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- Product quality issues
- Product use and build issues
- Questions regarding the technology employed in our products for learning and education
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- We also encourage your ideas and suggestions for new products and product improvements

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Please follow the following safety precautions when using or storing this product:

- Keep this product out of the reach of children under 6 years old.
- This product should be used only when there is adult supervision present as young children lack necessary judgment regarding safety and the consequences of product misuse.
- This product contains small parts and parts, which are sharp. This product contains electrically conductive parts. Use caution with electrically conductive parts near or around power supplies, batteries and powered (live) circuits.
- When the product is turned ON, activated or tested, some parts will move or rotate. To avoid injuries to hands and fingers, keep them away from any moving parts!
- It is possible that an improperly connected or shorted circuit may cause overheating. Should this happen, immediately disconnect the power supply or remove the batteries and do not touch anything until it cools down! When everything is safe and cool, review the product tutorial to identify the cause.
- Only operate the product in accordance with the instructions and guidelines of this tutorial, otherwise parts may be damaged or you could be injured.
- Store the product in a cool dry place and avoid exposing the product to direct sunlight.
- After use, always turn the power OFF and remove or unplug the batteries before storing.

About Freenove

Freenove provides open source electronic products and services worldwide.

Freenove is committed to assist customers in their education of robotics, programming and electronic circuits so that they may transform their creative ideas into prototypes and new and innovative products. To this end, our services include but are not limited to:

- Educational and Entertaining Project Kits for Robots, Smart Cars and Drones
- Educational Kits to Learn Robotic Software Systems for Arduino, Raspberry Pi, micro: bit and Raspberry Pi Pico W.
- Electronic Component Assortments, Electronic Modules and Specialized Tools
- **Product Development and Customization Services**

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http://www.freenove.com

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Contents

Preface

Designed exclusively for the Raspberry Pi 5, this NVMe SSD expansion card is available in dual- or quad-interface configurations, supporting 2 or 4 NVMe SSDs simultaneously for dramatically improved storage performance.

The Raspberry Pi 5 includes a PCIe x1 slot that is certified for PCIe Gen 2.0, providing a theoretical maximum throughput of 5GT/sec, which roughly translates to 500MB/sec for read and write operations. Due to the limitations of the expansion chip's specifications, at the time of writing, this product only supports the PCIe 2.0 protocol.

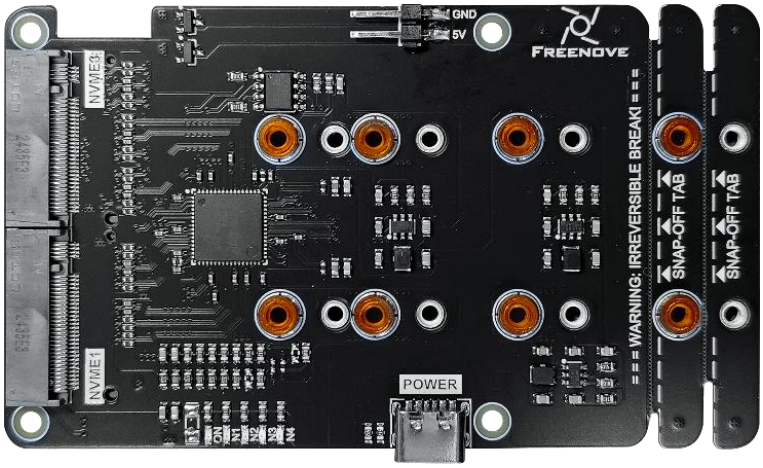
SSDs generally provide significantly faster read and write speeds compared to SD cards and USB drives, which can notably elevate the user experience when operating the Raspberry Pi 5.

This guide will walk you through the steps to effectively integrate and utilize this adapter on your Raspberry Pi 5.Additionally, if you encounter any issues or have questions about this tutorial or the contents of kit, you can always contact us for free technical support at:

support@freenove.com

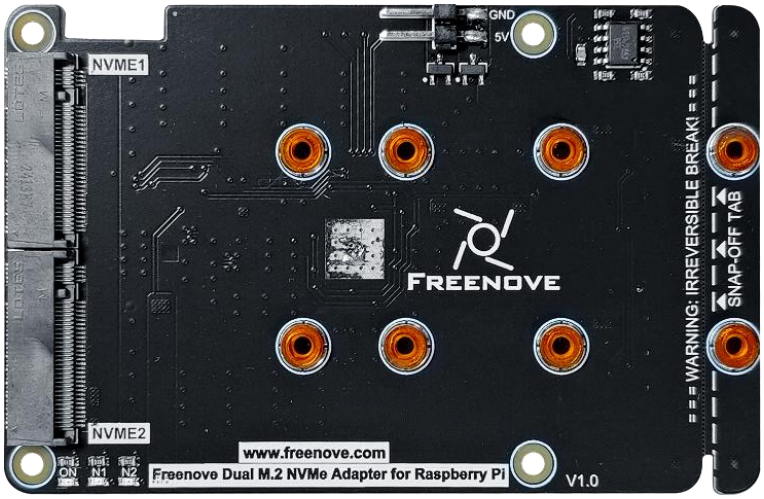
eenove Quad M.2 NVMe Adapter for Raspberry Pi

This model has four NVMe SSD interface, supporting up to 4 NVMe SSDs to run simultaneously. In this tutorial, we name this model as 4-Slot SSD Adapter Board.



- **Interface Type**: 4x M.2 with M-Key
- **Supported Protocol**: NVMe
- **Compatible Sizes**: 2230, 2242, 2260, 2280
- **Power Supply**: 3.3V, up to 3A (maximum)
- **Indicator Lights**: Includes both power and x4 SSD status LEDs.

This model has two NVMe SSD interface, supporting two NVMe SSDs to run simultaneously. In this tutorial, we name this model as 2-Slot SSD Adapter Board.



- **Interface Type**: 2x M.2 with M-Key
- **Supported Protocol**: NVMe
- **Compatible Sizes**: 2230, 2242, 2260, 2280
- **Power Supply**: 3.3V, up to 3A (maximum)
- **Indicator Lights**: Includes both power and x2 SSD status LEDs.

Overview

To boot Raspberry Pi 5 from an NVMe SSD, two core tasks need to be accomplished:

1. **Flash the Raspberry Pi's operating system image onto the NVMe SSD.**
2. Configure the boot order of Raspberry Pi to give priority to SSD. (Optional)

1. First of all, make sure you can enter the Raspberry Pi OS via SD card or U drive.
2. After booting the Raspberry Pi, you can use it to flash the OS image directly onto the NVMe SSD. Alternatively, you can purchase an NVMe SSD to USB adapter and flash the image using USB on Windows or macOS, much like you would for an SD card or USB drive.
3. With this analysis in mind, we can systematically carry out the necessary steps.

Raspberry Pi models manufactured at different times might not boot up in the same way as described, but that's okay; just follow our guide to proceed.
There are various ways to flash the Raspberry Pi OS to SSD, each requiring different hardware tools.

Ways	Flashing Methods	Requirements
1	Use Raspberry Pi to flash the OS. This requires that you can successfully boot up the Raspberry Pi via SD card or U disk. (**Recommended, described in this tutorial**)	An SD card or a U disk that can access the Raspberry Pi OS.
2	Purchase an NVMe SSD to USB adapter and flash the image just like you would with an SD card or USB drive.	NVME SSD to USB adapter (need to be bought separately)
3	If there are spare M.2 NVME interface on the motherboard of your PC, you can insert the SSD to it to flash the OS.	PC with M.2 NVME interface

The recognition and reading/writing of the NVME SSD are handled by the drivers of the Raspberry Pi 5. The 4-Slot SSD Adapter Board or 2-Slot SSD Adapter Board serves to connect and power the SSD. If you find that your SSD is not recognized or readable/writeable by the Pi 5, please try to find the drivers suitable for your SSD and install them on the Raspberry Pi, or replace the SSD, or purchase our Adapter kit that comes with an SSD.

Chapter 1 Flashing OS to SD Card or USB Drive

Based on the analysis above, our first step should be to install the Raspberry Pi operating system onto an SD card or USB drive, with a capacity of at least 16GB. If you are already able to boot the Raspberry Pi using an SD card or USB drive, you can skip this section and move on to the next chapter.

Required Components (self-prepared)

Raspberry Pi 5 	Raspberry Pi Official Power Adapter 
Micro SD Card (TF Card) x1, Card Reader x1 	

Optional Components

Under normal circumstances, there are two ways to login to Raspberry Pi: 1) Using a stand-alone monitor. 2) Using a remote desktop or laptop computer monitor "sharing" the PC monitor with your RPi.

Required Accessories for Monitor

If you choose to use an independent monitor, mouse and keyboard, you also need the following accessories:
1. A display with a HDMI interface
2. A Mouse and a Keyboard with an USB interface

As to Pi Zero and Pi Zero W, you also need the following accessories:
1. A Mini-HDMI to HDMI Adapter and Cable.
2. A Micro-USB to USB-A Adapter and Cable (Micro USB OTG Cable).
3. A USB HUB.
4. USB to Ethernet Interface or USB Wi-Fi receiver.

For different Raspberry Pi Modules, the optional items may vary slightly but they all aim to convert the interfaces to Raspberry Pi standards.

<table>
<tr><th></th><th>Pi Zero</th><th>Pi A+</th><th>Pi Zero W</th><th>Pi 3A+</th><th>Pi B+/2B</th><th>Pi 3B/3B+</th><th>Pi 4B/5B</th></tr>
<tr><td>Monitor</td><td colspan="7">Yes (All)</td></tr>
<tr><td>Mouse</td><td colspan="7">Yes (All)</td></tr>
<tr><td>Keyboard</td><td colspan="7">Yes (All)</td></tr>
<tr><td>Micro-HDMI to HDMI Adapter & Cable</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>Micro-HDMI to HDMI Adapter & Cable</td><td colspan="6">No</td><td>Yes</td></tr>
<tr><td>Micro-USB to USB-A Adapter & Cable (Micro USB OTG Cable)</td><td>Yes</td><td>No</td><td>Yes</td><td colspan="4">No</td></tr>
<tr><td>USB HUB</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td></td></tr>
<tr><td>USB to Ethernet Interface</td><td colspan="2" rowspan="2">select one from two or select two from two</td><td colspan="2" rowspan="2">optional</td><td>Internal Integration</td><td colspan="2" rowspan="2">Internal Integration</td></tr>
<tr><td>USB Wi-Fi Receiver</td><td>optional</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2">Internal Integration</td><td colspan="3"></td></tr>
</table>

Required Accessories for Remote Desktop

If you do not have an independent monitor, or if you want to use a remote desktop, you first need to login to Raspberry Pi through SSH, and then open the VNC or RDP service. This requires the following accessories.

	Pi Zero	Pi Zero W	Pi A+	Pi 3A+	Pi B+/2B	Pi 3B/3B+/4B/5B
Micro-USB to USB-A Adapter & Cable (Micro USB OTG Cable)	Yes	Yes	No	NO		
USB to Ethernet interface	Yes	Yes	Yes			

Without Screen - Use Raspberry Pi - under Windows PC: https://youtu.be/XpiT_ezb_7c
With Screen - Use Raspberry Pi - under Windows PC: https://youtu.be/HEywFsFrj3I

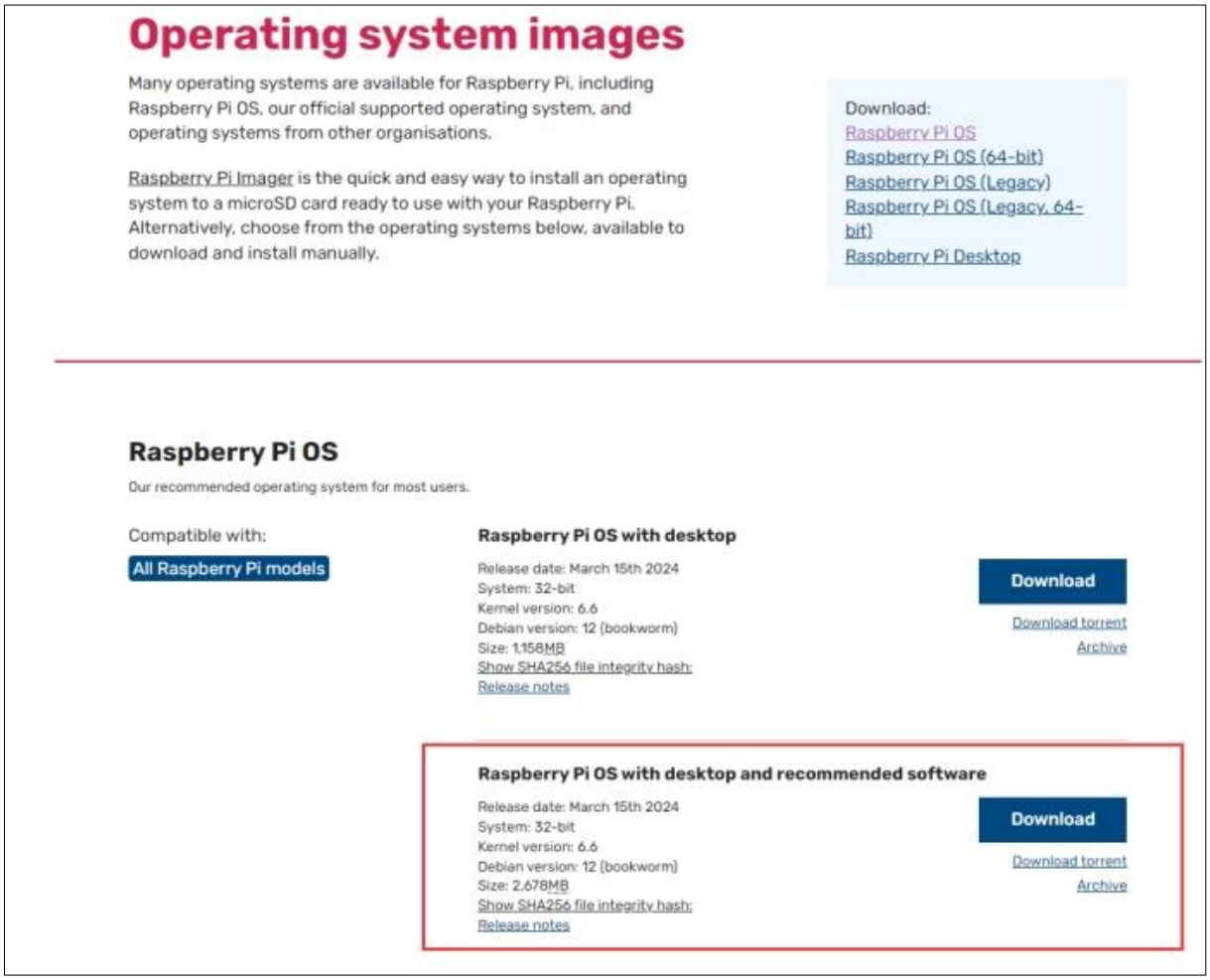
Automatically Method

You can follow the official method to install the system for raspberry pi via visiting link below:
https://projects.raspberrypi.org/en/projects/raspberry-pi-setting-up/2
In this way, the system will be downloaded **automatically** via the application.

Manually Method

After installing the Imager Tool in the **link above**. You can **also** download the system **manually** first.

Visit https://www.raspberrypi.com/software/operating-systems/



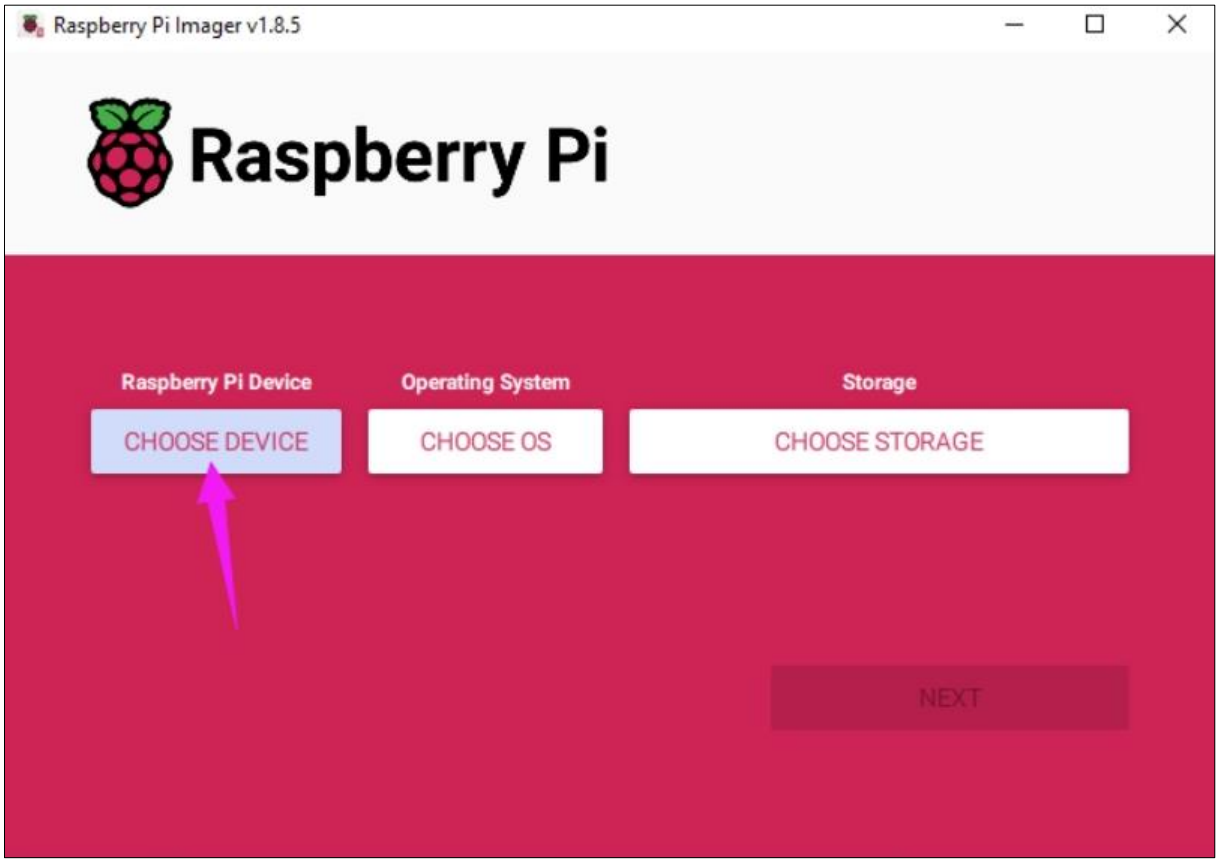
Then the zip file is downloaded.

Write System to Micro SD Card

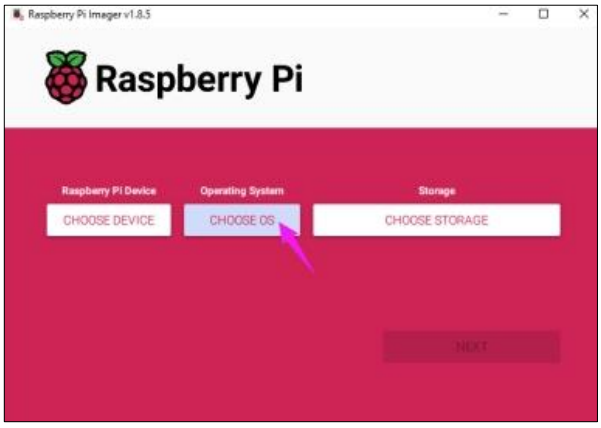
First, put your Micro **SD card** into card reader and connect it to USB port of PC.

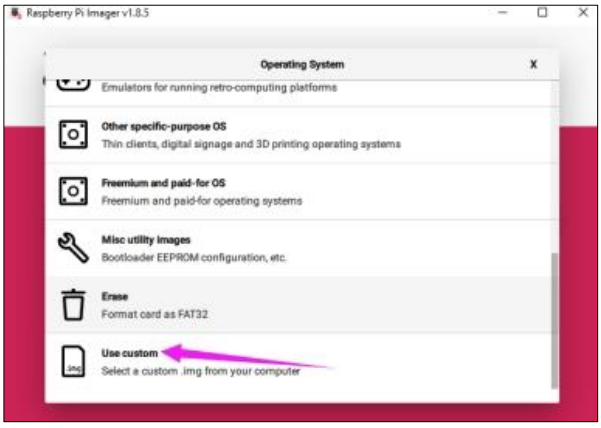
Open Raspberry Pi Imager.

Choose Raspberry Pi 5 as the device.

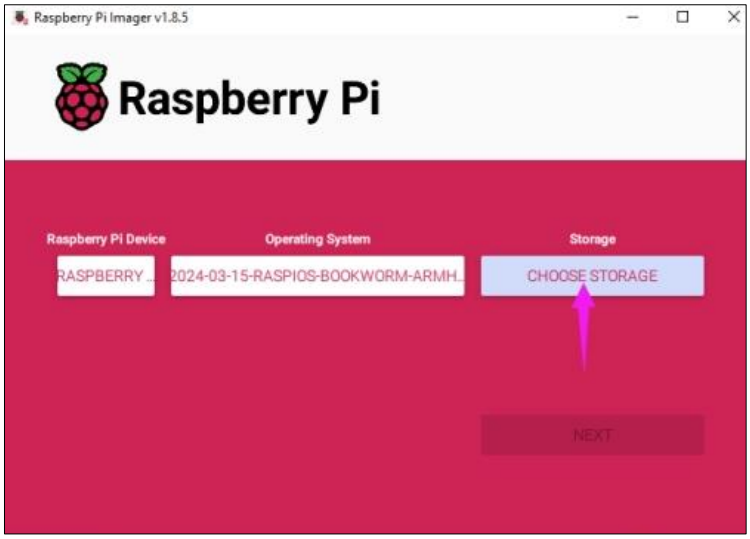


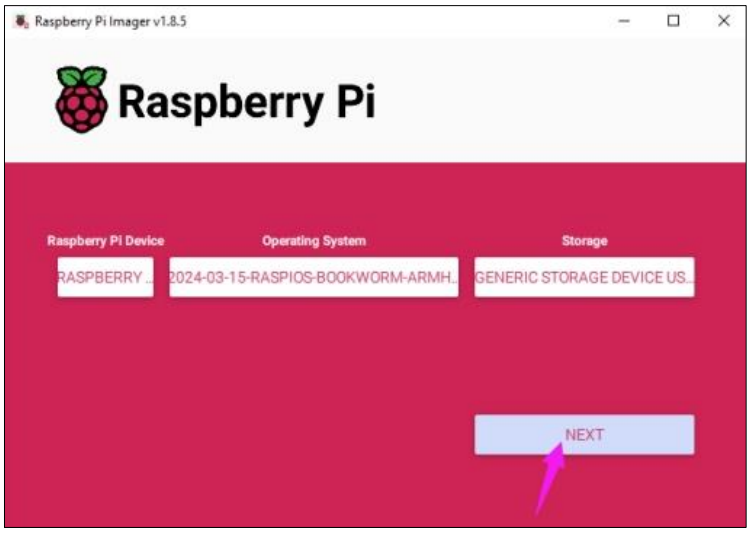
Choose the system that you just downloaded in Use custom.





Choose the SD card and click on Next.

