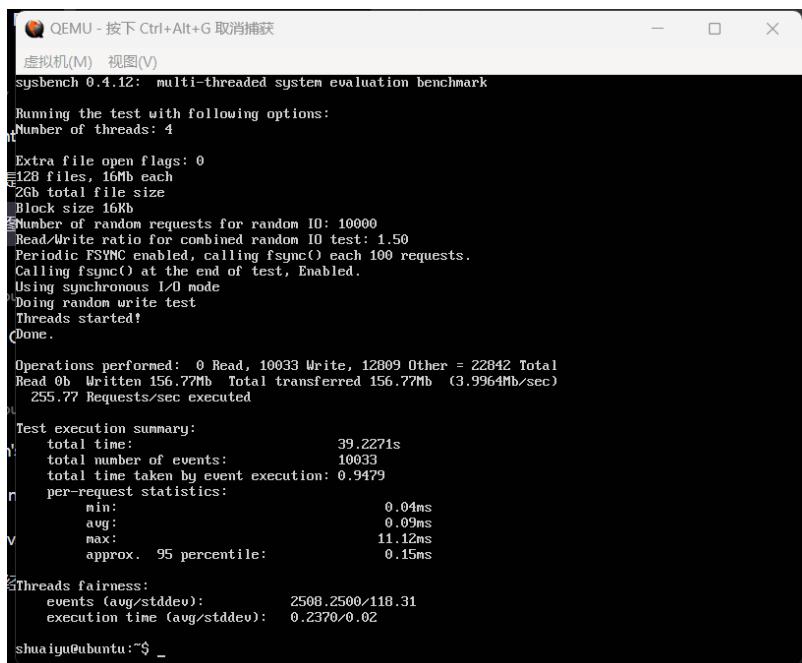
Threads fairness:
    events (avg/stddev): 754.0000/0.71
    execution time (avg/stddev): 30.0216/0.01

shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
prepare
sysbench 0.4.12: multi-threaded system evaluation benchmark

128 files, 16384Kb each, 2048Mb total
Creating files for the test...
shuaigu@ubuntu:~$ sysbench --test=fileio --num-threads=4 --file-total-size=2G --file-test-mode=rndwr
run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
```



QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)

```
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Number of random requests for random IO: 10000
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Threads started!
Done.

Operations performed: 0 Read, 10033 Write, 12809 Other = 22842 Total
Read 0b Written 156.77Mb Total transferred 156.77Mb (3.9964Mb/sec)
255.77 Requests/sec executed

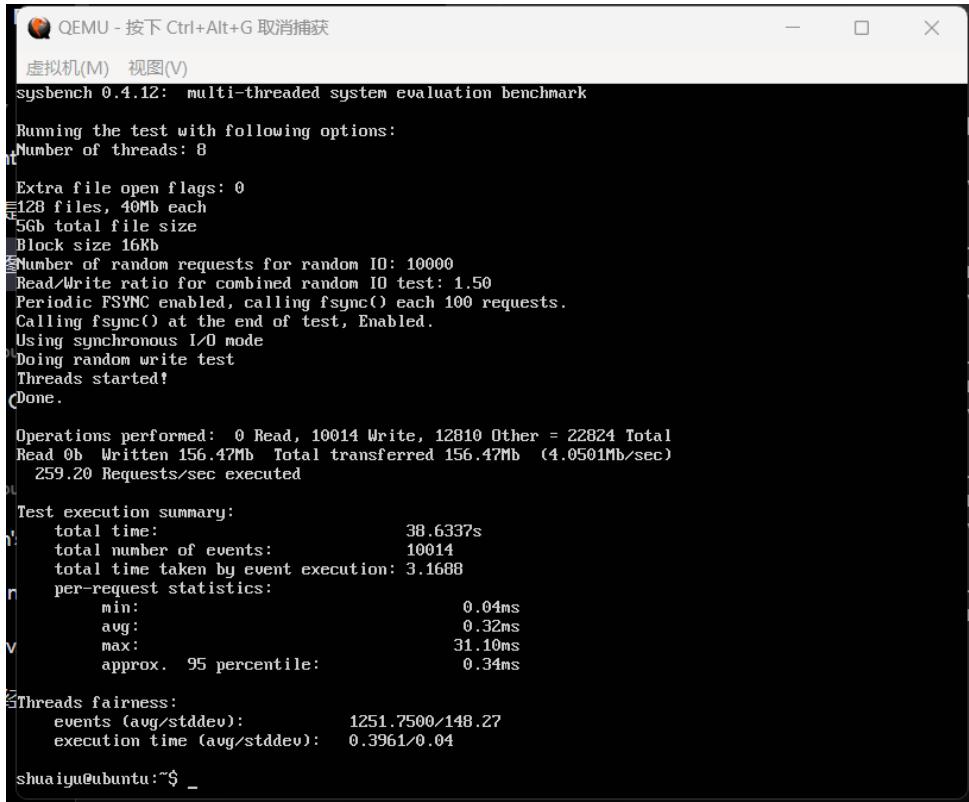
Test execution summary:
    total time: 39.2271s
    total number of events: 10033
    total time taken by event execution: 0.9479
    per-request statistics:
        min: 0.04ms
        avg: 0.09ms
        max: 11.12ms
        approx. 95 percentile: 0.15ms