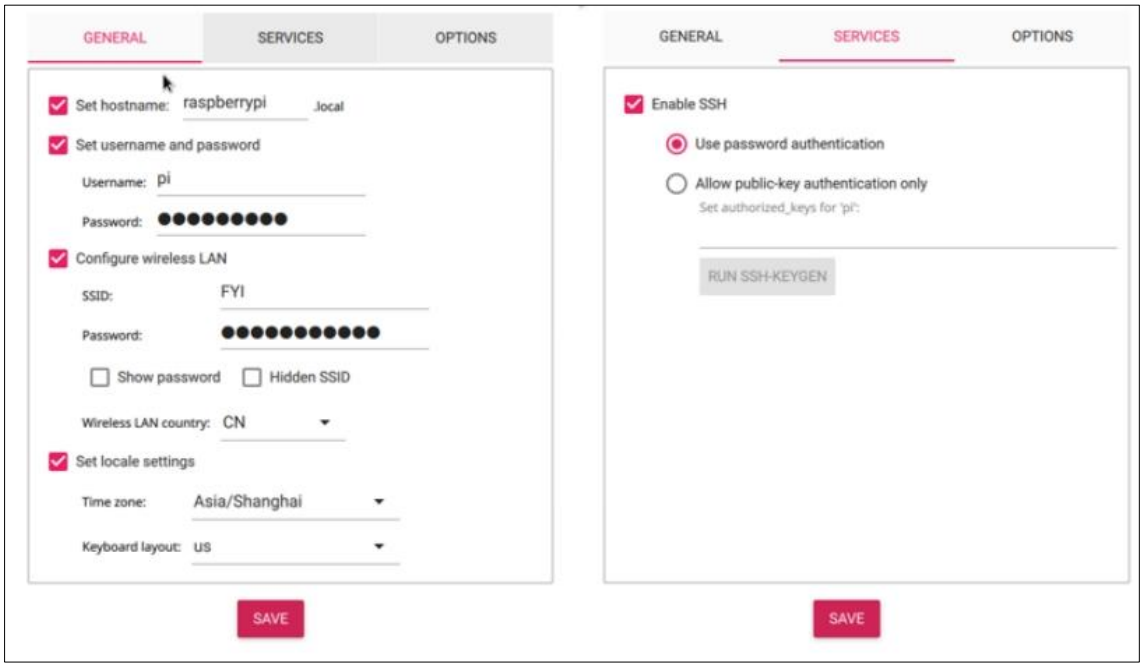


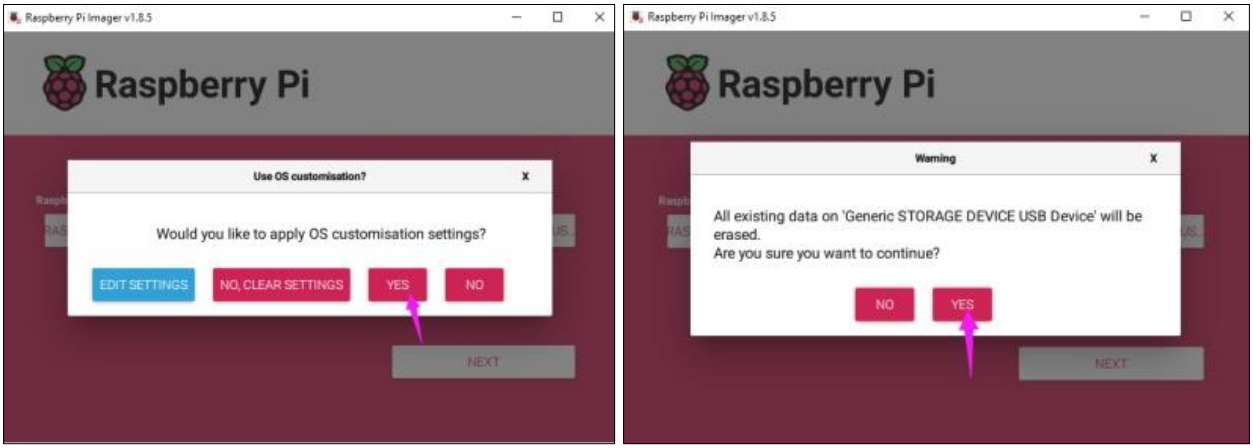


Enable ssh and configure WiFi

Click EDIT SETTINGS.

Configure wireless LAN, enable SSH and click Save.

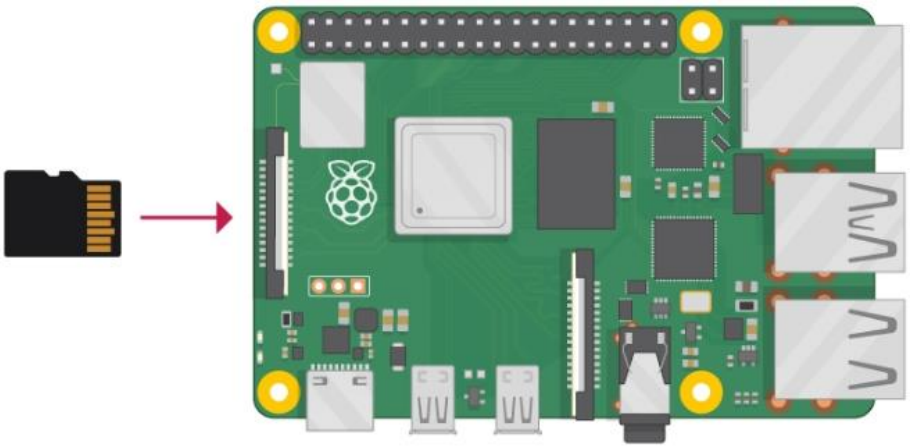




Wait for it to finish writing and verifying.

Insert SD card

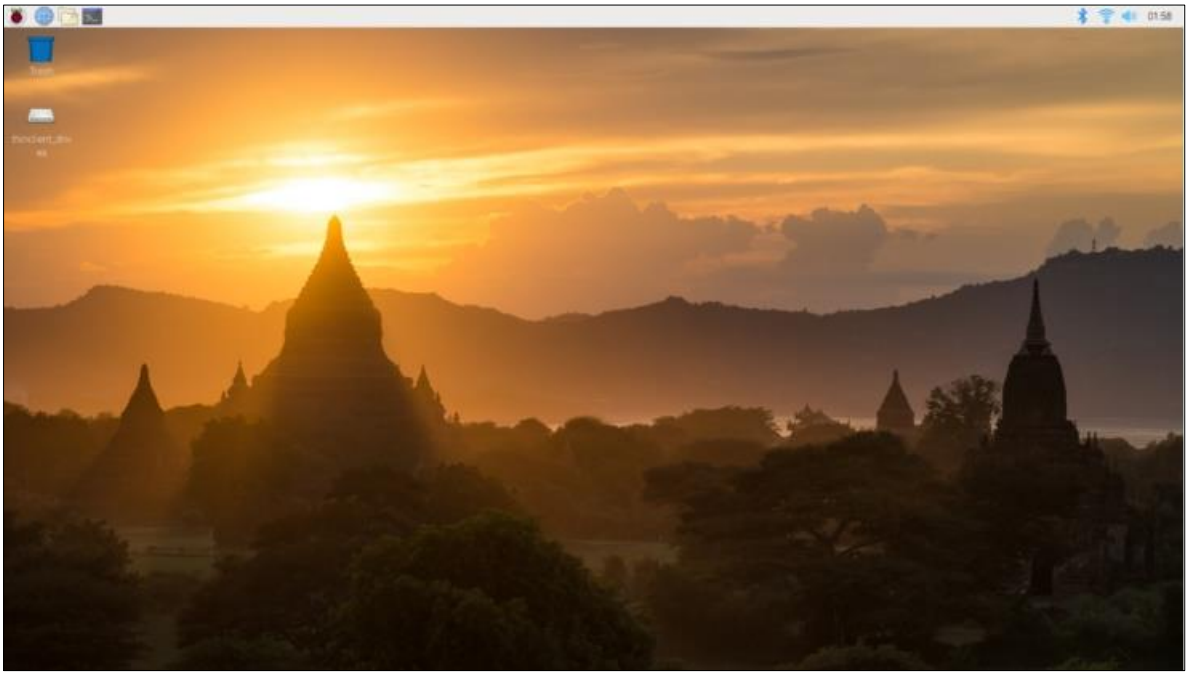
Then remove SD card from card reader and insert it into Raspberry Pi.



Monitor desktop

If you do not have a spare monitor, please skip to next section Remote desktop & VNC. If you have a spare monitor, please follow the steps in this section.

After the system is written successfully, take out Micro SD Card and put it into the SD card slot of RPi. Then connect your RPi to the monitor through the HDMI port, attach your mouse and keyboard through the USB ports, attach a network cable to the network port and finally, connect your power supply (making sure that it meets the specifications required by your RPi Module Version. Your RPi should start (power up). Later, after setup, you will need to enter your user name and password to login. The default user name: pi; password: raspberry. After login, you should see the following screen.



Congratulations! You have successfully installed the RASPBERRY PI OS operating system on your RPi.

Raspberry Pi 4B, 3B+/3B integrates a Wi-Fi adaptor. You can use it to connect to your Wi-Fi. Then you can use the wireless remote desktop to control your RPi. This will be helpful for the following work. Raspberry Pi of other models can use wireless remote desktop through accessing an external USB wireless card.

Remote desktop & VNC

If you have logged in Raspberry Pi via display, you can skip to VNC Viewer.

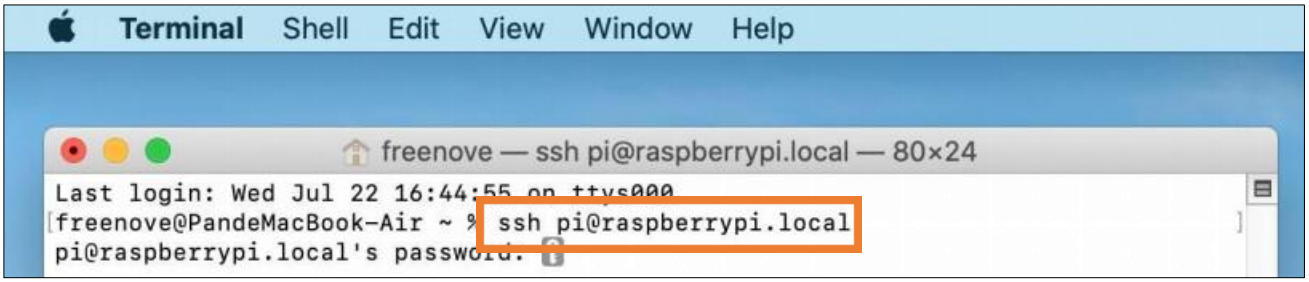
If you don't have a spare display, mouse and keyboard for your RPi, you can use a remote desktop to share a display, keyboard, and mouse with your PC. Below is how to use:
MAC OS remote desktop and Windows OS remote desktop.

MAC OS Remote Desktop

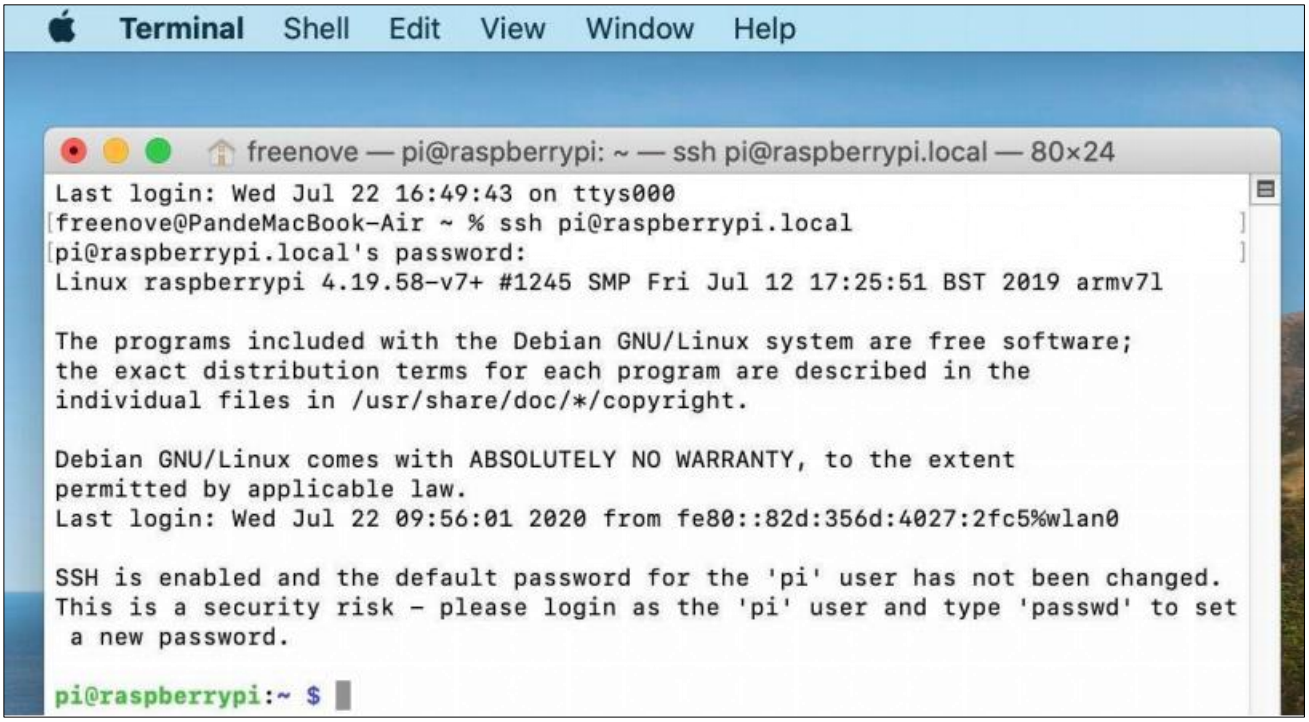
Open the terminal and type following command. **If this command doesn't work, please navigate to next page.**

```
ssh pi@raspberrypi.local
```

The password is **raspberry** by default, case sensitive.



You may need to type **yes** during the process.



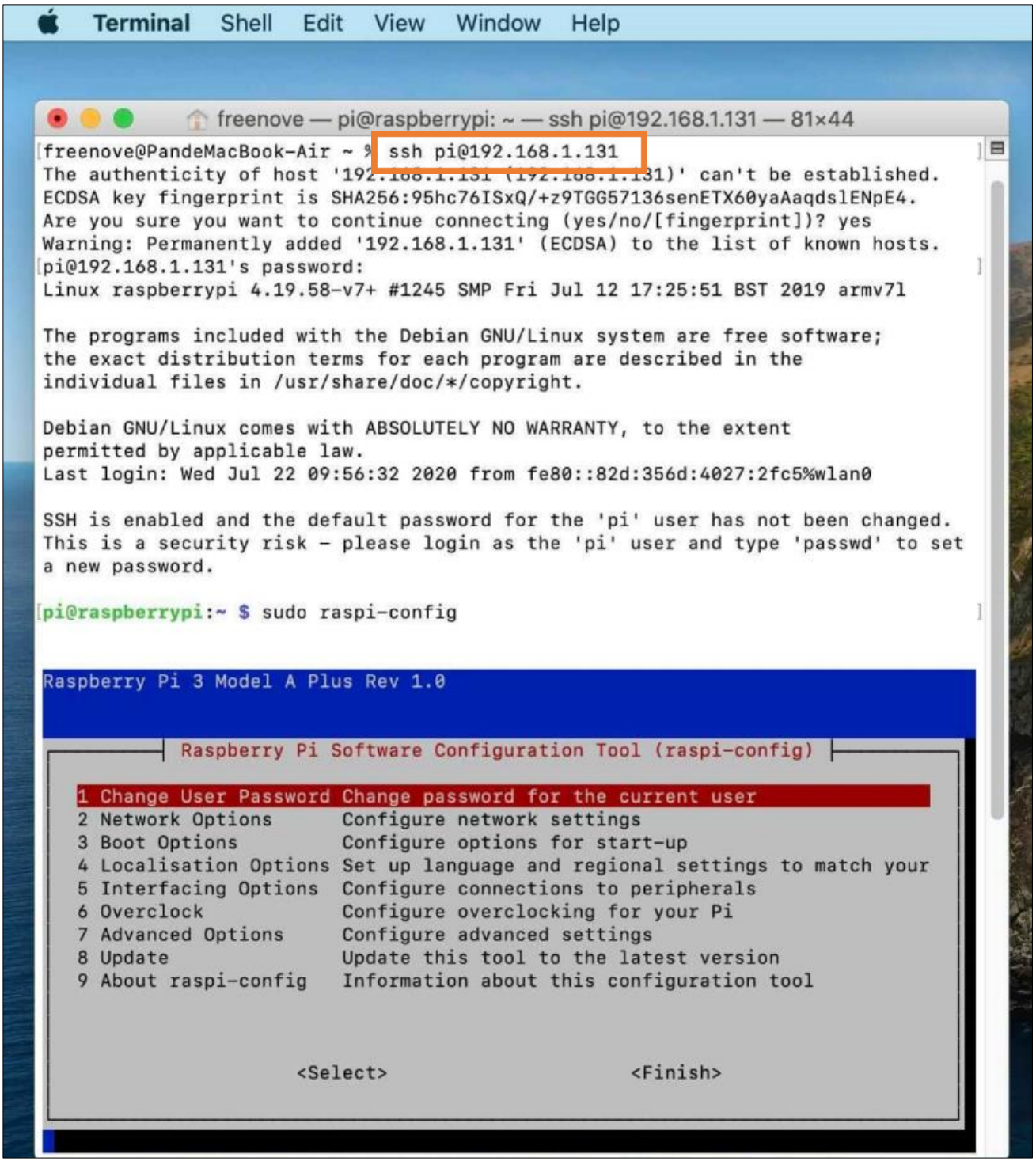
You can also use the IP address to log in Pi.

Enter **router** client to **inquiry IP address** named "raspberry pi". For example, I have inquired to **my RPi IP address, and it is "192.168.1.131".**

Open the terminal and type following command.

```
ssh pi@192.168.1.131
```

When you see pi@raspberrypi:~ $, you have logged in Pi successfully. Then you can skip to next section.



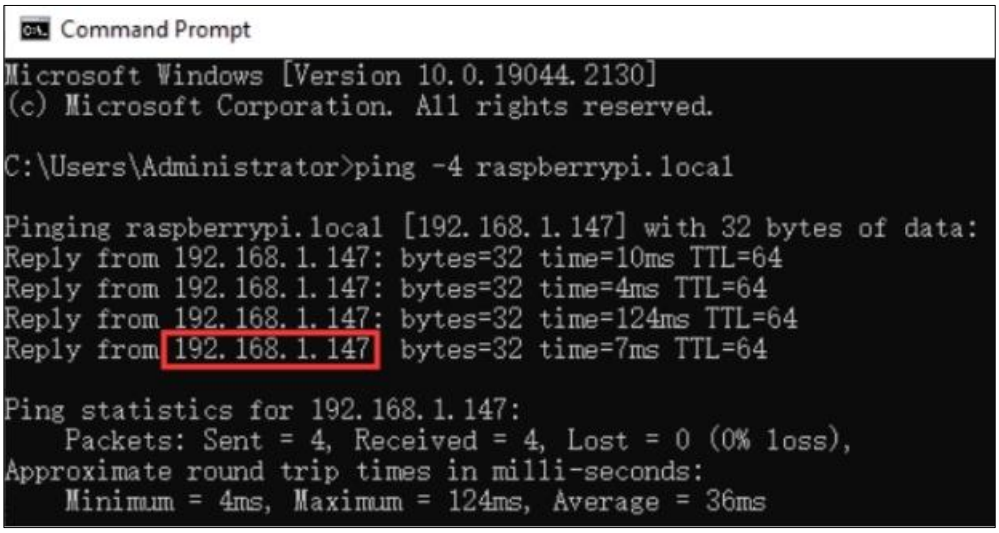
Then you can skip to VNC Viewer.

Windows OS Remote Desktop

If you are using win10, you can use follow way to login Raspberry Pi without desktop.

Press **Win+R**. Enter **cmd**. Then use this command to check IP:

```
ping -4 raspberrypi.local
```



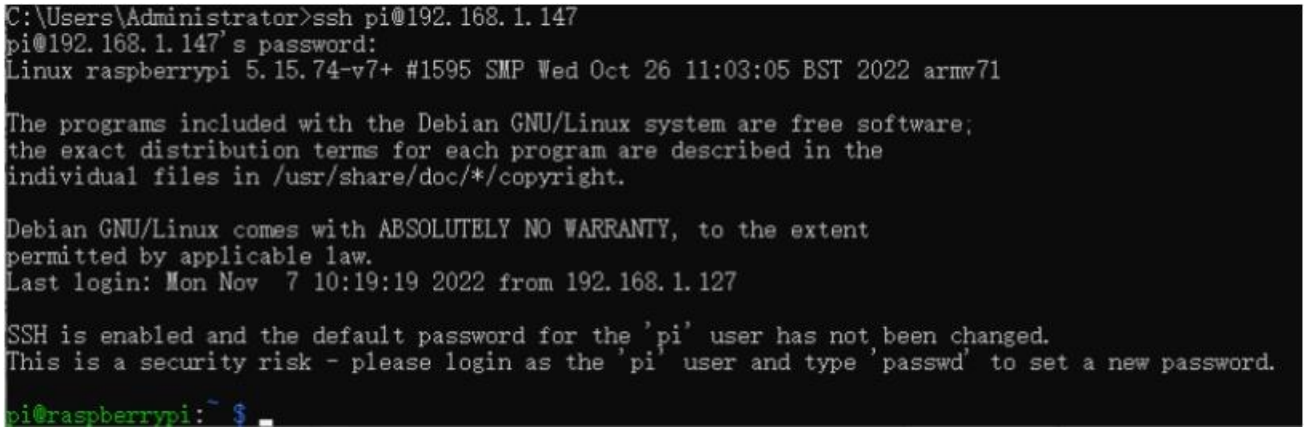
From the above command, you can get the IP address of your RPi. In our case, the IP address is 192.168.1.147.

Alternatively, you can login your router client to inquiry IP address named “raspberrypi”. **IP address and it is “192.168.1.147".**

Enter the following command:

Replace [192.168.1.147] with your Pi's actual IP address.

```
ssh pi@192.168.1.147
```

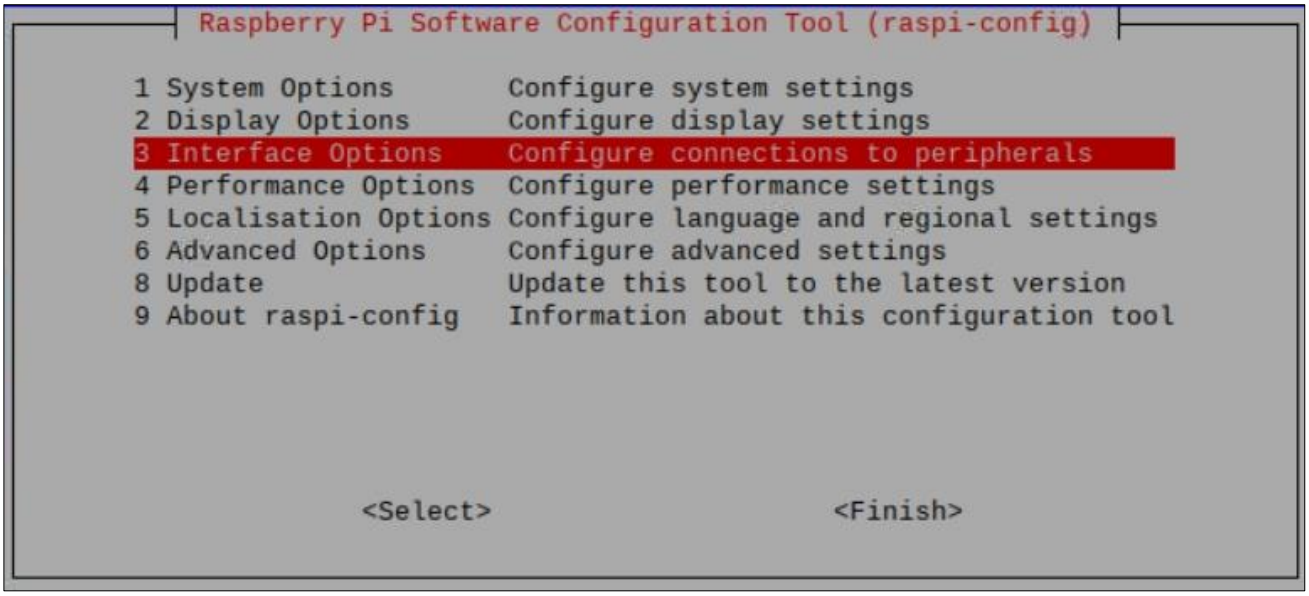


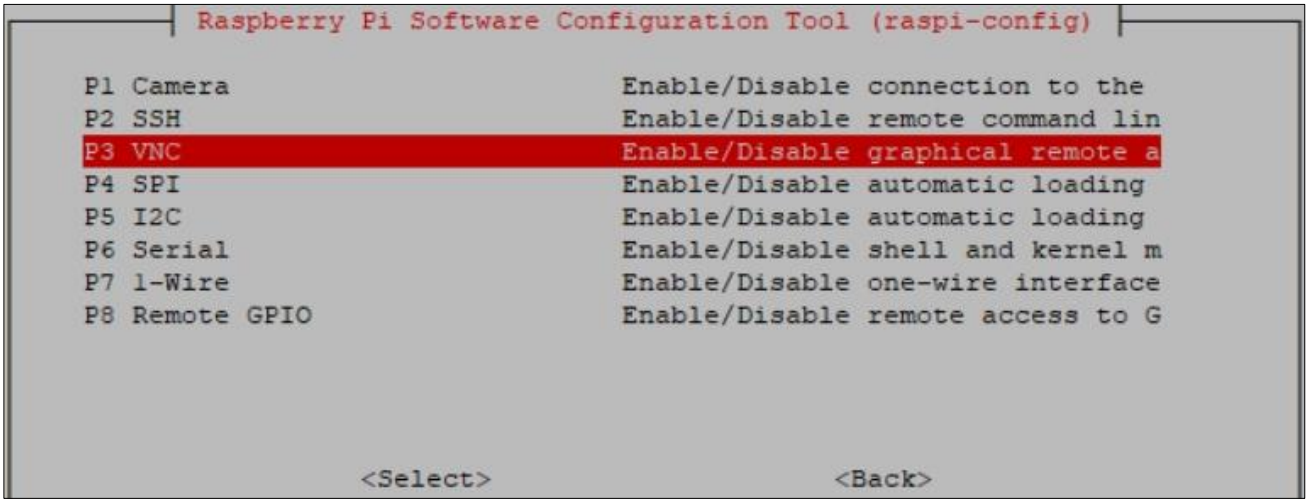
VNC Viewer & VNC

Enable VNC

Type the following command. Select Interface Options→P3 VNC → Enter→Yes→OK. Here Raspberry Pi may need restart, and choose ok. Then open VNC interface.

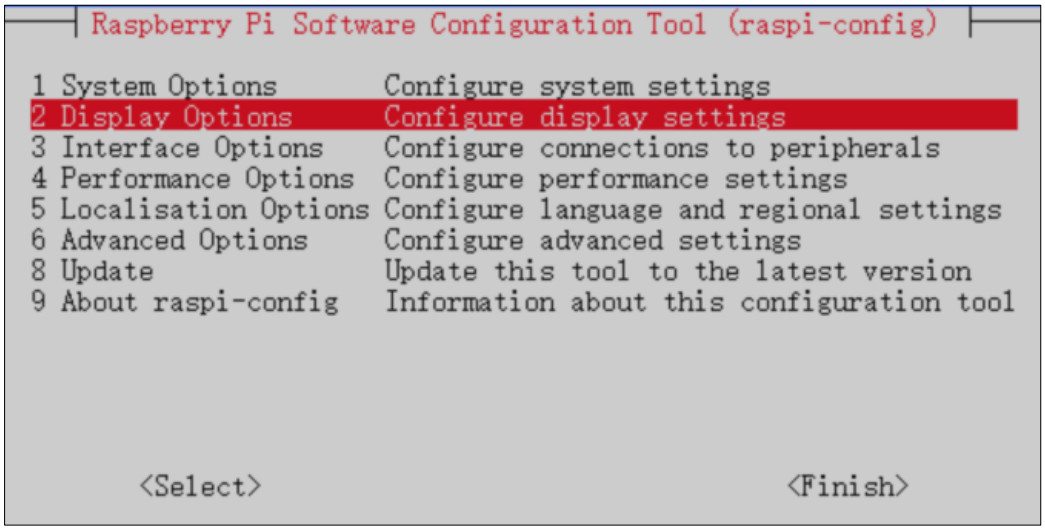
```
sudo raspi-config
```

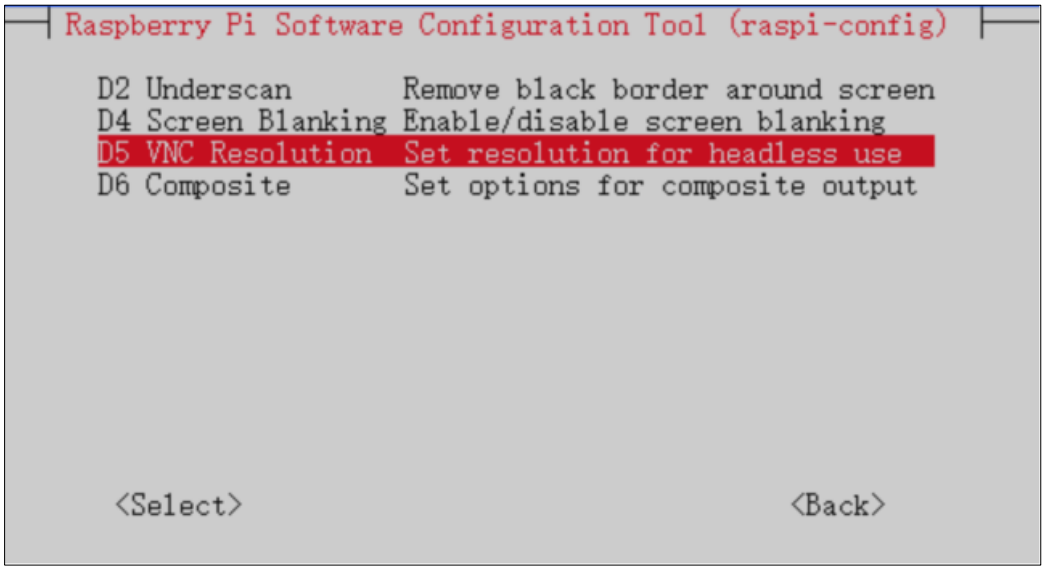


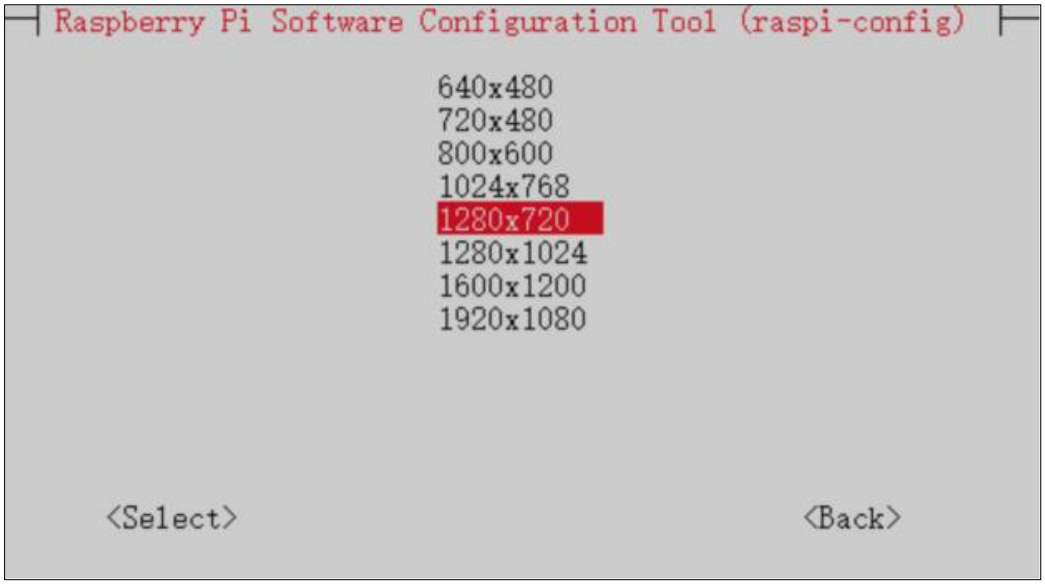


Set Resolution

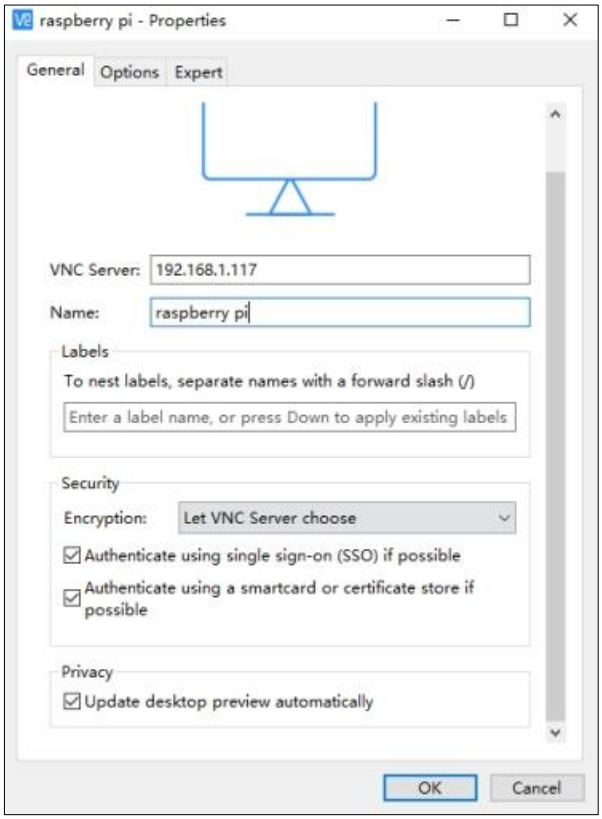
You can also set other resolutions. If you don't know what to set, you can set it as 1280x720 first.





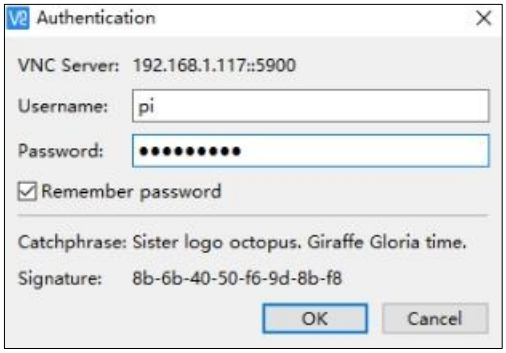


Then download and install VNC Viewer according to your computer system by click following link:
https://www.realvnc.com/en/connect/download/viewer/
After installation is completed, open VNC Viewer. Click File → New Connection. Then the interface is shown below.

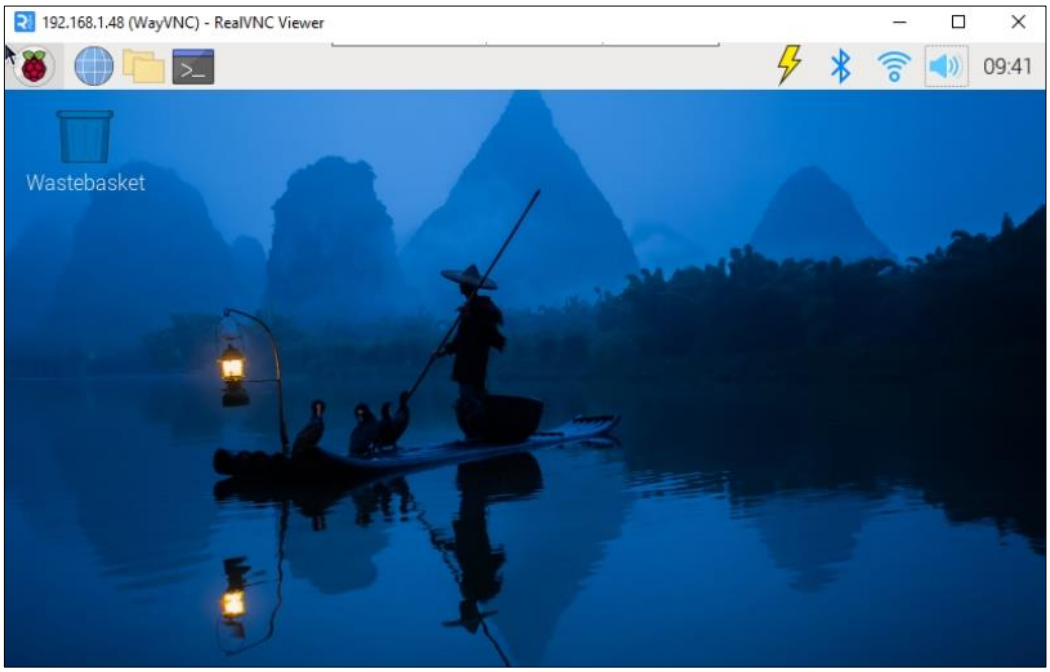


Enter ip address of your Raspberry Pi and fill in a name. Then click OK.
Then on the VNC Viewer panel, double-click new connection you just created,

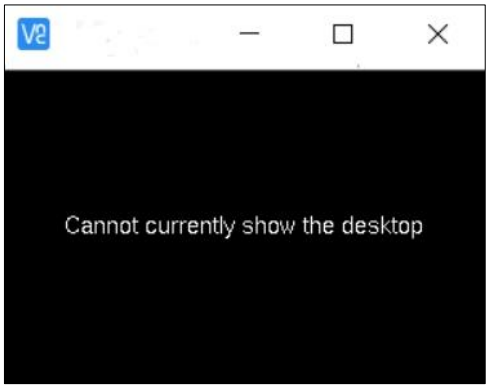
and the following dialog box pops up.



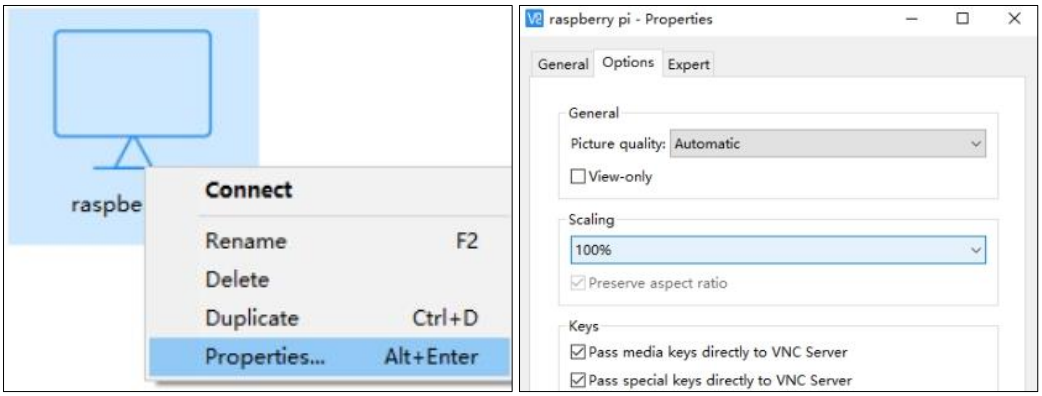
Enter username: **pi** and Password: **raspberry**. Click OK.



Here, you have logged in to Raspberry Pi successfully by using VNC Viewer.
If there is black window, please set another resolution.



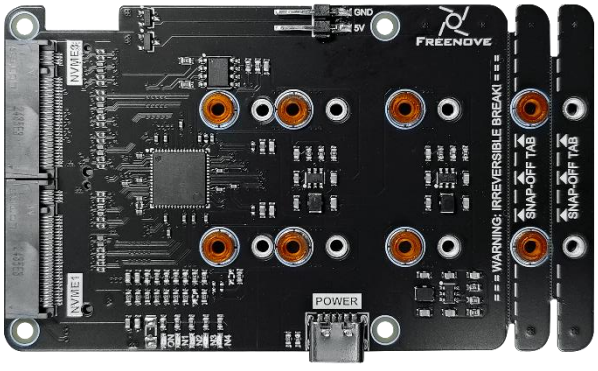
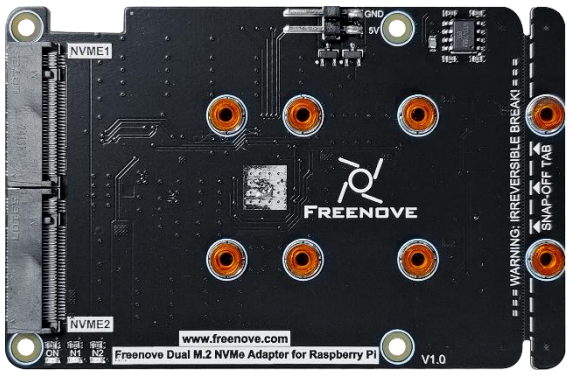
In addition, your VNC Viewer window may zoom your Raspberry Pi desktop. You can change it. On your VNC View control panel, click right key. Select Properties->Options label->Scaling. Then set proper scaling.



Here, you have logged in to Raspberry Pi successfully by using VNC Viewer and operated proper setting.

Chapter 2 Flashing OS to NVMe SSD

Mount the NVMe SSD adapter and the SSD to your Raspberry Pi.

Raspberry Pi 5 	Raspberry Pi Official Power Adapter 
Micro SD Card (TF Card) x1, Card Reader x1 	NVME SSD x2 or NVME SSD x4 
4-Slot SSD Adapter Board x1 or 2-Slot SSD Adapter Board x1  	
M2.5x3 Screws x8 	M2.5*12+4 single-pass brass standoffs x8 	M2.5*12 dual-pass brass standoffs x4 

Reverse curved cable x1 or reverse straight cable x1

Note:

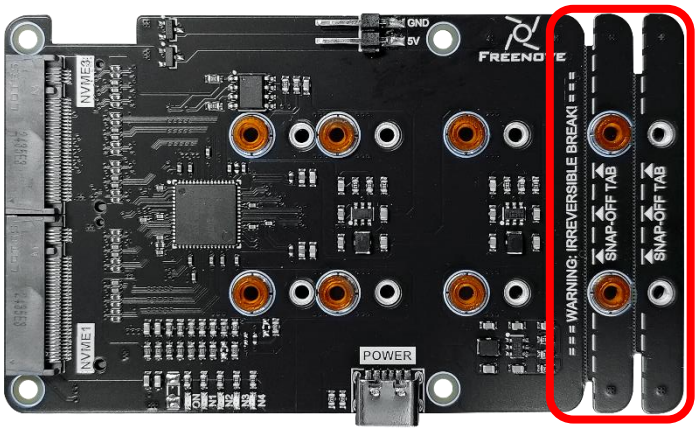
The curve cable (left) is for Freenove Quad M.2 Adapter for Raspberry Pi

The straight cable (right) is for Freenove Dual M.2 Adapter for Raspberry Pi

2P Jump Wire x1

You may skip this step if you do not wish to resize the board.

The board supports size adjustment via snap-off edges. If support for a 2280 SSD is not required, use pliers to break off the marked Snap-off TAB. (Warning: This operation is irreversible).

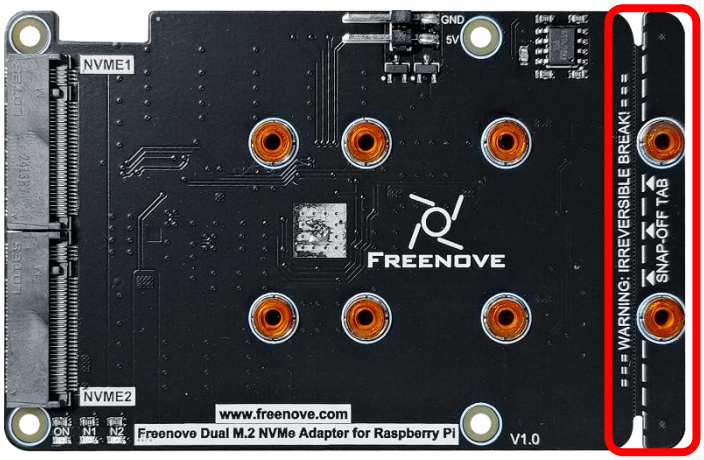


The 4-Slot SSD Adapter Board includes two Snap-off TABs:

Outer TAB Secures a 2280 SSD on the back side.

Inner TAB: Secures a 2280 SSD on the front side.

Note: Removing either TAB will permanently disable 2280 SSD installation on the corresponding side.



The 2-Slot SSD Adapter Board has only one Snap-off TAB (Removing the TAB will permanently disable 2280 SSD installation).

If you have any concerns, please feel free to contact us via support@freenove.com

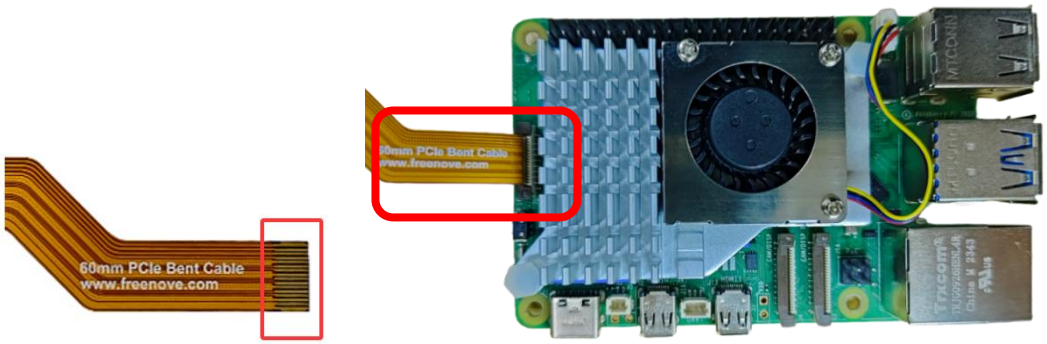
For assembly steps of the **4-Slot SSD Adapter Board**, click HERE
For assembly steps of the **2-Slot SSD Adapter Board**, click HERE

2.3.1 Assembling 4-Slot SSD Adapter Board

The 4-Slot SSD Adapter Board can be assembled either above or below the Raspberry Pi 5. You can install it in the way you prefer

Assembling above the Raspberry Pi 5

1. Connect the cable to Raspberry Pi 5. (Pay attention to the cable orientation. The side with contact pins faces the inner of the Raspberry Pi.)