Threads fairness:
    events (avg/stddev): 2508.2500/118.31
    execution time (avg/stddev): 0.2370/0.02

shuaigu@ubuntu:~$ _
```

b. Test 8:

```
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr prepare  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr run  
sysbench --num-threads=8 fileio --file-total-size=5G --file-test-mode=rndwr cleanup
```

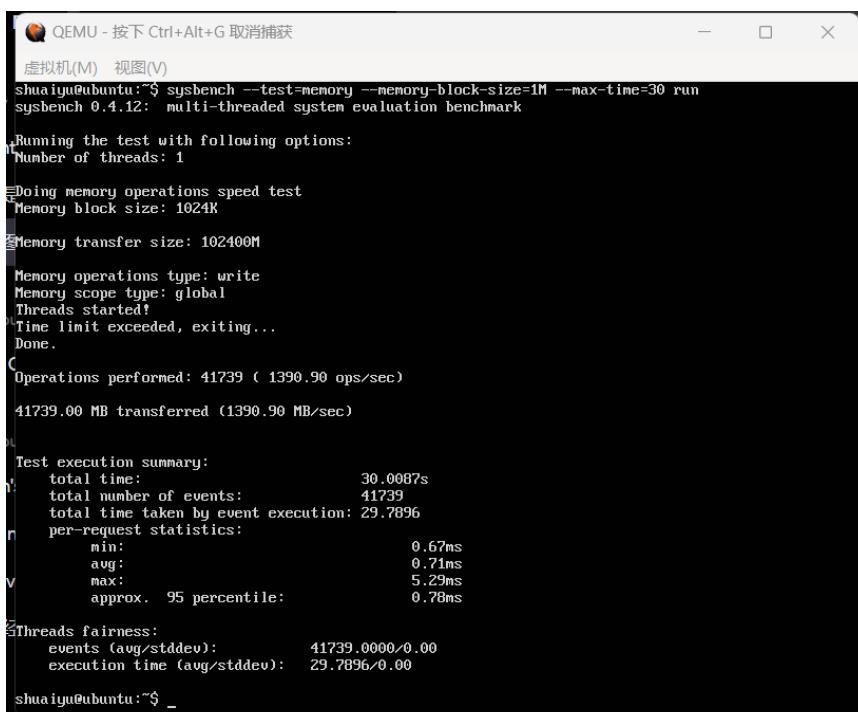


```
QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
  
Running the test with following options:  
Number of threads: 8  
File open flags: 0  
128 files, 40Mb each  
5Gb total file size  
Block size 16Kb  
Number of random requests for random IO: 10000  
Read/Write ratio for combined random IO test: 1.50  
Periodic FSYNC enabled, calling fsync() each 100 requests.  
Calling fsync() at the end of test, Enabled.  
Using synchronous I/O mode  
Doing random write test  
Threads started!  
Done.  
  
Operations performed: 0 Read, 10014 Write, 12810 Other = 22824 Total  
Read 0b Written 156.47Mb Total transferred 156.47Mb (4.0501Mb/sec)  
259.20 Requests/sec executed  
  
Test execution summary:  
total time: 38.6337s  
total number of events: 10014  
total time taken by event execution: 3.1688  
per-request statistics:  
    min: 0.04ms  
    avg: 0.32ms  
    max: 31.10ms  
    approx. 95 percentile: 0.34ms  
  
Threads fairness:  
events (avg/stddev): 1251.7500/148.27  
execution time (avg/stddev): 0.3961/0.04  
  
shuaigu@ubuntu:~$ _
```

4. Memory test:

a. Test 7:

```
sysbench memory --memory-block-size=1M --time=30 run
```



```
QEMU - 按下 Ctrl+Alt+G 取消捕获  
虚拟机(M) 视图(V)  
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=1M --max-time=30 run  
sysbench 0.4.12: multi-threaded system evaluation benchmark  
  
Running the test with following options:  
Number of threads: 1  
  
Doing memory operations speed test  
Memory block size: 1024K  
Memory transfer size: 102400M  
Memory operations type: write  
Memory scope type: global  
Threads started!  
Time limit exceeded, exiting...  
Done.  
  