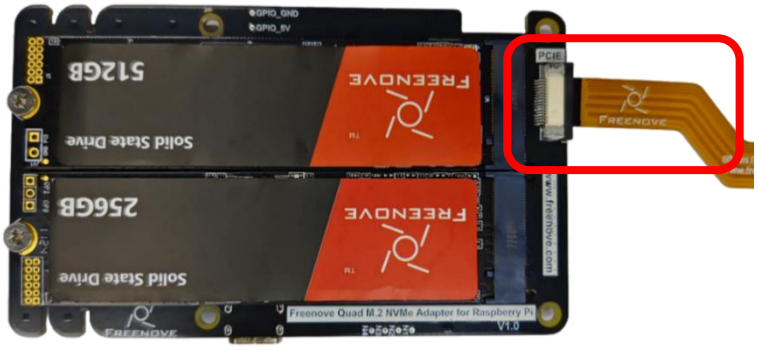


2. Stack two M2.5×12+4 single-pass brass standoffs together, insert them into one mounting hole of the Raspberry Pi, and secure with a single-pass standoff; repeat this process for the remaining three holes.

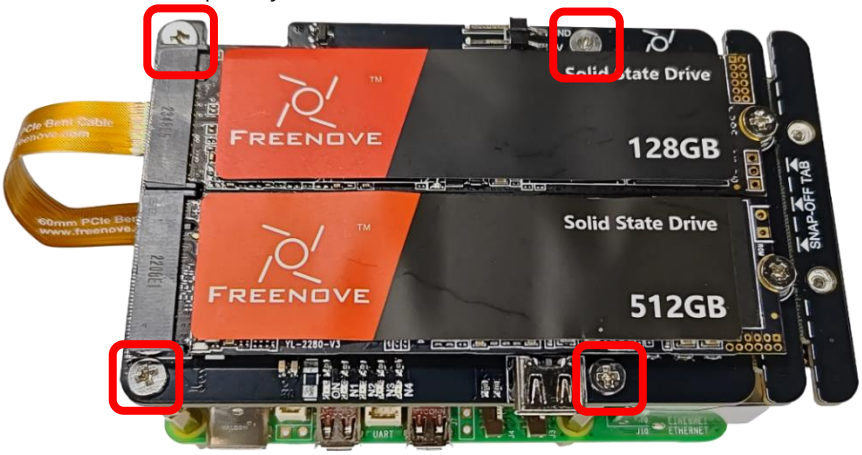
3. Tilt to insert the SSD into the board, and fix it with an M2.5x3 screw.

The 4-Slot SSD Adapter Board features a dual-sided layout (two slots per side), supporting simultaneous connection of four NVMe SSDs. It is compatible with 2232/2242/2260/2280 form factors, enabling high-density storage expansion in a compact footprint.

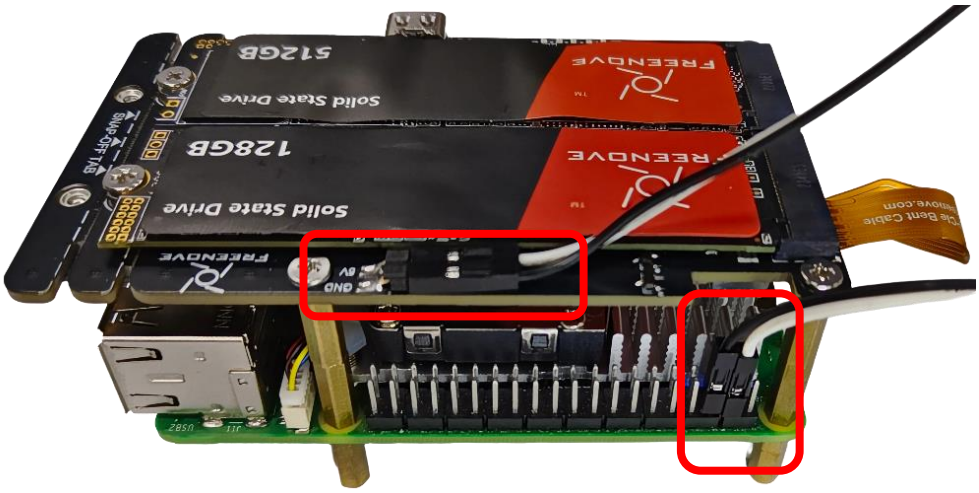
4. Connect the other end of the cable to adapter board.

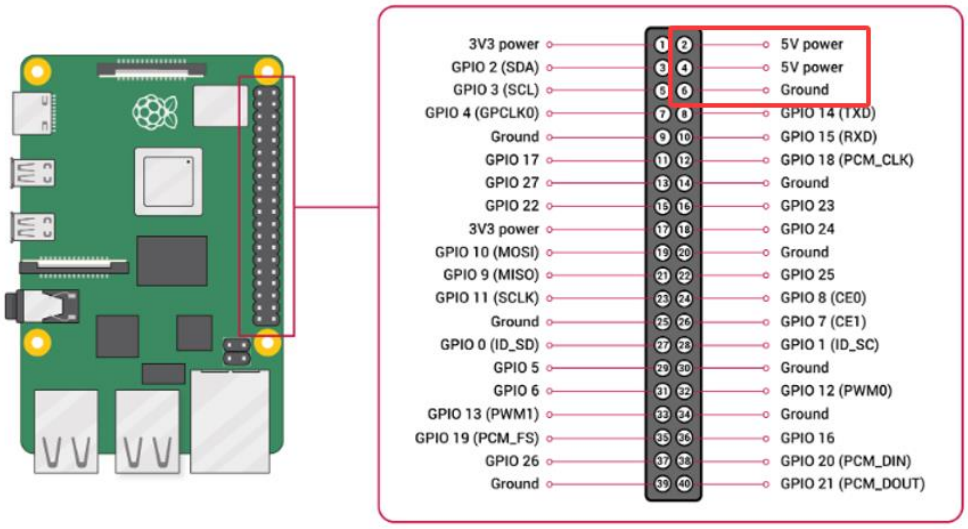


5. Fix the adapter board to the Raspberry Pi 5 with four M2.5x3 screws.



6. Consistently connect the adapter board's 5V and GND pins to the corresponding 5V/GND pins on the Raspberry Pi 5 using jumper wires. (Refer to Raspberry Pi 5 GPIO pinout diagram). https://www.raspberrypi.com/documentation/computers/raspberry-pi.html#gpio)



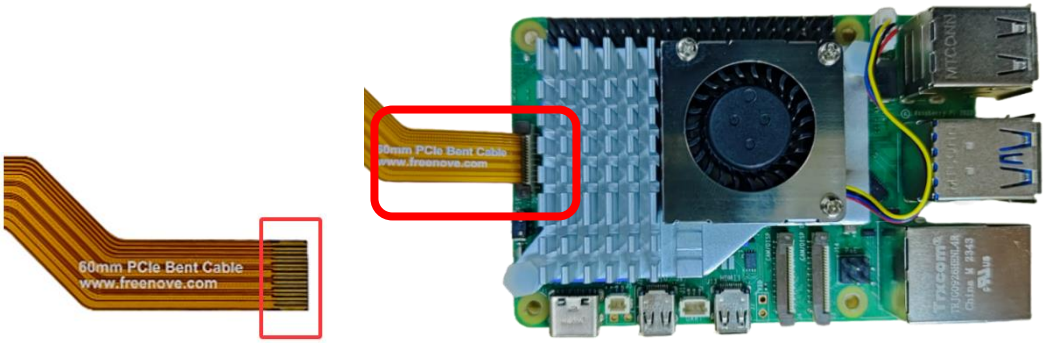


The 4-Slot SSD Adapter Board also supports external power via its onboard USB-C port (5V/3A recommended).

Note: Powering the adapter board from USB-C and jumper wire simultaneously is NOT supported!

Assembling below the Raspberry Pi 5

1. Connect the cable to Raspberry Pi 5. (Pay attention to the cable orientation. The side with contact pins faces the inner of the Raspberry Pi.)

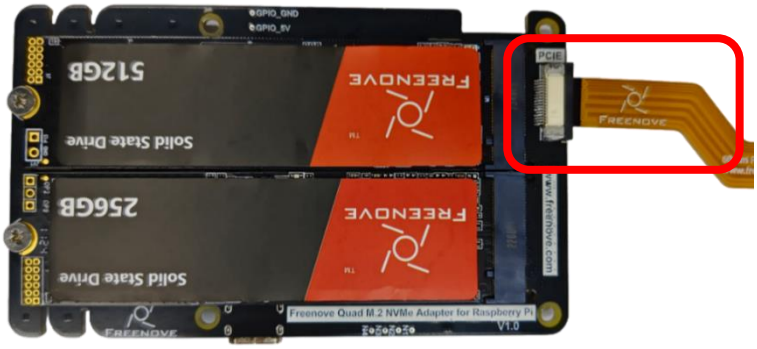


2. Tilt to insert the SSD into the board, and fix it with an M2.5x3 screw.

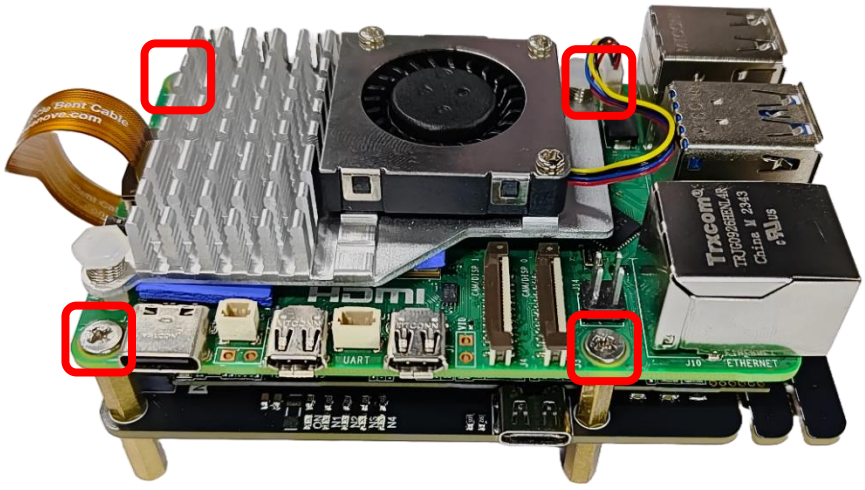
The 4-Slot SSD Adapter Board features a dual-sided layout (two slots per side), supporting simultaneous connection of four NVMe SSDs. It is compatible with 2232/2242/2260/2280 form factors, enabling high-density storage expansion in a compact footprint.

3. Insert an M2.5×12+4 single-pass brass standoffs into one mounting hole of the adapter board, and secure with a single-pass standoff; repeat this process for the remaining three holes.

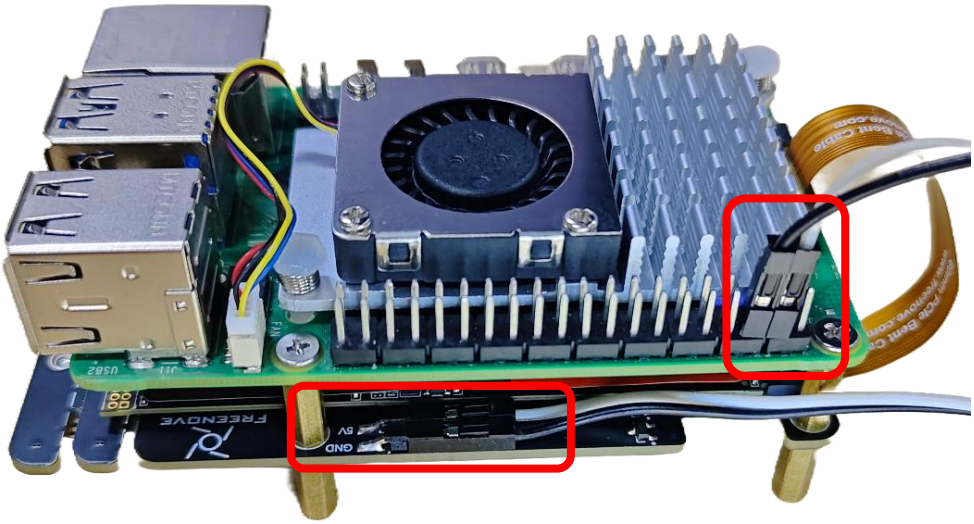
4. Connect the other end of the cable to adapter board.

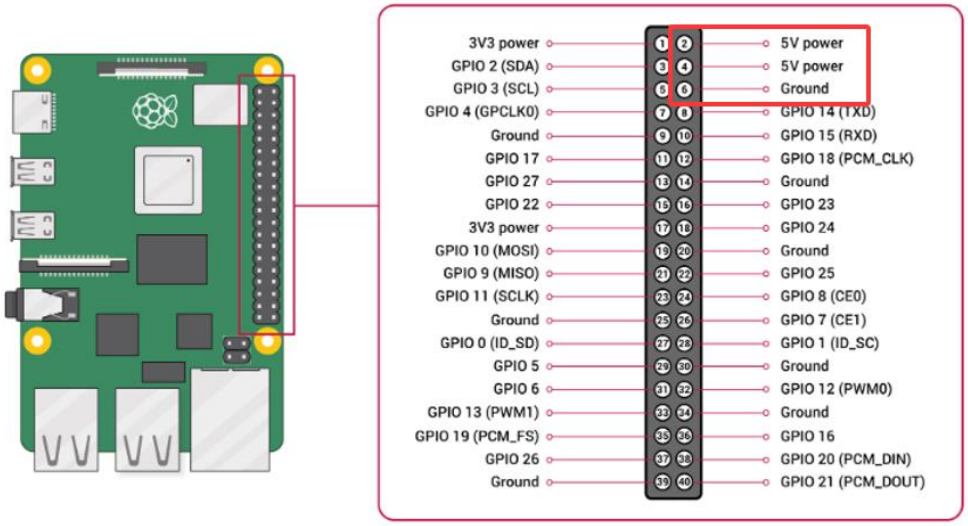


5. Put the adapter board below the Raspberry pi and fix with M2.5x3 screws.

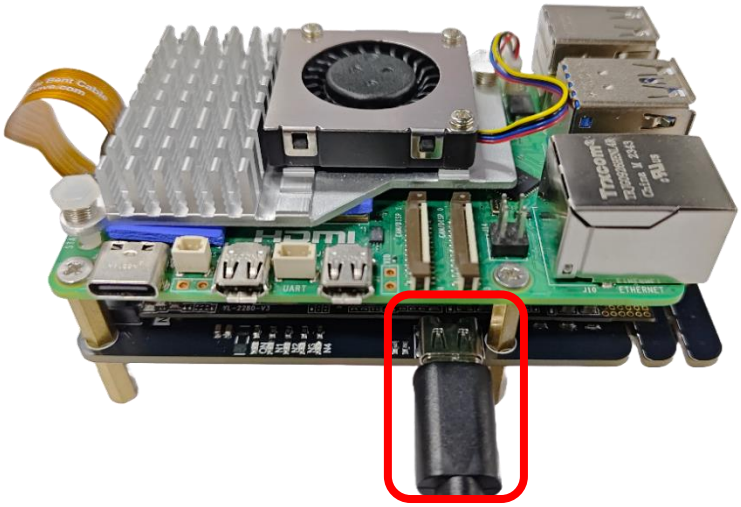


6. Consistently connect the adapter board's 5V and GND pins to the corresponding 5V/GND pins on the Raspberry Pi 5 using jumper wires. (Refer to Raspberry Pi 5 GPIO pinout diagram). https://www.raspberrypi.com/documentation/computers/raspberry-pi.html#gpio)





The 4-Slot SSD Adapter Board also supports external power via its onboard USB-C port (5V/3A recommended).



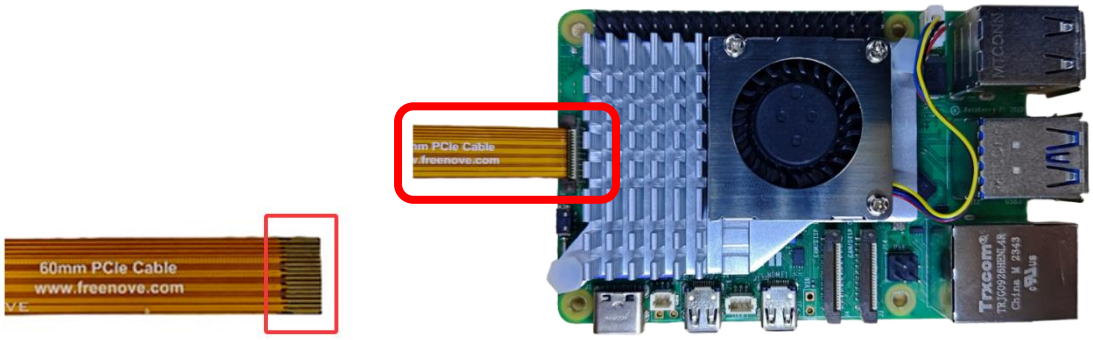
Note: Powering the adapter board from USB-C and jumper wire simultaneously is NOT supported!

2.3.2 Assembling 2-Slot SSD Adapter Board

The 2-Slot SSD Adapter Board can be assembled either above or below the Raspberry Pi 5. You can install it in the way you prefer.

Assembling above the Raspberry Pi 5

1. Connect the cable to Raspberry Pi 5. (Pay attention to the cable orientation. The side with contact pins faces the inner of the Raspberry Pi.)

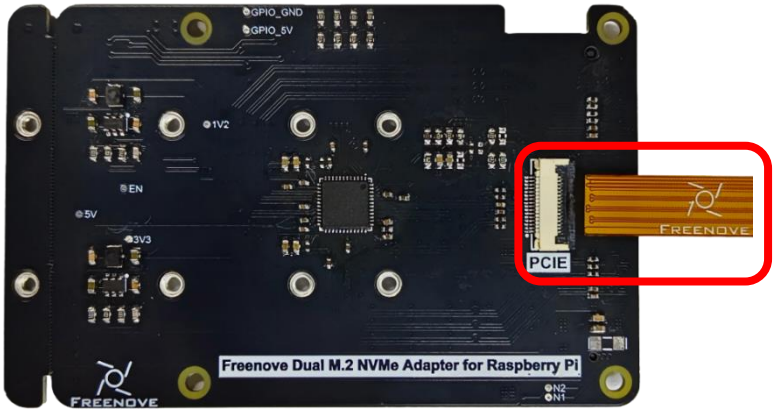


2. Stack two M2.5×12+4 single-pass brass standoffs together, insert them into one mounting hole of the Raspberry Pi, and secure with a single-pass standoff; repeat this process for the remaining three holes.

3. Tilt to insert the SSD into the board, and fix it with an M2.5x3 screw.

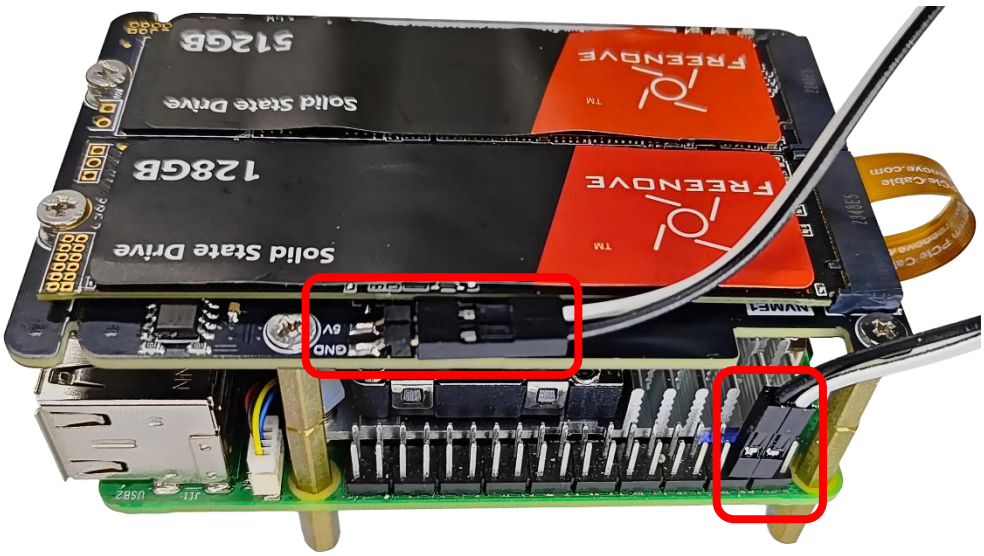
The 2-Slot SSD Adapter Board supports simultaneous connection of two NVMe SSDs, compatible with 2232/2242/2260/2280 form factors.

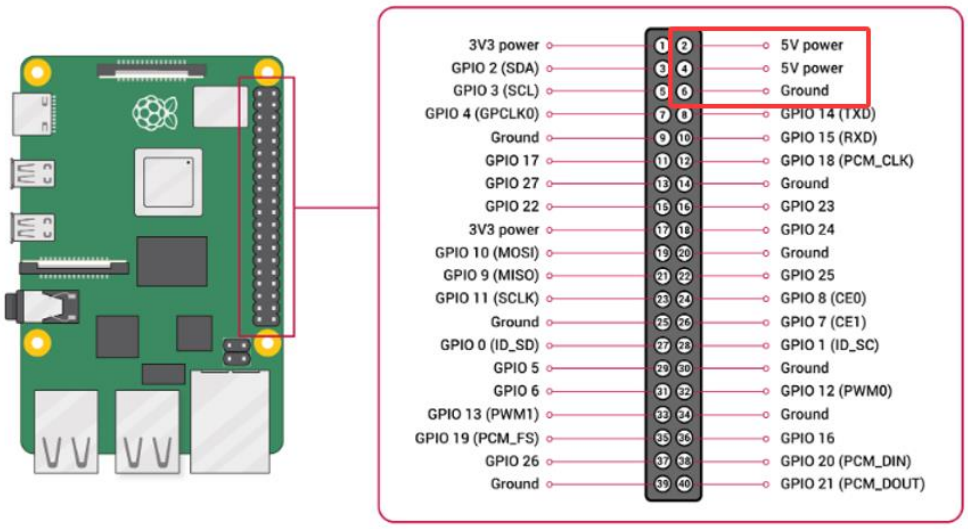
4. Connect the other end of the cable to adapter board.



5. Fix the adapter board to the Raspberry Pi 5 with four M2.5x3 screws.

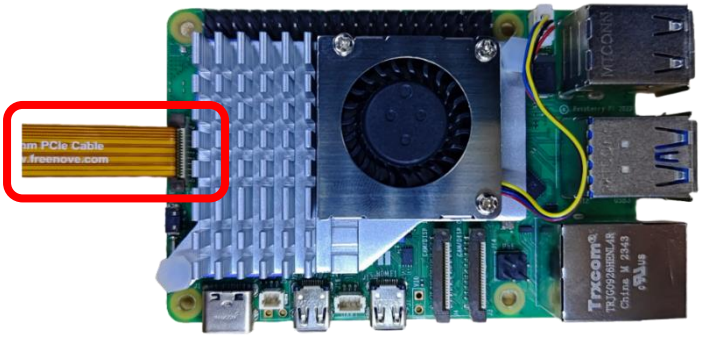
6. Consistently connect the adapter board's 5V and GND pins to the corresponding 5V/GND pins on the Raspberry Pi 5 using jumper wires. (Refer to Raspberry Pi 5 GPIO pinout diagram). https://www.raspberrypi.com/documentation/computers/raspberry-pi.html#gpio)





Assembling below the Raspberry Pi 5

1. Connect the cable to Raspberry Pi 5. (Pay attention to the cable orientation. The side with contact pins faces the inner of the Raspberry Pi.)

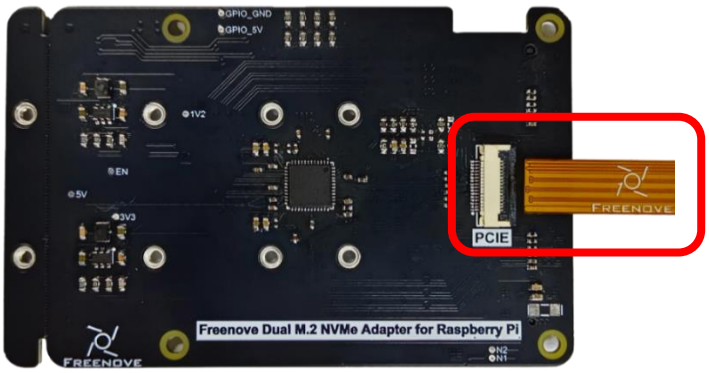


2. Tilt to insert the SSD into the board, and fix it with an M2.5x3 screw.

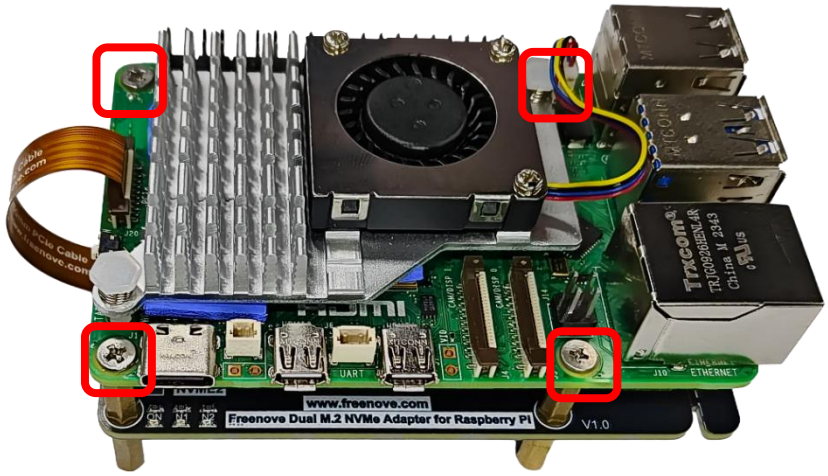
The 2-Slot SSD Adapter Board supports simultaneous connection of two NVMe SSDs, compatible with 2232/2242/2260/2280 form factors.

3. Insert an M2.5×12+4 single-pass brass standoffs into one mounting hole of the adapter board, and secure with a single-pass standoff; repeat this process for the remaining three holes.

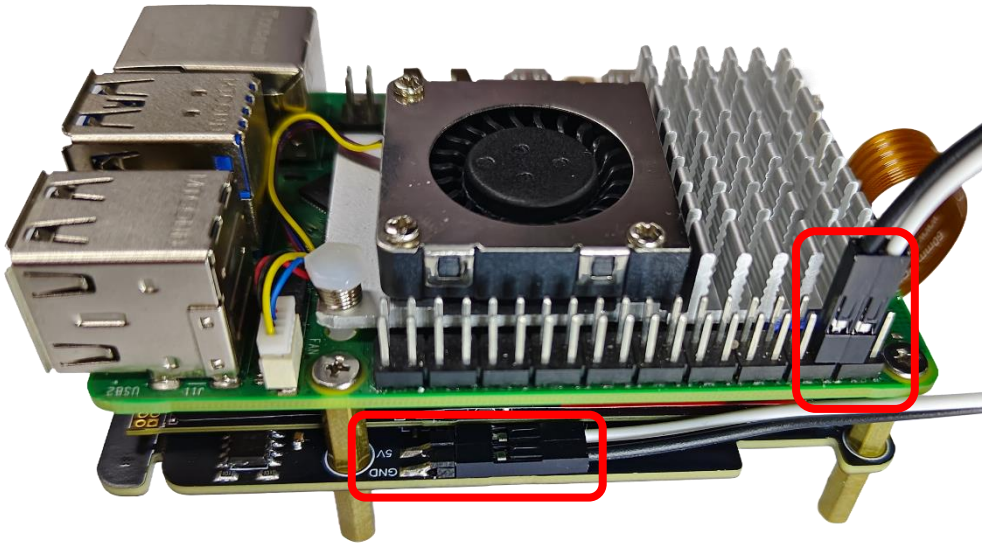
4. Connect the other end of the cable to adapter board.

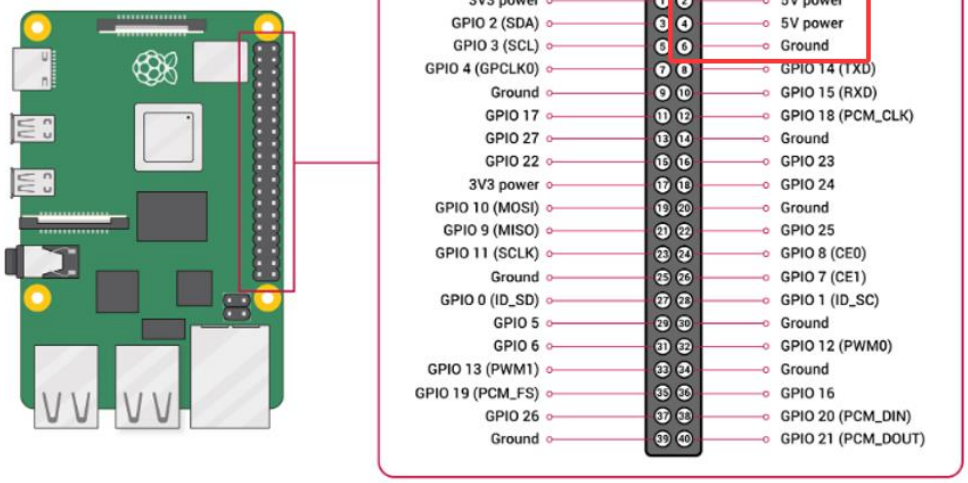


5. Put the adapter board below the Raspberry pi and fix with M2.5x3 screws.



6. Consistently connect the adapter board's 5V and GND pins to the corresponding 5V/GND pins on the Raspberry Pi 5 using jumper wires. (Refer to Raspberry Pi 5 GPIO pinout diagram). https://www.raspberrypi.com/documentation/computers/raspberry-pi.html#gpio)





Once everything is set up, power on the Raspberry Pi and boot into the system. **We'll be using the 4-Slot SSD Adapter Board for this demonstration**. Compared to the dual-slot model, this version simply adds two additional NVMe slots while maintaining identical operation methods.
(Note: For this demo, all SSDs are not partitioned.)

2.4.1 SSD Detection

(Note: Not all SSDs are supported by Pi5.)
Run the following command in the Terminal to check whether SSD is detected.
Note that different SSDs display different content.

```
lspci
```

```
pi@raspberrypi:~ $ lspci
0001:00:00.0 PCI bridge: Broadcom Inc. and subsidiaries BCM2712 PCIe Bridge (rev 21)
0001:01:00.0 PCI bridge: ASMedia Technology Inc. ASM1184e 4-Port PCIe x1 Gen2 Packet Switch
0001:02:01.0 PCI bridge: ASMedia Technology Inc. ASM1184e 4-Port PCIe x1 Gen2 Packet Switch
0001:02:03.0 PCI bridge: ASMedia Technology Inc. ASM1184e 4-Port PCIe x1 Gen2 Packet Switch
0001:02:05.0 PCI bridge: ASMedia Technology Inc. ASM1184e 4-Port PCIe x1 Gen2 Packet Switch
0001:02:07.0 PCI bridge: ASMedia Technology Inc. ASM1184e 4-Port PCIe x1 Gen2 Packet Switch
0001:03:00.0 Non-Volatile memory controller: Silicon Motion, Inc. SM2263EN/SM2263XT SSD Controller (rev 03)
0001:04:00.0 Non-Volatile memory controller: Silicon Motion, Inc. SM2261XT x2 NVMe SSD Controller (DRAM-less)
0001:05:00.0 Non-Volatile memory controller: Silicon Motion, Inc. SM2263EN/SM2263XT SSD Controller (rev 03)
0001:06:00.0 Non-Volatile memory controller: Silicon Motion, Inc. SM2261XT x2 NVMe SSD Controller (DRAM-less)
0002:00:00.0 PCI bridge: Broadcom Inc. and subsidiaries BCM2712 PCIe Bridge (rev 21)
0002:01:00.0 Ethernet controller: Raspberry Pi Ltd RP1 PCIe 2.0 South Bridge
```

```
lsblk
```

```
pi@raspberrypi:~ $ lsblk
NAME        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINTS
mmcblk0     179:0    0  14.8G  0 disk
├─mmcblk0p1 179:1    0   512M  0 part /boot/firmware
└─mmcblk0p2 179:2    0  14.3G  0 part /
nvme0n1     259:0    0 476.9G  0 disk
nvme1n1     259:1    0 119.2G  0 disk
nvme2n1     259:2    0 476.9G  0 disk
nvme3n1     259:3    0 238.5G  0 disk
```

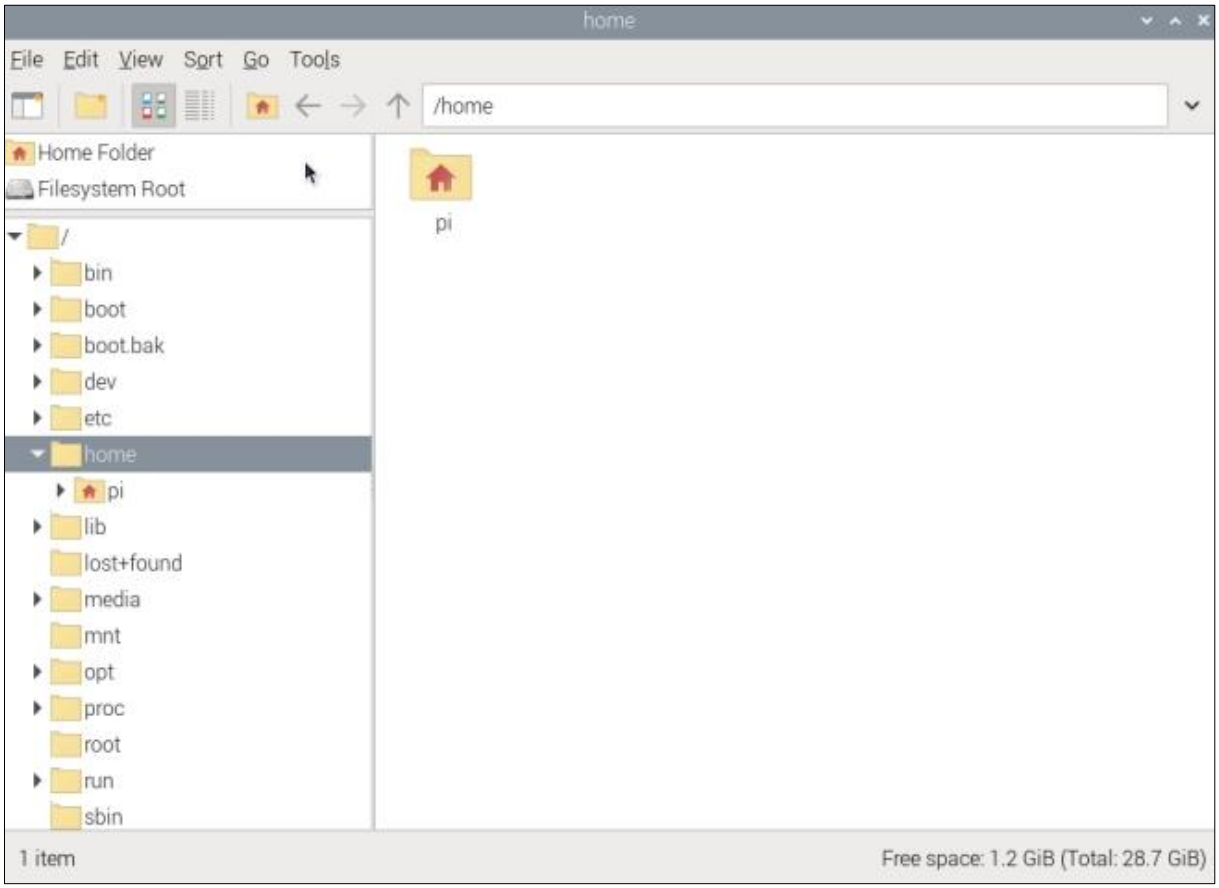
As shown in the above figure, four SSD devices, namely nvme0n1, nvme1n1, nvme2n1, and nvme3n1 are detected, indicating that the SSDs have been correctly recognized. The detected capacity will depend on the size of your SSD. If your drive has been previously partitioned, you may also see some partition information displayed.

Please note: Installing the system will format the SSD, erasing all data. If necessary, please back up any data on your SSD before proceeding.

2.4.2 SSD Partitioning and Formatting

This step is not a must-do, but it can further test whether the SSD perform normally on Raspberry Pi to ensure smooth performance in later steps.

At this point, the hard drive cannot be seen in the file manager, as the disk has not been partitioned yet.



Install a disk management tool with the following command:

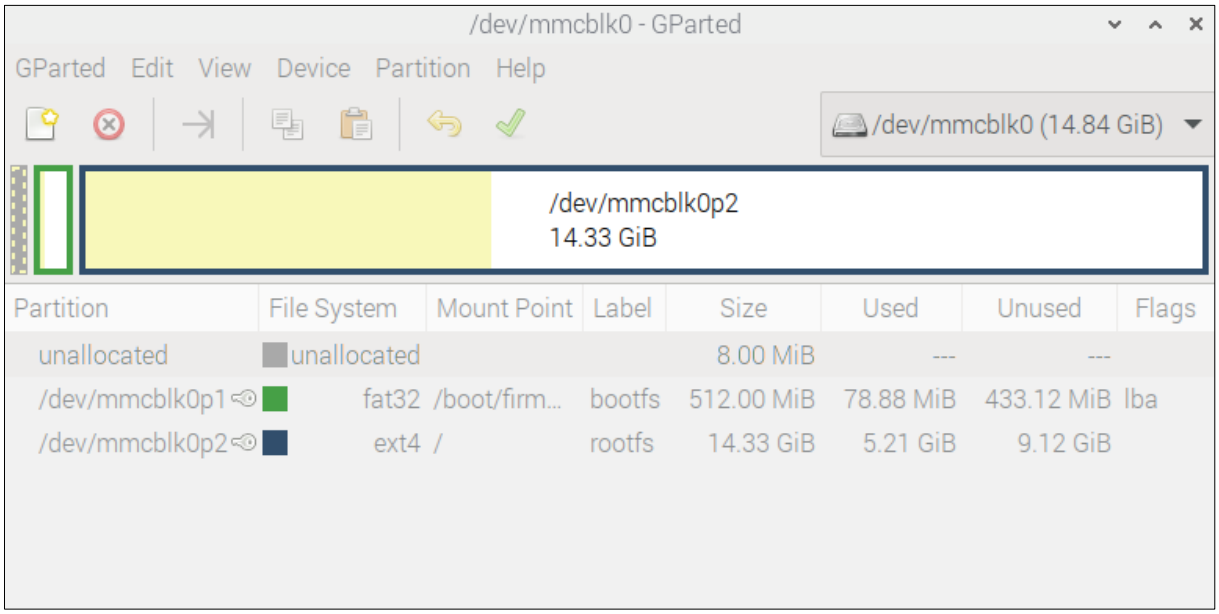
```
sudo apt-get install gparted
```

```
pi@raspberrypi:~ $ sudo apt-get install gparted
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  gparted-common
Suggested packages:
  dmraid gpart jfsutils kpartx mtools reiser4progs reiserfsprogs udftools xfsprogs yelp
The following NEW packages will be installed:
  gparted gparted-common
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 2,483 kB of archives.
After this operation, 8,638 kB of additional disk space will be used.
Do you want to continue? [Y/n] Y
```

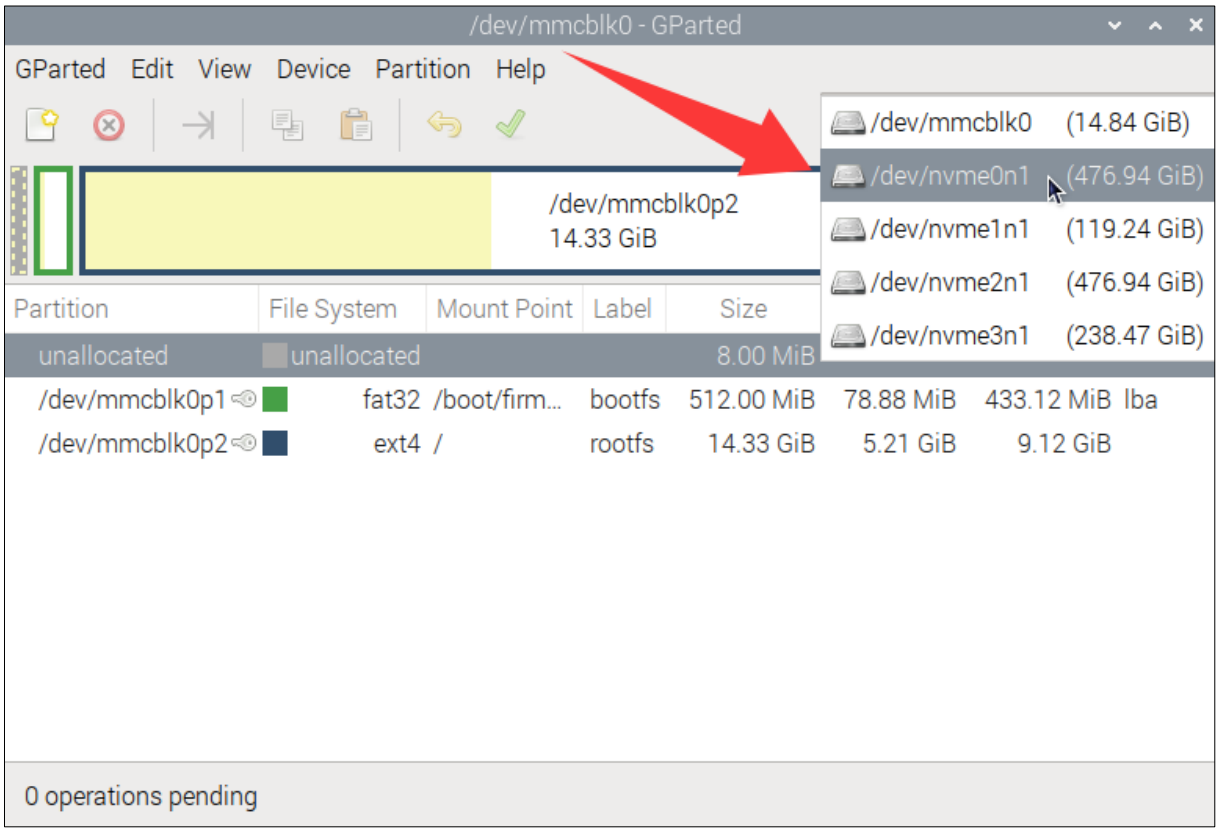
Open gparted with the command:

```
sudo gparted
```

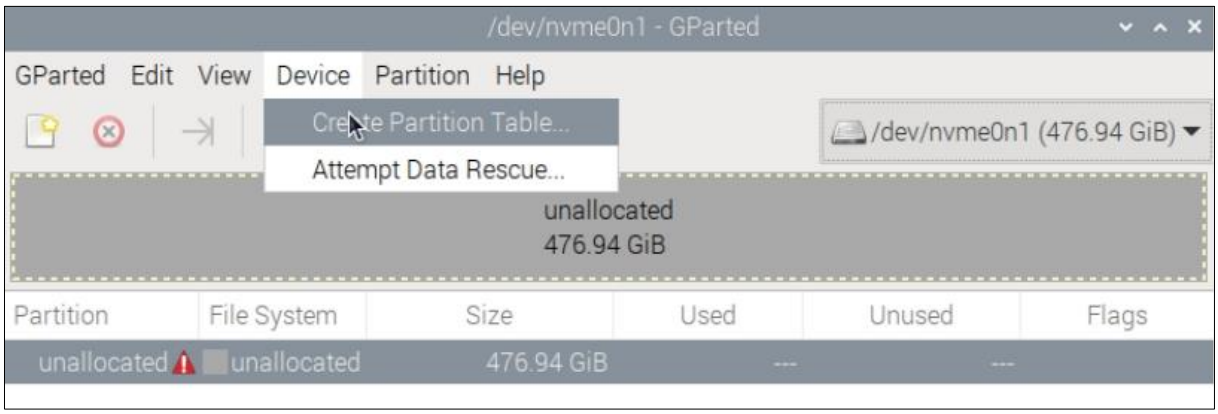
```
pi@raspberrypi:~ $ sudo gparted
GParted 1.3.1
configuration --enable-libparted-dmraid --enable-online-resize
libparted 3.5
```



Click on the dropdown menu in the upper right corner and switch to NVME SSD. Here we use nvme0n1 as an example.

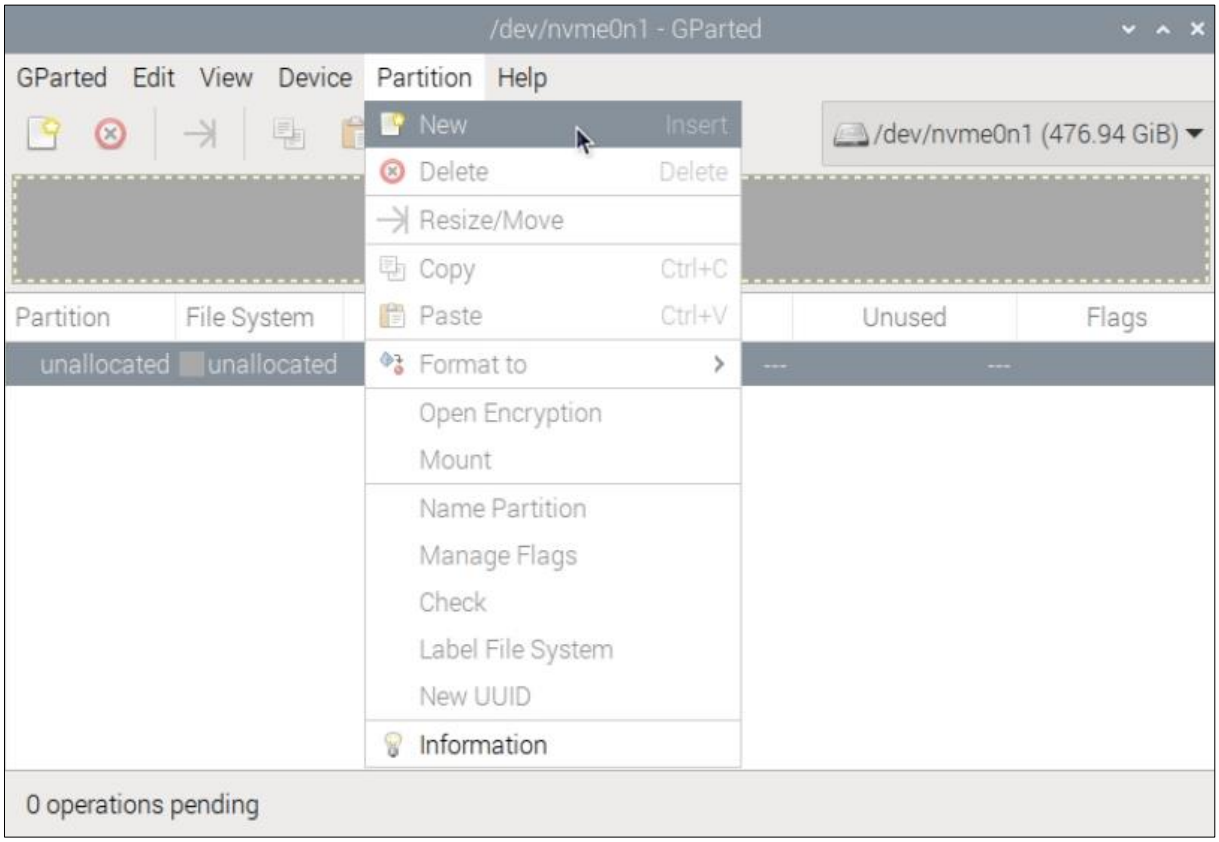


Click Device on the menu bar and select Create Partition Table.