Operations performed: 41739 ( 1390.90 ops/sec)  
41739.00 MB transferred (1390.90 MB/sec)  
  
Test execution summary:  
total time: 30.0087s  
total number of events: 41739  
total time taken by event execution: 29.7896  
per-request statistics:  
    min: 0.67ms  
    avg: 0.71ms  
    max: 5.29ms  
    approx. 95 percentile: 0.78ms  
  
Threads fairness:  
events (avg/stddev): 41739.0000/0.00  
execution time (avg/stddev): 29.7896/0.00  
  
shuaigu@ubuntu:~$ _
```

b. Test 8:

```
sysbench memory --memory-block-size=512K --time=30 run
```

```
QEMU - 按下 Ctrl+Alt+G 取消捕获
虚拟机(M) 视图(V)
shuaigu@ubuntu:~$ sysbench --test=memory --memory-block-size=512K --max-time=30 run
sysbench 0.4.12: multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 512K

Memory transfer size: 102400M

Memory operations type: write
Memory scope type: global
Threads started!
Time limit exceeded, exiting...
Done.

Operations performed: 89019 ( 2966.66 ops/sec)

44509.50 MB transferred (1483.33 MB/sec)

Test execution summary:
total time: 30.0065s
total number of events: 89019
total time taken by event execution: 29.5844
per-request statistics:
    min: 0.31ms
    avg: 0.33ms
    max: 5.39ms
    approx. 95 percentile: 0.38ms

Threads fairness:
events (avg/stddev): 89019.0000/0.00
execution time (avg/stddev): 29.5844/0.00

shuaigu@ubuntu:~$ _
```

## Analysis of Results

### CPU Test:

Following parameters are considered while performing the cpu test.

- a. **--cpu-max-prime**: This parameter sets the maximum prime number to check for in the CPU tests.
- b. **--time**: This parameter sets the total time for the test in seconds.
- c. **--threads**: This parameter sets the number of parallel threads to use in the test. The experiment is done by altering the values of the above parameters and running each test case 5 times to obtain the average, min, max and std. values of the results.

### Test 1:

```
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=10 run
```

Platform	Image	Environment	Min	Avg	Max	Std

Docker	ubuntu	1	0.69	0.72	1.59	0.67
Docker	ubuntu	2	0.69	1.42	51.15	23.37
Docker	ubuntu	3	0.69	1.43	51.27	61.70
Docker	ubuntu	4	0.69	0.72	1.58	0.40
QEMU	ubuntujmp	1	1.58	1.70	12.74	5.78
QEMU	ubuntujmp	2	1.60	1.72	5.23	1.66
QEMU	ubuntujmp	3	1.59	1.71	11.86	5.12
QEMU	ubuntujmp	4	1.59	1.70	5.06	1.73
QEMU	disk1jmp	1	1.59	1.70	5.42	1.92
QEMU	disk1jmp	2	1.59	1.69	5.04	1.73
QEMU	disk1jmp	3	1.60	1.71	5.16	1.80
QEMU	disk1jmp	4	1.59	1.69	5.47	1.93

Test 2:

sysbench cpu --threads=4 --cpu-max-prime=100000 --time=30 run

Platform	Image	Environment	Min	Avg	Max	Std
Docker	ubuntu	1	16.75	69.72	181.44	78.11
Docker	ubuntu	2	16.71	136.71	199.78	87.25
Docker	ubuntu	3	16.75	137.17	199.96	87.58
Docker	ubuntu	4	16.78	70.20	303.76	133.56
QEMU	ubuntujmp	1	47.01	72.50	92.12	21.19
QEMU	ubuntujmp	2	45.18	72.84	101.27	27.32
QEMU	ubuntujmp	3	35.94	40.42	137.21	46.99
QEMU	ubuntujmp	4	35.37	39.54	71.69	18.19
QEMU	disk1jmp	1	47.25	73.55	100.15	27.34
QEMU	disk1jmp	2	53.83	72.82	96.94	21.47
QEMU	disk1jmp	3	36.31	40.51	65.56	14.96
QEMU	disk1jmp	4	35.93	39.82	74.78	19.98

FileIO Test:

Following parameters are considered to perform FileIO Test

- a. --file-total-size: This parameter sets the total size of the test file in megabytes. --file-test-mode: This parameter sets the type of file I/O test to run (e.g. "seqwr", "seqrewr").
- b. --threads: This parameter sets the total number of threads used for the process.

The experiment is done by altering the values of the above parameters and running each test case 5 times to obtain the average, min, max and std. values of the results.

Test 1:

sysbench --threads=4 fileio --file-total-size=2G --file-test-mode=rndwr run

Platform	Image	Environment	Min	Avg	Max	Std
Docker	ubuntu	1	0.00	0.35	76.83	39.45
Docker	ubuntu	2	0.00	0.34	26.71	13.43
Docker	ubuntu	3	0.00	0.34	24.47	12.80

Docker	ubuntu	4	0.00	0.30	94.34	49.60
QEMU	ubuntujmp	1	0.04	0.16	15.57	7.73
QEMU	ubuntujmp	2	0.04	0.10	22.44	10.66
QEMU	ubuntujmp	3	0.05	0.15	10.15	4.72
QEMU	ubuntujmp	4	0.04	0.09	9.26	4.09
QEMU	disk1jmp	1	0.04	0.19	38.18	18.54
QEMU	disk1jmp	2	0.04	0.10	22.13	10.34
QEMU	disk1jmp	3	0.04	0.15	11.39	5.68
QEMU	disk1jmp	4	0.04	0.09	11.12	5.55

Test 2:

sysbench --threads=8 fileio --file-total-size=5G --file-test-mode=seqwr run

Platform	Image	Environment	Min	Avg	Max	Std
Docker	ubuntu	1	0.01	0.70	58.79	27.55
Docker	ubuntu	2	0.01	0.82	223.85	105.33
Docker	ubuntu	3	0.01	0.89	99.64	46.73
Docker	ubuntu	4	0.01	0.66	54.70	25.63
QEMU	ubuntujmp	1	0.05	0.42	53.88	25.29
QEMU	ubuntujmp	2	0.04	0.37	54.08	25.40
QEMU	ubuntujmp	3	0.05	0.29	45.46	21.35
QEMU	ubuntujmp	4	0.04	0.34	50.07	23.51
QEMU	disk1jmp	1	0.05	0.40	48.73	22.87
QEMU	disk1jmp	2	0.04	0.29	34.14	16.02
QEMU	disk1jmp	3	0.05	0.28	46.01	21.61
QEMU	disk1jmp	4	0.04	0.32	31.10	14.58

### Memory Test:

Following parameters are considered to perform Memory Test

a. --memory-block-size: This parameter sets the block size of the test memory in megabytes.

The experiment is done by altering the values of the above parameters and running each test case 5 times to obtain the average, min, max and std. values of the results.

Test 1:

sysbench memory --memory-block-size=1M --time=30 run

Platform	Image	Environment	Min	Avg	Max	Std
Docker	ubuntu	1	0.04	0.04	0.35	0.15
Docker	ubuntu	2	0.04	0.09	50.37	25.56
Docker	ubuntu	3	0.04	0.09	50.35	25.54
Docker	ubuntu	4	0.04	0.05	0.35	0.15
QEMU	ubuntujmp	1	0.61	0.65	11.69	1.90
QEMU	ubuntujmp	2	0.66	0.73	13.32	1.52
QEMU	ubuntujmp	3	0.61	0.65	15.38	2.84

QEMU	ubuntujmp	4	0.67	0.72	75.47	84.53
QEMU	disk1jmp	1	0.61	0.68	232.48	81.95
QEMU	disk1jmp	2	0.67	0.72	13.89	3.00
QEMU	disk1jmp	3	0.67	0.71	4.66	0.27
QEMU	disk1jmp	4	0.67	0.71	5.29	0.46

Test 2:

sysbench memory --memory-block-size=512K --time=30 run

Platform	Image	Environment	Min	Avg	Max	Std
Docker	ubuntu	1	0.02	0.02	0.29	0.09
Docker	ubuntu	2	0.02	0.04	50.33	25.56
Docker	ubuntu	3	0.02	0.04	50.39	25.57
Docker	ubuntu	4	0.02	0.02	0.34	0.09
QEMU	ubuntujmp	1	0.31	0.32	4.24	1.33
QEMU	ubuntujmp	2	0.31	0.34	8.68	2.18
QEMU	ubuntujmp	3	0.30	0.35	22.83	8.93
QEMU	ubuntujmp	4	0.31	0.33	13.62	3.39
QEMU	disk1jmp	1	0.31	0.34	7.02	3.19
QEMU	disk1jmp	2	0.31	0.35	21.89	8.77
QEMU	disk1jmp	3	0.34	0.37	6.47	3.59
QEMU	disk1jmp	4	0.31	0.33	5.39	2.38

Performance:

In a Windows 11 system, we can check the performance by typing  
CTRL+SHIFT+ESC to open the Windows Task Manager.

Performance data of QEMU:

CPU Memory FileIO

Image 1:

(1) During CPU test:



(2) During File IO test:

名称	状态	23%	94%	48%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Microsoft Edge (16)	繁忙	0%	236.1 MB	0 MB/秒	0 Mbps
> Microsoft Word (4)		0%	111.2 MB	0 MB/秒	0 Mbps
> QEMU machine emulators ...		15.5%	1,919.9 ...	8.1 MB/秒	5.3 Mbps

(3) During Memory test:

名称	状态	37%	95%	5%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Microsoft Edge (15)	繁忙	0%	153.4 MB	0.1 MB/秒	0 Mbps
> Microsoft Word (4)		0%	146.1 MB	0.1 MB/秒	0 Mbps
> QEMU machine emulators ...		16.0%	2,069.2 ...	0.3 MB/秒	0 Mbps

Image 2:

(1) During CPU test:

名称	状态	33%	89%	1%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Microsoft Edge (16)	繁忙	0%	211.6 MB	0 MB/秒	0 Mbps
> Microsoft Word (4)		0%	159.4 MB	0 MB/秒	0 Mbps
> QEMU machine emulators ...		11.5%	1,505.4 ...	0 MB/秒	0 Mbps

(2) During File IO test:

名称	状态	31%	90%	61%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Microsoft Edge (15)	繁忙	0%	103.1 MB	0 MB/秒	0 Mbps
> Microsoft Word (4)		0.3%	76.2 MB	0.1 MB/秒	0 Mbps
> QEMU machine emulators ...		27.9%	2,310.7 ...	4.2 MB/秒	0 Mbps

(3) During memory test:

名称	状态	43%	93%	17%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Microsoft Edge (15)	繁忙	0.9%	165.7 MB	0.1 MB/秒	0 Mbps
> Microsoft Word (4)		0.9%	141.8 MB	0.1 MB/秒	0 Mbps
> QEMU machine emulators ...		26.1%	2,224.4 ...	0.2 MB/秒	0 Mbps

Performance data of Docker:

(1) During CPU test:

名称	状态	22%	87%	2%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Docker Desktop (4)		0.1%	99.5 MB	0 MB/秒	0 Mbps

(2) During File IO test:

名称	状态	36%	93%	71%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Docker Desktop (4)		0%	66.5 MB	0.1 MB/秒	0 Mbps

(3) During Memory test:

名称	状态	17%	92%	3%	0%
		CPU	内存	磁盘	网络
<b>应用 (6)</b>					
> Docker Desktop (4)		0%	79.7 MB	0 MB/秒	0 Mbps

For CPU Test:

CPU utilization in case of QEMU image 1 was around 12.5%, image 2 was around 11.5% whereas in case of Docker it was 0.1%.

For File I/O Test:

The FileIO utilization of QEMU image 1 was around 48%, image 2 was around 61% whereas in case of Docker it was 71%.

For Memory Test:

The memory utilization of QEMU image 1 was around 95%, image 2 was around 93%, whereas in case of Docker it was 92%.

Conclusion:

From the above CPU, file I/O and memory performance data, we can easily see that the performance of Docker is much higher than that of QEMU. Taking performance into consideration only, we can conclude that containers are a better choice for virtualization than virtual machines.

Git Repository Information:

<https://github.com/StormYuchen/CSEN241-HMs.git>

## References

- [1] QEMU Documentation: <https://www.qemu.org/docs/master/>
- [2] Homebrew: <https://brew.sh/>
- [3] How do I run QEMU on Windows: <https://linuxhint.com/qemu-windows/>
- [4] Sysbench manual: <https://imysql.com/wp-content/uploads/2014/10/sysbench-manual.pdf>
- [5] Docker CLI Reference: <https://docs.docker.com/engine/reference/commandline/cli/>
- [6] Docker exec: <https://docs.docker.com/engine/reference/commandline/exec/>
- [7] Docker Tutorials: <https://docker-curriculum.com/>