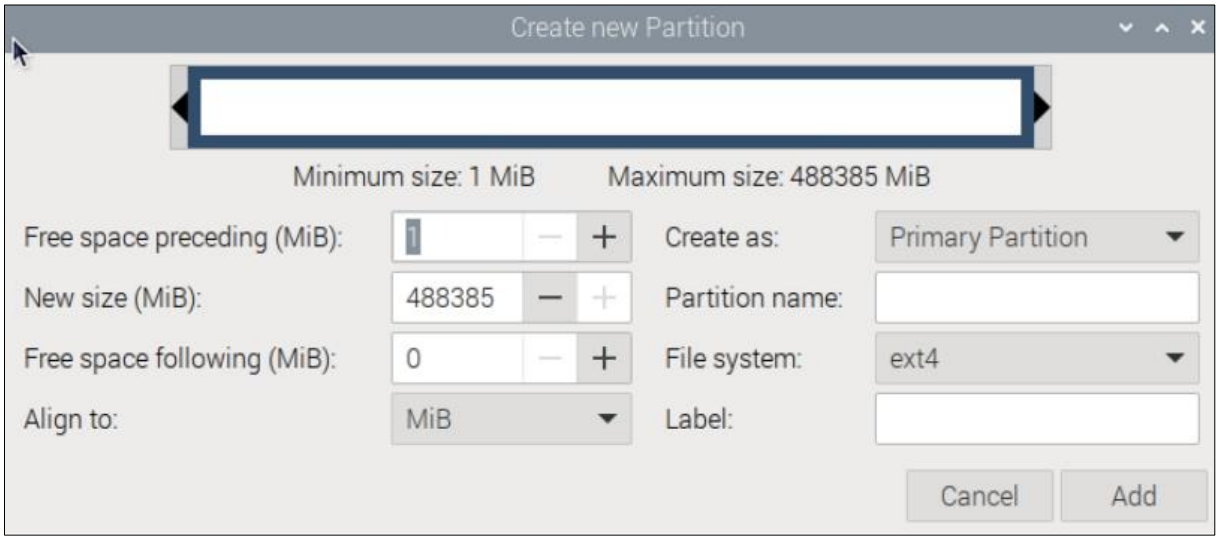


You will see the prompt that data will be erased. It is recommended to select gpt for partition table type. Click Apply.

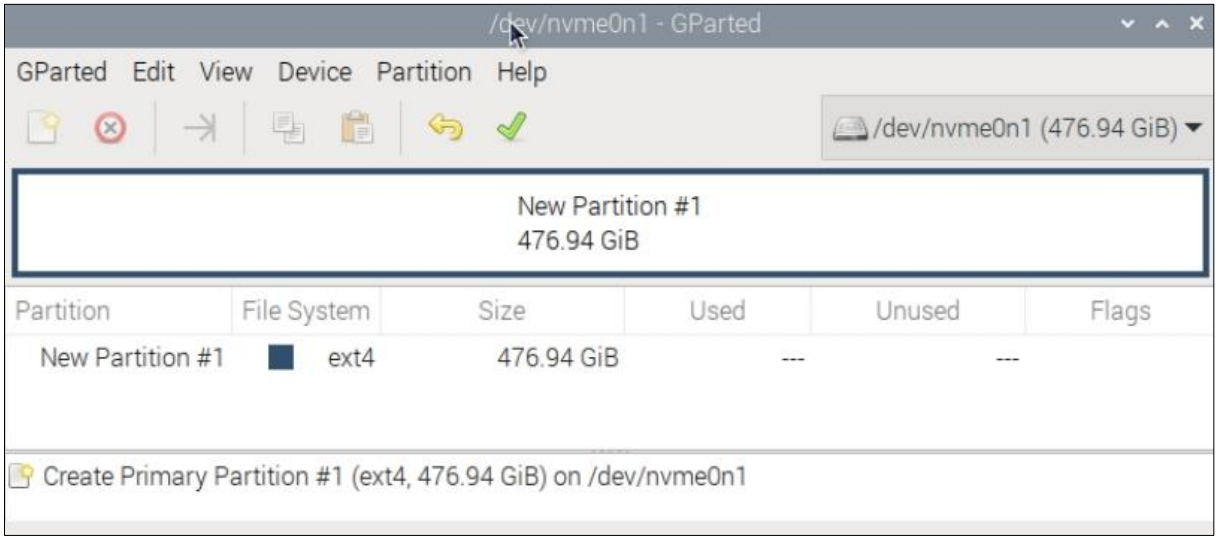
Click Partition on the menu bar, choose New.



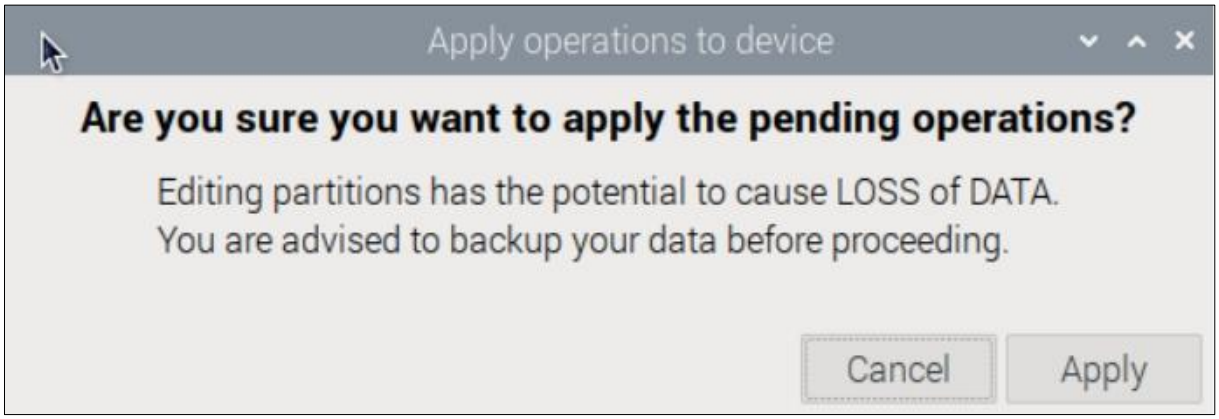
As shown in the figure below, the size of partition can be adjusted by dragging the mouse left and right, or by entering the size directly. The other options can be left as default setting. Here, we allocate all the capacity to a single partition. Click on Add.



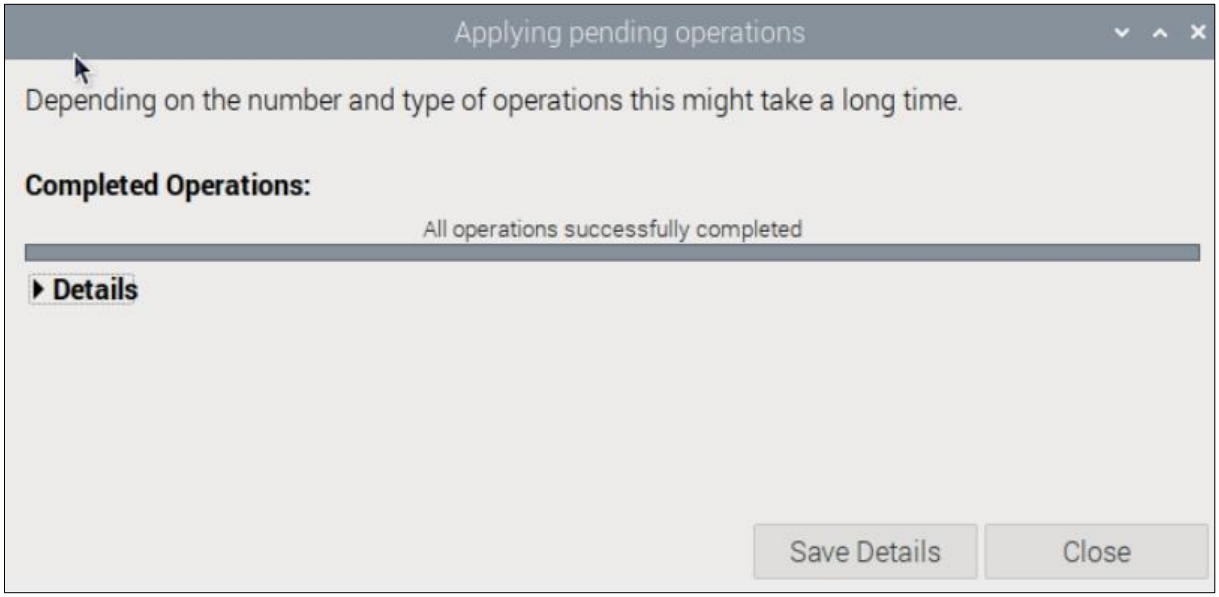
Click the check icon  to save the partition just built, as illustrated below.



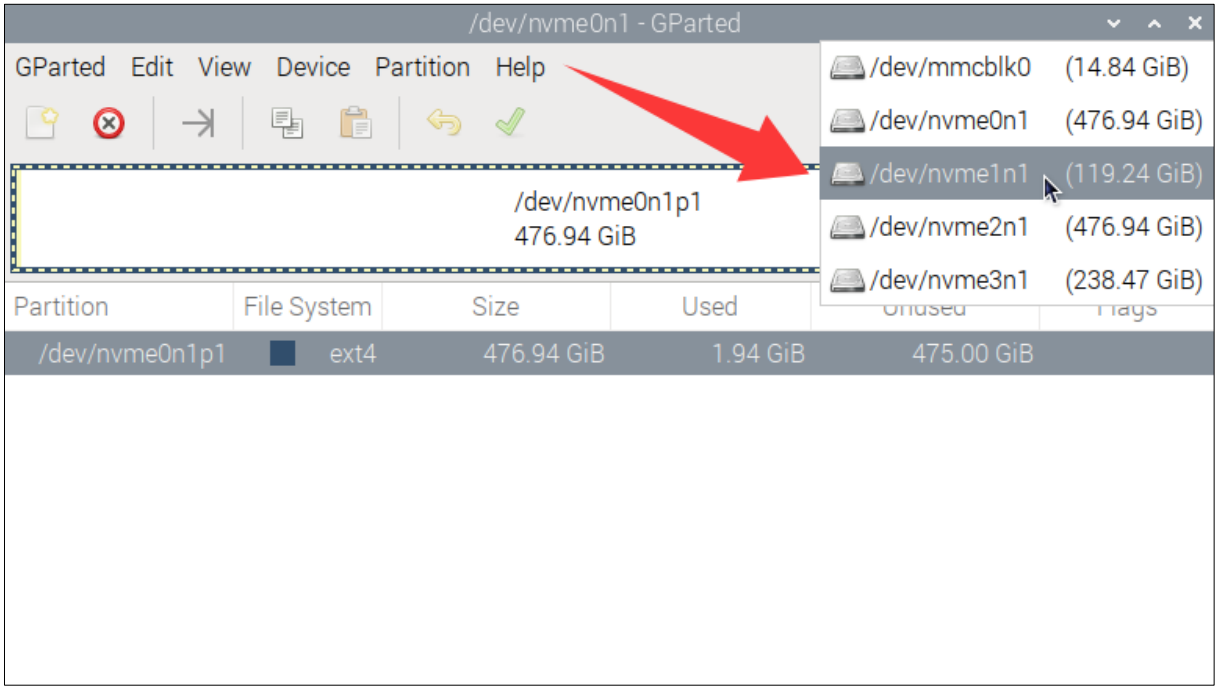
Click on Apply.



Wait for it to complete and click on Close.



Click the drop-down menu in the upper-right corner again, select the next NVMe SSD, and repeat the partition creation process until all SSDs have been properly partitioned.



Next, you can mount these SSD devices. First, create mount points using the following commands:

```
sudo mkdir -p /mnt/ssd1
sudo mkdir -p /mnt/ssd2
sudo mkdir -p /mnt/ssd3
sudo mkdir -p /mnt/ssd4
```

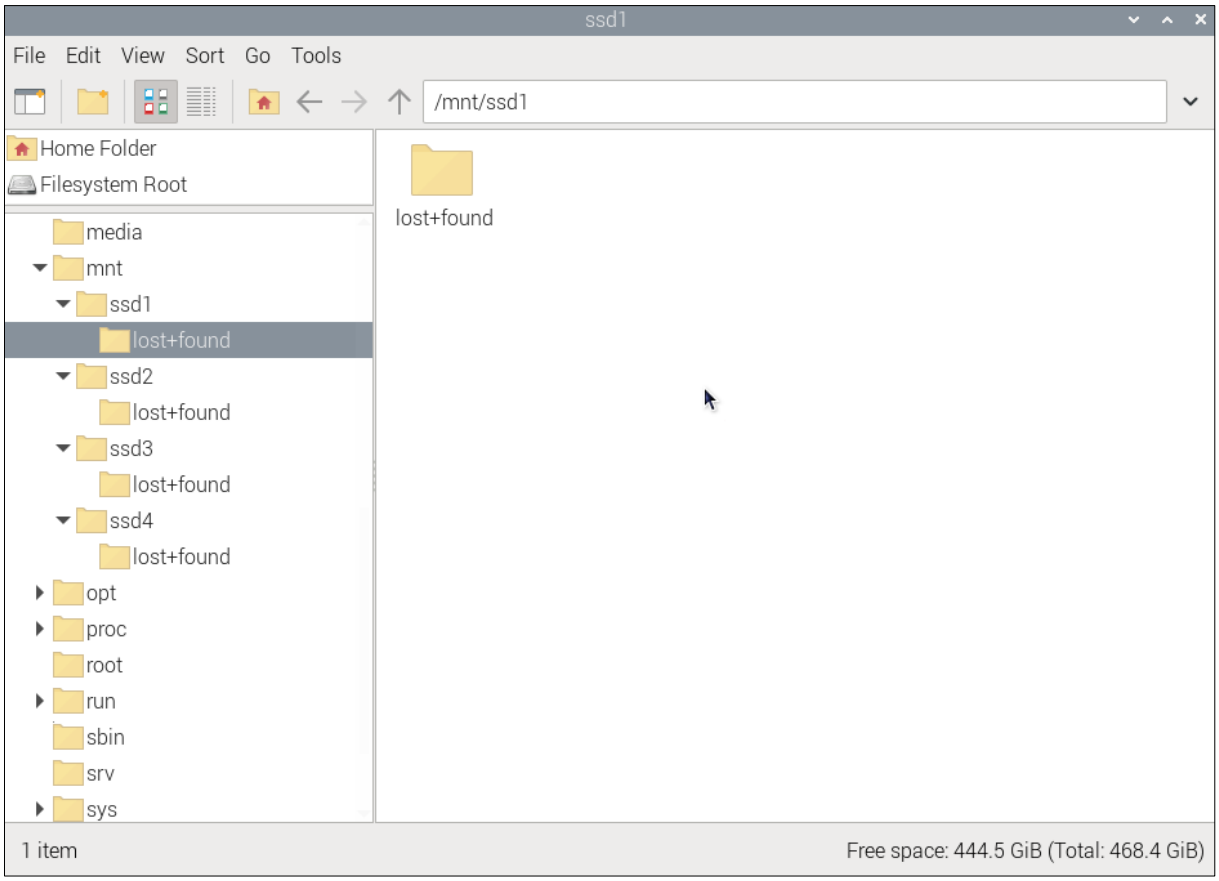
```
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd1
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd2
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd3
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd4
```

After creating mount points, use the following commands to mount each SSD to its designated location:

```
sudo mount /dev/nvme0n1p1 /mnt/ssd1
sudo mount /dev/nvme1n1p1 /mnt/ssd2
sudo mount /dev/nvme2n1p1 /mnt/ssd3
sudo mount /dev/nvme3n1p1 /mnt/ssd4
```

```
pi@raspberrypi:~ $ sudo mount /dev/nvme0n1p1 /mnt/ssd1
pi@raspberrypi:~ $ sudo mount /dev/nvme1n1p1 /mnt/ssd2
pi@raspberrypi:~ $ sudo mount /dev/nvme2n1p1 /mnt/ssd3
pi@raspberrypi:~ $ sudo mount /dev/nvme3n1p1 /mnt/ssd4
```

Open the file manager, as shown below.



If you plan to use the SSD as a standard storage device, you can conclude the process here. However, if you want to further proceed with installing an operating system on the SSD, please read on.

2.4.3 Flashing the OS

Install the OS to SSD with the method similar to that in the previous section on installing a system onto an SD card. This time, operate on the Raspberry Pi.

Install rpi-imager with the following command:

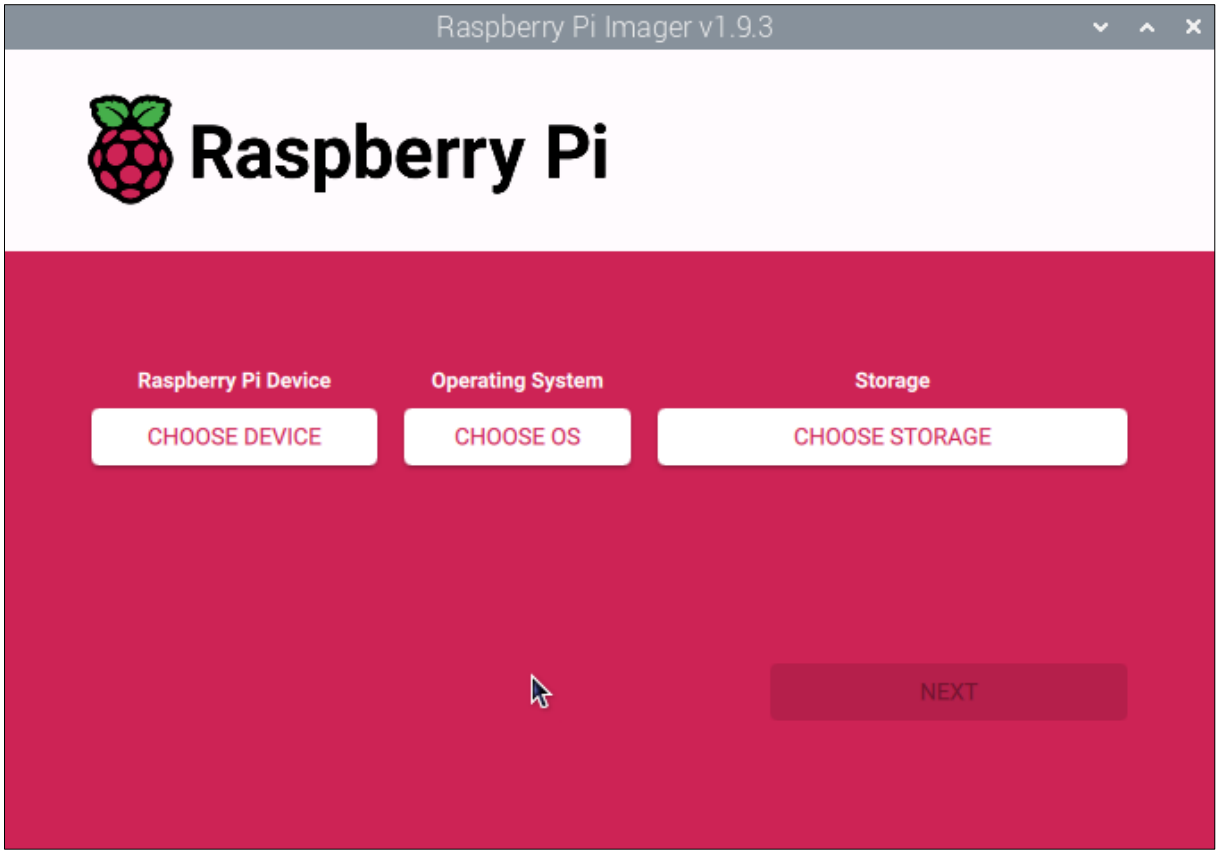
```
sudo apt install rpi-imager
```

```
pi@raspberrypi:~ $ sudo apt install rpi-imager
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
rpi-imager is already the newest version (1.8.5+rpt1).
0 upgraded, 0 newly installed, 0 to remove and 164 not upgraded.
pi@raspberrypi:~ $
```

Open rpi-imager:

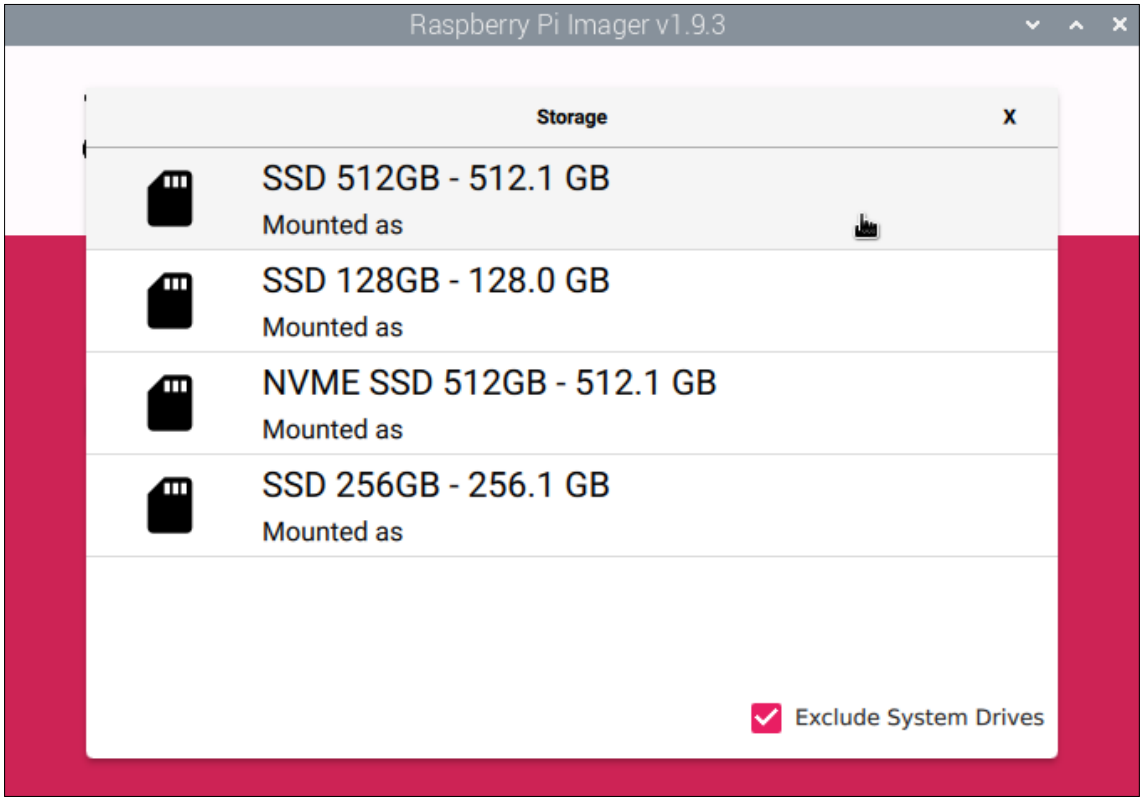
```
sudo rpi-imager
```

```
pi@raspberrypi:~ $ sudo rpi-imager
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root'
error: XDG_RUNTIME_DIR is invalid or not set in the environment.
```

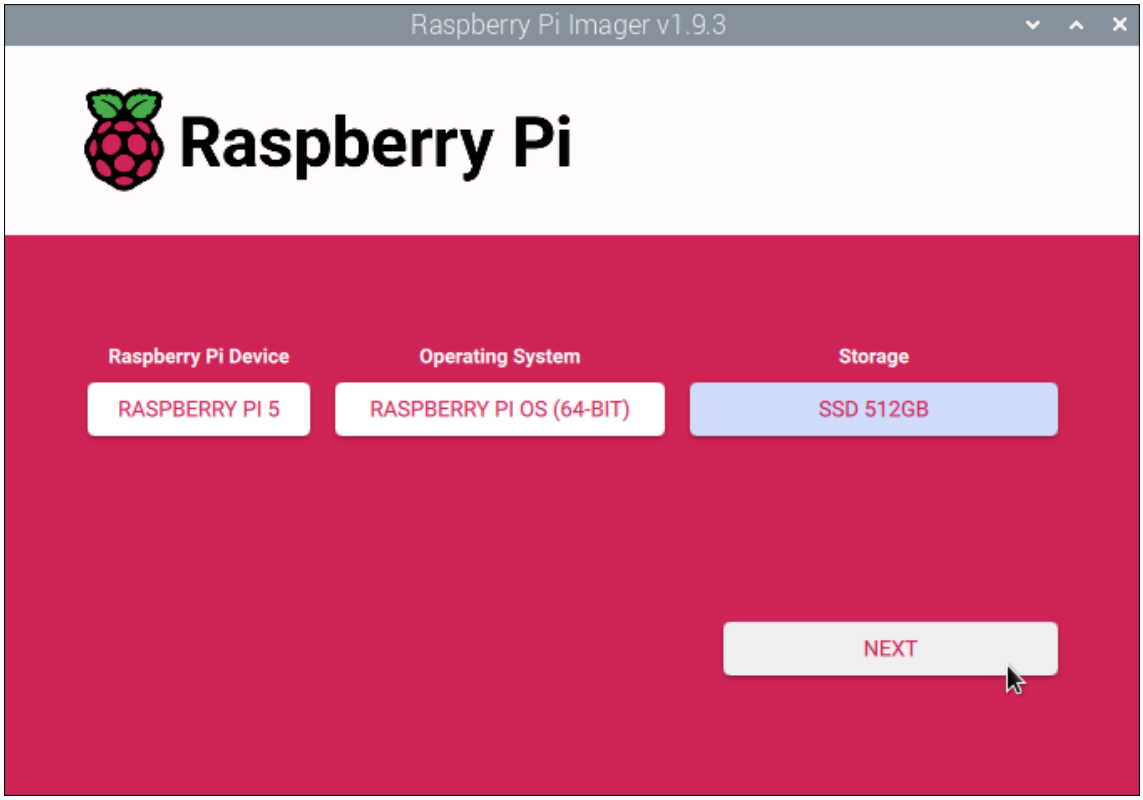


By this point, you should be quite familiar with the process.

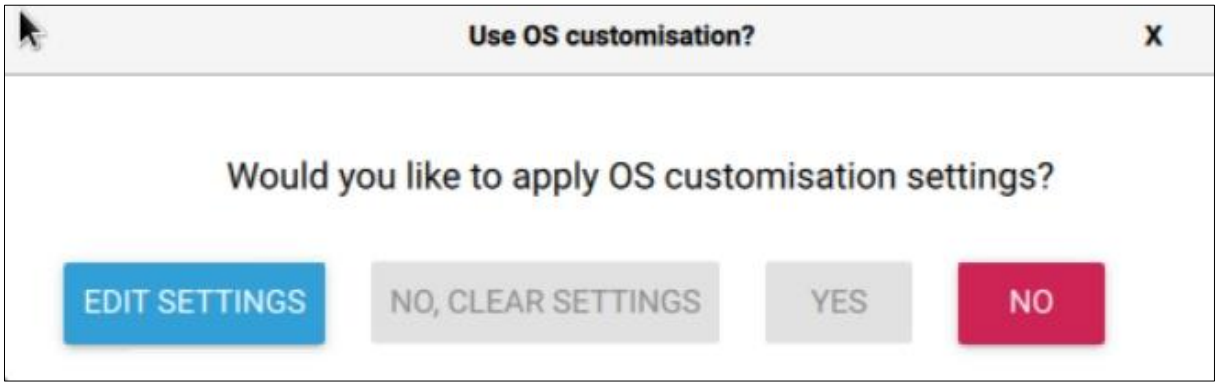
Select the Raspberry Pi 5 as your device and choose either an online download or an offline file for the operating system; in this case, an offline file is selected. (It is recommended to use a 64-bit Raspberry Pi system with recommended software). You can install the OS to any of the SSDs.



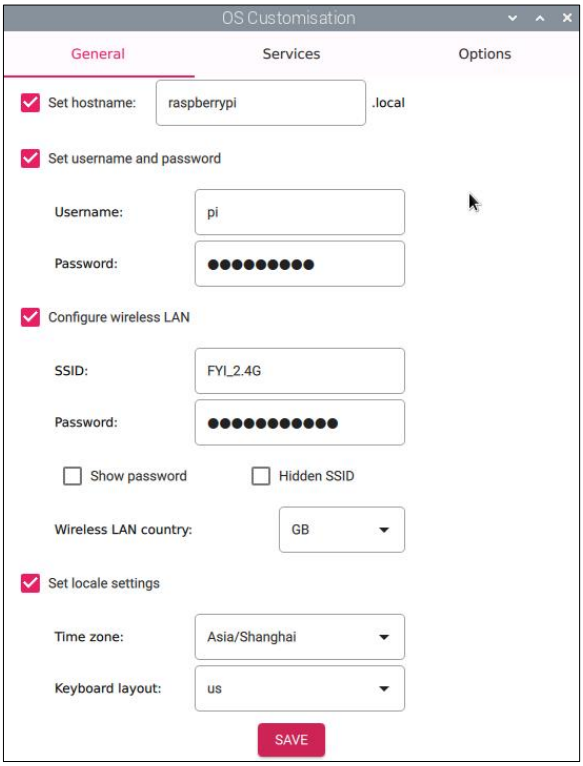
In this example, we choose the first SSD. Click NEXT.

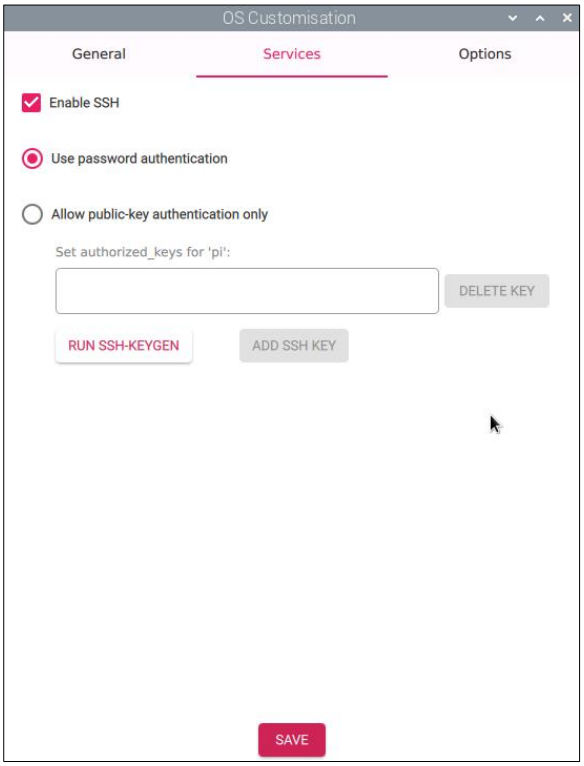


Click on EDIT SETTINGS.

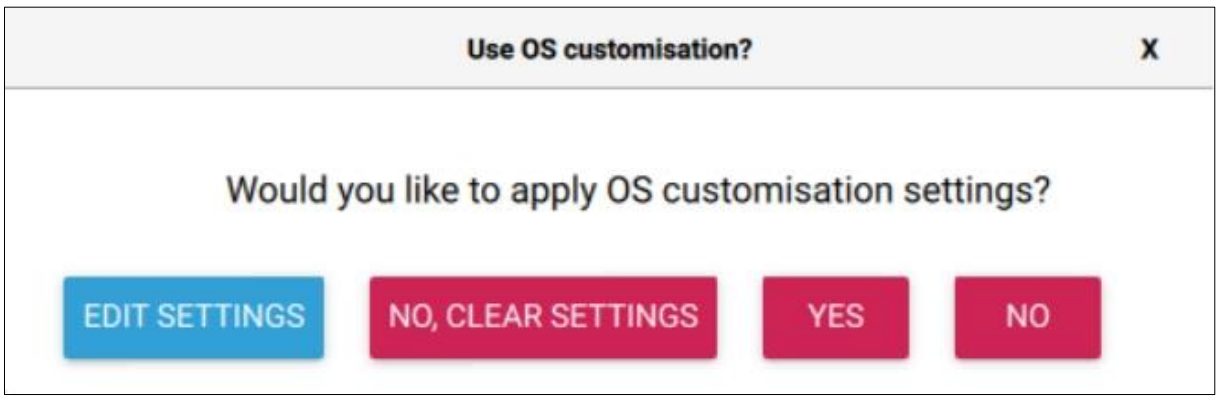


Wireless LAN Country must be correctly set; otherwise, it may fail to search the WiFi.
Enable SSH and click Save.



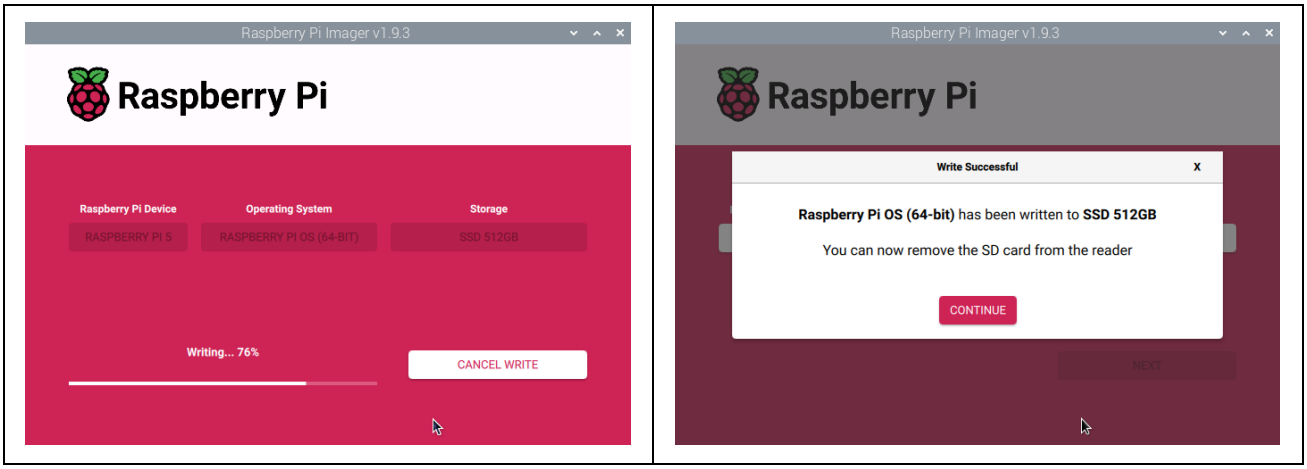


Click on YES.



Click on YES.

Wait for it to finish.



Congratulations! You have done the trickiest and the time-consuming part. Now that you have successfully installed the operating system onto the NVMe SSD, you are very close to achieving a triumph.

Next, boot into the system from SSD.

Chapter 3 Booting from SSD

After finishing flashing the OS to SSD, shutdown Raspberry Pi, remove the power supply, and remove the SD card. Then connect the power, the Raspberry Pi will boot from SSD.

The default boot order of Raspberry Pi is SD card -> SSD -> USB, **Therefore, when the SD card is removed, the Raspberry Pi cannot detect the SD card, it will boot from SSD**. By far, the Raspberry Pi can boot successfully from NVME SSD.

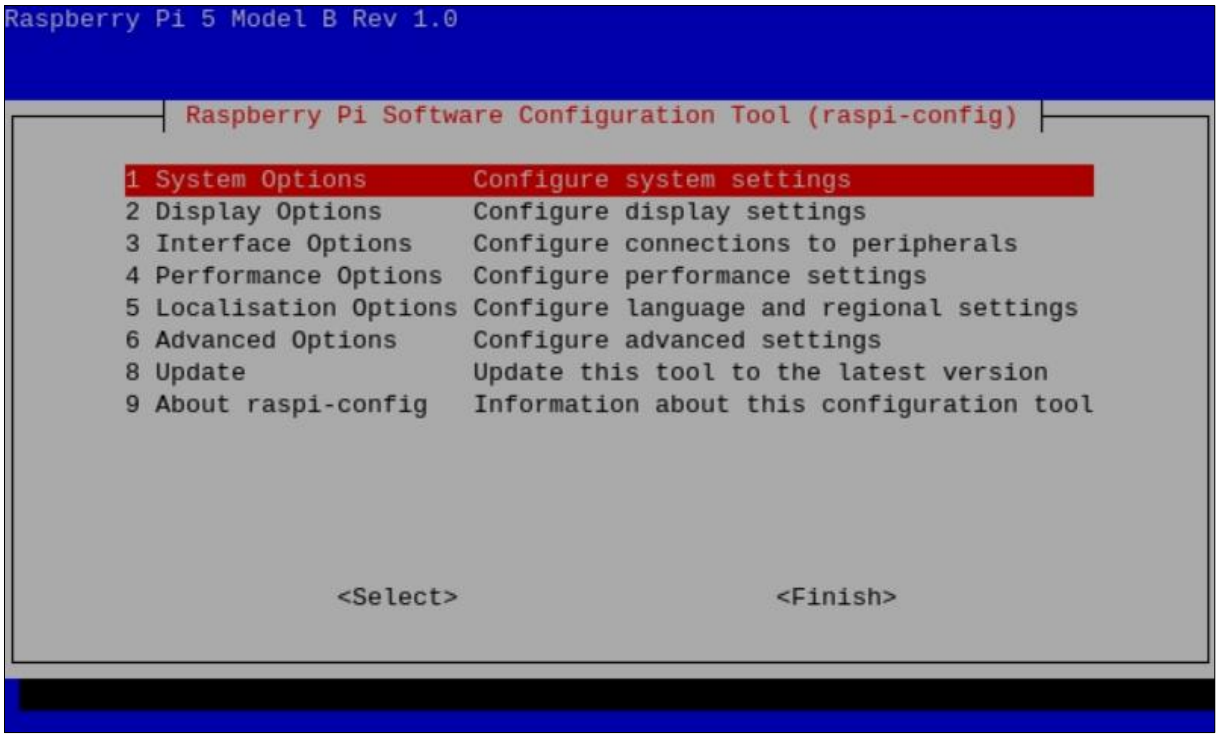
```
B1 SD Card Boot  Boot from SD Card before trying NVMe and then USB (RECOMMENDED)
B2 NVMe/USB Boot Boot from NVMe before trying USB and then SD Card
B3 Network Boot  Boot from Network unless override by SD Card
```

If you want the Raspberry Pi to boot from the SSD first, please continue with the following steps to modify the boot order. The boot order is saved in the Pi's EEPROM, so it does not matter whether you modify the boot order on SD card system or SSD system. If you do not want to change the boot order, please skip this chapter.

Configuring the Boot Order

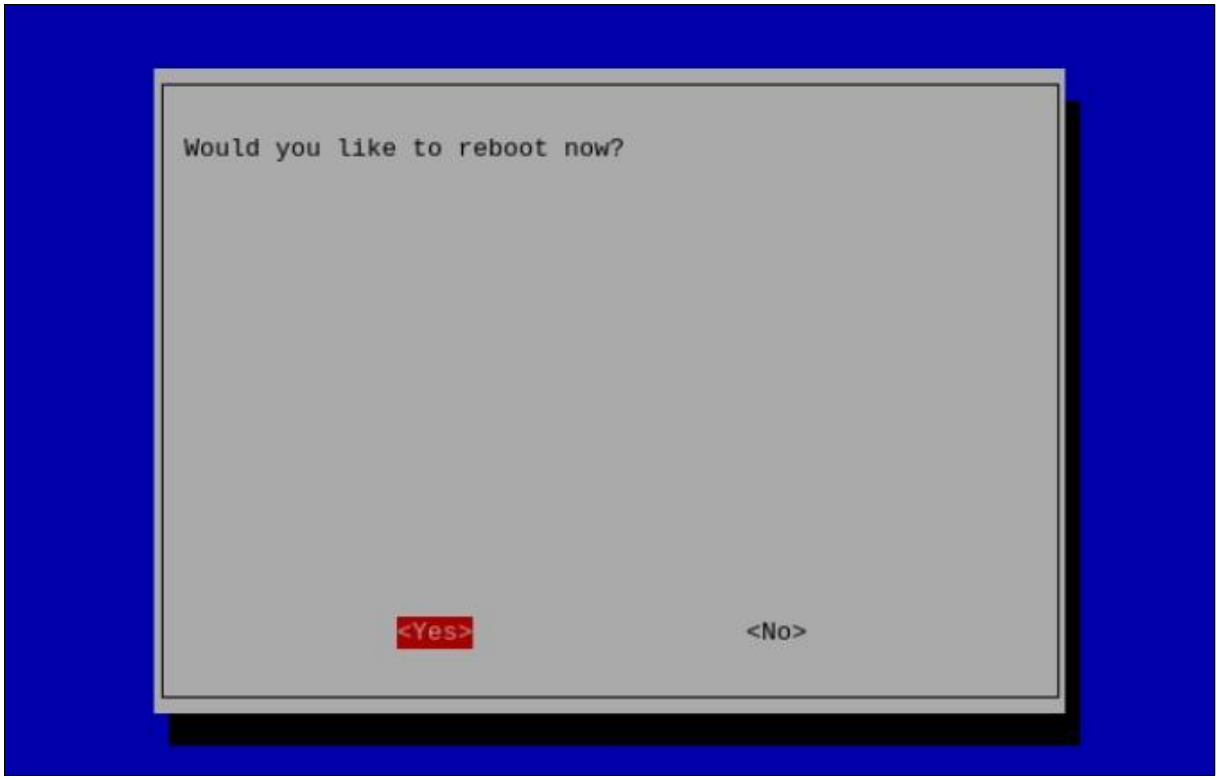
Type the following command in the Terminal.

```
sudo raspi-config
```

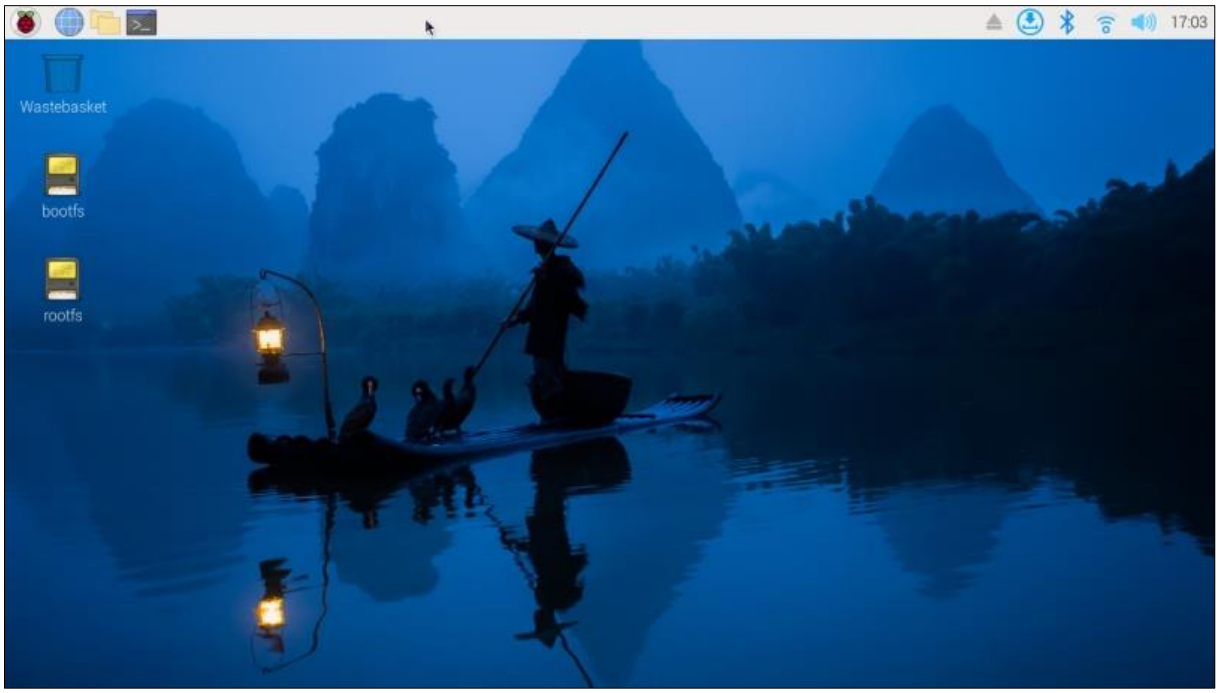


Using the keyboard's arrow keys and the Enter key, select the options in sequence.
“6 Advanced Options” →”A4 Boot Order”→”B2 NVME/USB Boot ···”

Select “OK”→”Finish”→”Yes”, and reboot your Raspberry Pi.



At this point, upon restarting, the Raspberry Pi will boot from the NVME SSD first. If you are using an external monitor, you will see that the Raspberry Pi has booted up correctly. If your SD card is still inserted, you will also see an icon on the desktop as shown below.
With this, the process of booting the Raspberry Pi from the NVME SSD has been fully completed.



If you use VNC viewer, you will need to repeat the previous steps to activate the VNC service, as it is not yet enabled in the new system on the SSD. Here, we take Windows as an example.
Run the following command:

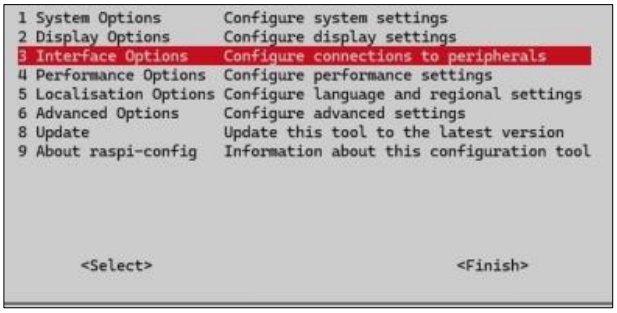
```
ssh pi@raspberrypi.local
```

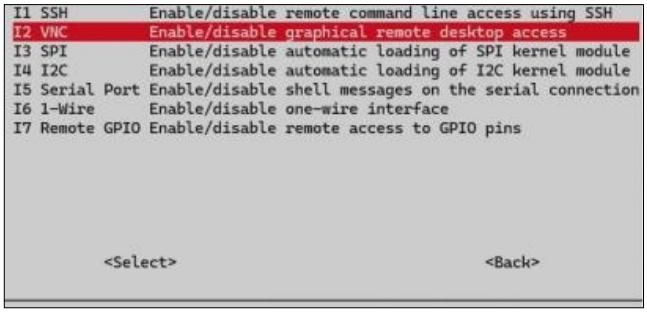
```
C:\Users\Administrator>ssh pi@raspberrypi.local
The authenticity of host 'raspberrypi.local (240e:3b4:3812:1fc0:954e:f55f:a772:fed5)' can't be established.
ECDSA key fingerprint is SHA256:hcx7u6H73nUsIc5WXA3HWa5GPSZEDroiz/mMbQx3ogc.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'raspberrypi.local,240e:3b4:3812:1fc0:954e:f55f:a772:fed5' (ECDSA) to the list of known hosts
.
pi@raspberrypi.local's password:
Linux raspberrypi 6.6.20+rpt-rpi-2712 #1 SMP PREEMPT Debian 1:6.6.20-1+rpt1 (2024-03-07) aarch64

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

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Mon Jun  3 16:50:25 2024

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set a new password.

pi@raspberrypi:~ $
```

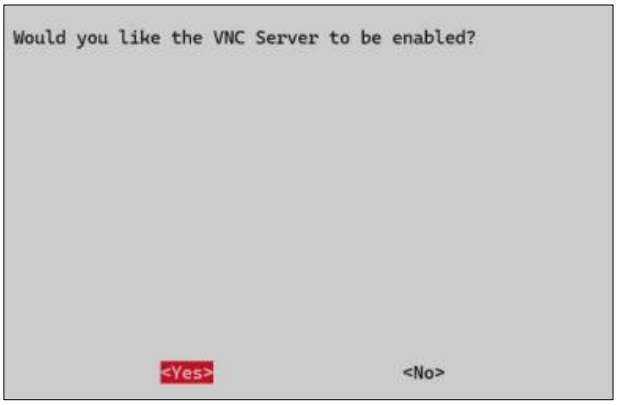
Once successfully ssh into Raspberry Pi, run the following command to open the configuration and enable VNC.

```
sudo raspi-config
```

Select “3 Interface Options”→”I2 VNC”→”Yes”→”Finish”.







Now you should be able to access Raspberry Pi via VNC.

Chapter 4 Speed Test

The Raspberry Pi 5 includes a PCIe x1 slot that is certified for PCIe Gen 2.0, providing a theoretical maximum throughput of 5GT/sec, which roughly translates to 500MB/sec for read and write operations. Due to the limitations of the expansion chip's specifications, at the time of writing, this product only supports the PCIe 2.0 protocol.

This is an additional chapter for those who wish to test the read and write speeds of their SSD.
Before testing, please mount all SSDs first. Open the command terminal, and enter the following command to check the SSD devices.

```
Lsblk
```

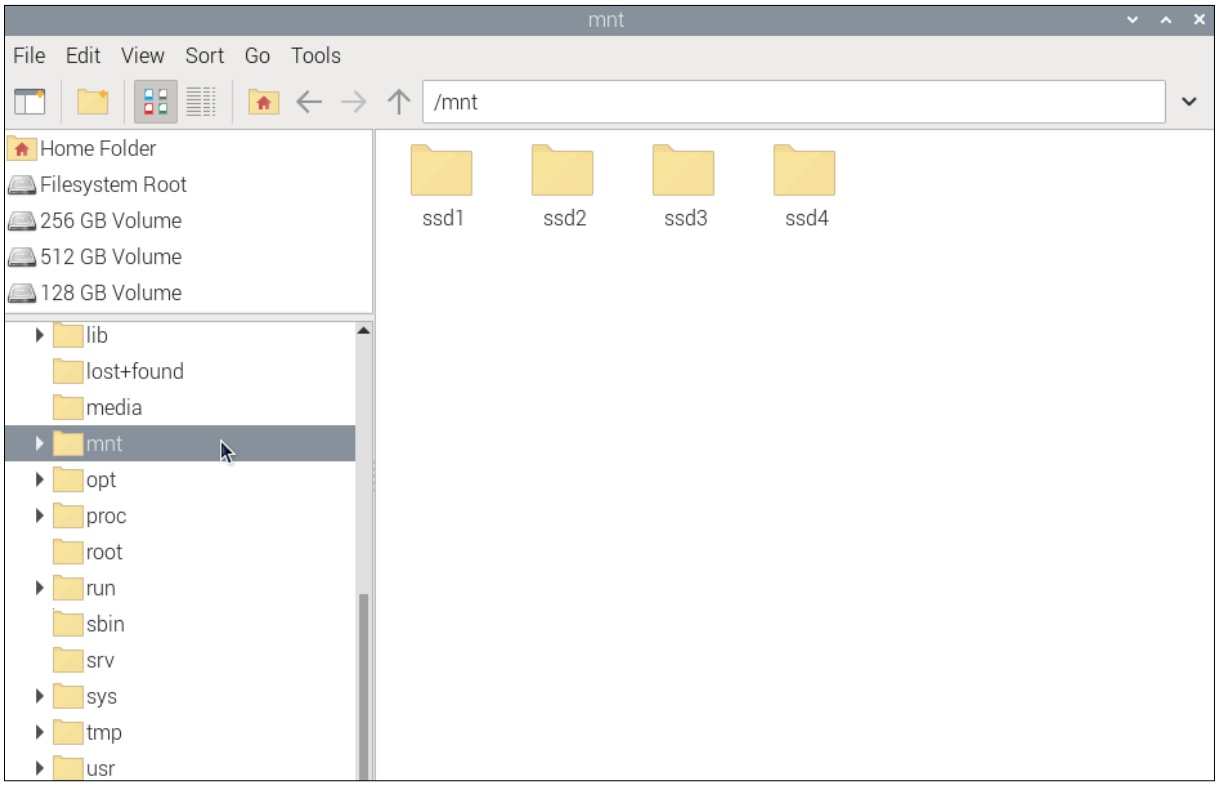
```
pi@raspberrypi:~ $ lsblk
NAME        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINTS
nvme0n1     259:0    0 476.9G  0 disk
├─nvme0n1p1 259:1    0   512M  0 part /boot/firmware
└─nvme0n1p2 259:2    0 476.4G  0 part /
nvme1n1     259:3    0 119.2G  0 disk
└─nvme1n1p1 259:4    0 119.2G  0 part
nvme2n1     259:5    0 476.9G  0 disk
└─nvme2n1p1 259:6    0 476.9G  0 part
nvme3n1     259:7    0 238.5G  0 disk
└─nvme3n1p1 259:8    0 238.5G  0 part
```

As shown in the image above, the Raspberry Pi 5 has successfully detected four NVMe SSDs, with nvme0n1 being the system drive. Prior to this, we have already partitioned all NVMe SSD devices (click here if your SSD is not partitioned).
Next, we need to mount all the SSDs so they can be used by the Raspberry Pi's file system. If you have already mounted them, click here to proceed to the next step.

```
sudo mkdir -p /mnt/ssd1
sudo mkdir -p /mnt/ssd2
sudo mkdir -p /mnt/ssd3
sudo mkdir -p /mnt/ssd4
```

```
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd1
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd2
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd3
pi@raspberrypi:~ $ sudo mkdir -p /mnt/ssd4
```

You can view the created SSD mount points (ssd1/ssd2/ssd3/ssd4) in the /mnt directory.



Execute the following commands to complete the mounting process (if the SSD is installed with Raspberry Pi OS, please mount the p2 partition of the system SSD):

```
sudo mount /dev/nvme0n1p2 /mnt/ssd1
sudo mount /dev/nvme1n1p1 /mnt/ssd2
sudo mount /dev/nvme2n1p1 /mnt/ssd3
sudo mount /dev/nvme3n1p1 /mnt/ssd4
```

```
pi@raspberrypi:~ $ sudo mount /dev/nvme0n1p2 /mnt/ssd1
pi@raspberrypi:~ $ sudo mount /dev/nvme1n1p1 /mnt/ssd2
pi@raspberrypi:~ $ sudo mount /dev/nvme2n1p1 /mnt/ssd3
pi@raspberrypi:~ $ sudo mount /dev/nvme3n1p1 /mnt/ssd4
```

Run the following command to install PiBenchmarks.

```
git clone https://github.com/TheRemote/PiBenchmarks
```

```
pi@raspberrypi:~ $ git clone https://github.com/TheRemote/PiBenchmarks
Cloning into 'PiBenchmarks'...
remote: Enumerating objects: 652, done.
remote: Counting objects: 100% (112/112), done.
remote: Compressing objects: 100% (80/80), done.
remote: Total 652 (delta 69), reused 65 (delta 31), pack-reused 540 (from 1)
Receiving objects: 100% (652/652), 119.41 KiB | 210.00 KiB/s, done.
Resolving deltas: 100% (386/386), done.
```

Enter the directory:

```
cd PiBenchmarks/
```

Grant executable permissions to the script:

```
chmod +x Storage.sh
```

```
pi@raspberrypi:~ $ cd PiBenchmarks/
pi@raspberrypi:~/PiBenchmarks $ ls
CODE_OF_CONDUCT.md  CONTRIBUTING.md  LICENSE  README.md  Storage.sh
pi@raspberrypi:~/PiBenchmarks $ chmod +x Storage.sh
pi@raspberrypi:~/PiBenchmarks $ ls
CODE_OF_CONDUCT.md  CONTRIBUTING.md  LICENSE  README.md  Storage.sh
```

Start the speed test. Please be aware that the first execution will involve downloading the required dependencies, so the process could take a relatively long time.

```
sudo ./Storage.sh /mnt/ssd1
```

```
pi@raspberrypi:~/PiBenchmarks $ sudo ./Storage.sh /mnt/ssd1
Trimming and syncing drives ...
/mnt/ssd4: 233.7 GiB (250905362432 bytes) trimmed on /dev/nvme3n1p1
/mnt/ssd3: 468.4 GiB (502925447168 bytes) trimmed on /dev/nvme2n1p1
/mnt/ssd2: 116.8 GiB (125425897472 bytes) trimmed on /dev/nvme1n1p1
/boot/firmware: 433.1 MiB (454166528 bytes) trimmed on /dev/nvme0n1p1
/: 463.9 GiB (498089222144 bytes) trimmed on /dev/nvme0n1p2
Board information: Manufacturer: Raspberry Pi Foundation - Model: Raspberry Pi 5 Model B Rev 1.0 -
Architecture: aarch64 - OS: Debian GNU/Linux 12 (bookworm)
Fetching required components ...
Install lshw
Reading package lists... Done
E: Could not get lock /var/lib/apt/lists/lock. It is held by process 1491 (packagekitd)
N: Be aware that removing the lock file is not a solution and may break your system.
E: Unable to lock directory /var/lib/apt/lists/
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
```

After the speed test is completed, follow the prompts to enter a description and a name for your SSD (you can use any arbitrary characters).

```
RandRead: 51424 - RandWrite: 137275 - Read: 170906 - Write: 135278
Enter a description of your storage and setup (Example: Kingston A400 SSD on Pi 4 using
StarTech SATA to USB adapter)
Description: ssd1
(Optional) Enter alias to use on benchmark results.  Leave blank for completely anonymou
s.
Alias (leave blank for Anonymous): ssd1
Result submitted successfully and will appear live on https://pibenchmarks.com within a
couple of minutes.
```

Test result:

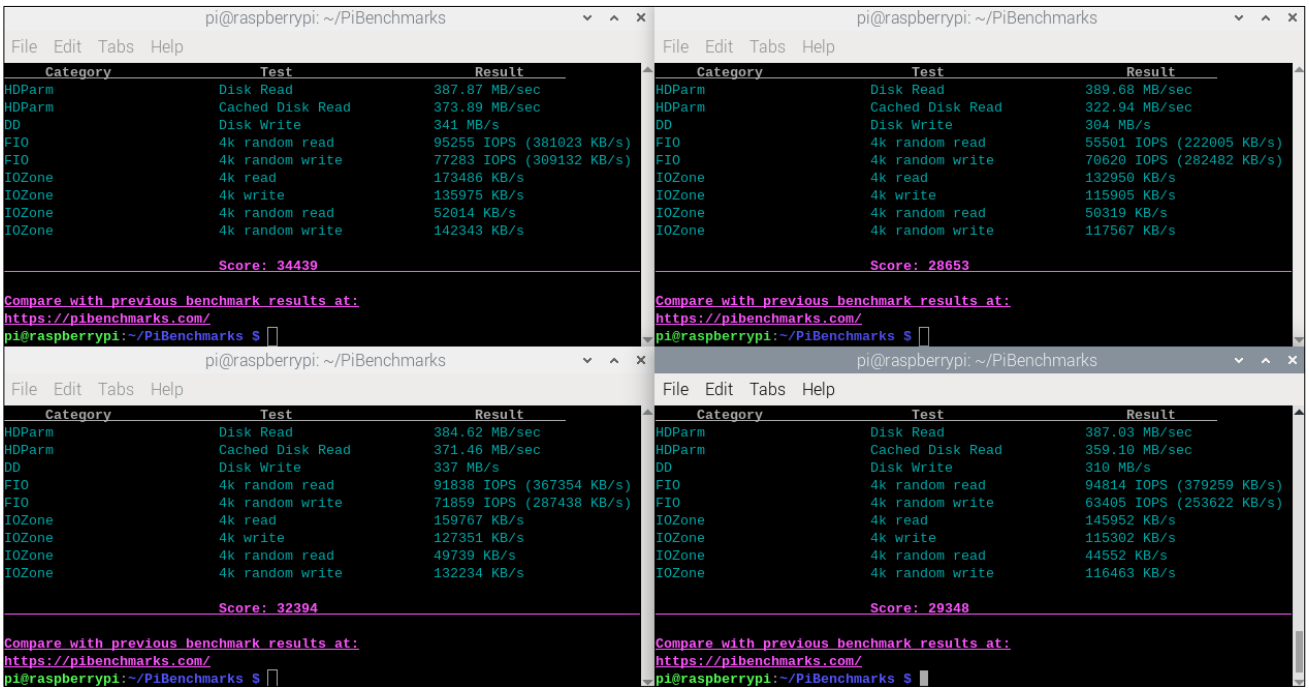
Category	Test	Result
HDParm	Disk Read	387.83 MB/sec
HDParm	Cached Disk Read	376.84 MB/sec
DD	Disk Write	339 MB/s
FIO	4k random read	95255 IOPS (381023 KB/s)
FIO	4k random write	76704 IOPS (306816 KB/s)
IOZone	4k read	170906 KB/s
IOZone	4k write	135278 KB/s
IOZone	4k random read	51424 KB/s
IOZone	4k random write	137275 KB/s
	Score: 33798	

Next, we will sequentially execute the following commands to perform individual speed tests on each SSD.

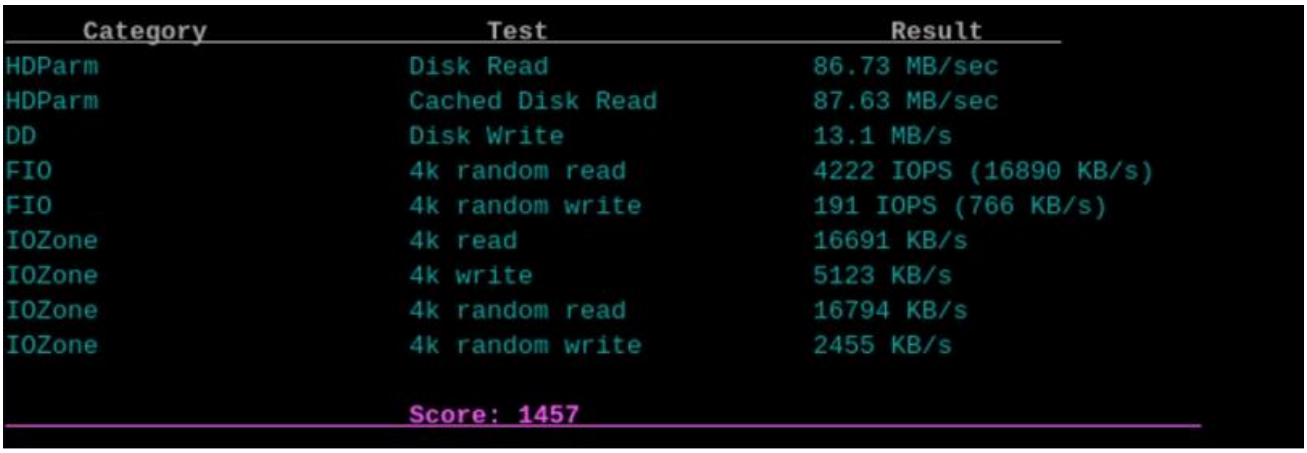
```
sudo ./Storage.sh /mnt/ssd2
sudo ./Storage.sh /mnt/ssd3
sudo ./Storage.sh /mnt/ssd4
```

```
pi@raspberrypi:~/PiBenchmarks $ sudo ./Storage.sh /mnt/ssd2
Trimming and syncing drives ...
/mnt/ssd4: 0 B (0 bytes) trimmed on /dev/nvme3n1p1
/mnt/ssd3: 0 B (0 bytes) trimmed on /dev/nvme2n1p1
/mnt/ssd2: 0 B (0 bytes) trimmed on /dev/nvme1n1p1
/boot/firmware: 433.1 MiB (454166528 bytes) trimmed on /dev/nvme0n1p1
/: 932.5 MiB (977747968 bytes) trimmed on /dev/nvme0n1p2
Board information: Manufacturer: Raspberry Pi Foundation - Model: Raspberry Pi 5 Model B Rev 1.0 -
Architecture: aarch64 - OS: Debian GNU/Linux 12 (bookworm)
Fetching required components ...
Clock speeds: CPU: 2400 - Core: 910
Chosen partition (/mnt/ssd2) has been detected as /dev/nvme1n1p1 (nvme1n1p1)
Starting INXI hardware identification...
```

The performance varies among different SSDs, and each test may have certain error, which is normal. The following figures show the speed test results of the four SSDs.



This is a speed test result for a TF (micro SD) card, and it shows a significant difference in speed compared to an SSD.



Chapter 5 Other Application

This project combines the Raspberry Pi 5 with this product to build a Raspberry Pi Network Attached Storage (NAS) based on the OMV solution, suitable for home environments or small home offices.

Introduction to openmediavault

openmediavault is the next generation network attached storage (NAS) solution based on Debian Linux. It contains services like SSH, (S)FTP, SMB/CIFS, rsync and many more. Thanks to the modular design of the framework, it can be enhanced via plugins. openmediavault is primarily designed to be used in home environments or small home offices, but is not limited to those scenarios. It is a simple and easy to use out-of-the-box solution that will allow everyone to install and administrate a Network Attached Storage without deeper knowledge.

Note: openmediavault (like other NAS solutions) expects to have full, exclusive control over OS configuration and cannot be used within a container. In addition, no graphical desktop user interface can be installed in parallel.

For more detailed information on OMV, please refer to its official website:
https://www.openmediavault.org/

Cautions

- **Project Copyright**: The original author of this project is OpenMediaVault. Freenove implements it as a Network Attached Storage (NAS) solution for the Raspberry Pi. This project adheres to the GNU General Public License v3.0 (GPL-3.0).

- **Supprted Countries & Regions:** The system supports a wide range of protocols including SSH, FTP/SFTP, SMB/CIFS, and rsync, among others.

- **Pricing:** The openmediavault software is currently free to use. Please note that we cannot guarantee it will remain free of charge in the future.

- **Seeking Help If you encounter any issues after carefully following the provided tutorial**, please do not hesitate to contact our support team at **support@freenove.com.**
  Important Note: This project's API and user interface are entirely dependent on openmediavault. Should OpenMediaVault cease to provide these components, we will also delete the corresponding documentation, tutorials, and code.

Disclaimer

openmediavault is an open-source NAS (Network Attached Storage) solution available at: https://github.com/openmediavault/openmediavault

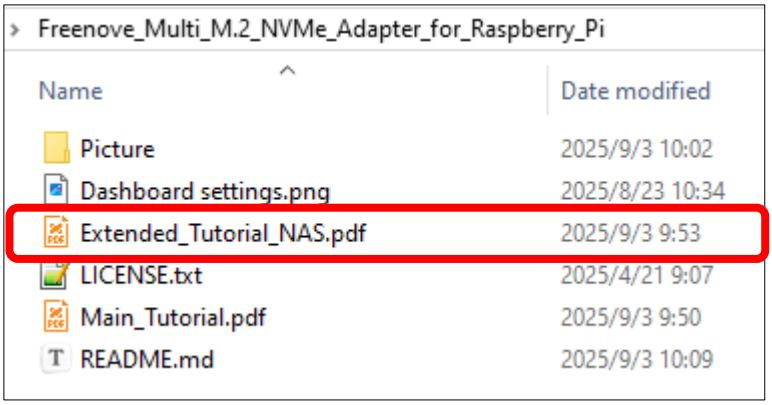
We have only adapted it for third-party learning and NAS functionality trials, without any commercial promotion or application. This tutorial is intended solely for enthusiasts to supplement their learning.

Important Notes:

1. As this project utilizes a third-party open-source platform, please direct any technical issues encountered during setup to the original repository: https://github.com/openmediavault/openmediavault/issues
2. For advanced functionality extensions—including plugins, RAID configurations, Docker integration, and more—please refer to the official openmediavault forum: https://forum.openmediavault.org/

A step-by-step tutorial for configuring a Raspberry Pi NAS using this product is available in our resources for Freenove PCIe HUB for Raspberry Pi; you can click here to download.

The tutorial can be accessed at the following location:



If you have any concerns, please feel free to contact us via support@freenove.com

What's Next?

Thank you again for choosing Freenove products.

THANK YOU for participating in this learning experience!

We have reached the end of this Tutorial. If you find errors, omissions, or you have suggestions and/or questions about the Tutorial or component contents of this Kit, please feel free to contact us:
support@freenove.com

We will make every effort to make changes and correct errors as soon as feasibly possible and publish a revised version.

If you want to learn more about Arduino, ESP32, Raspberry Pi Pico W, Raspberry Pi, Smart Cars, Robotics and other interesting products in science and technology, please continue to visit our website. We will continue to launch fun, cost effective, innovative and exciting products.
http://www.freenove.com/

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