



BeagleY-AI

Release 1.0.20240516-wip

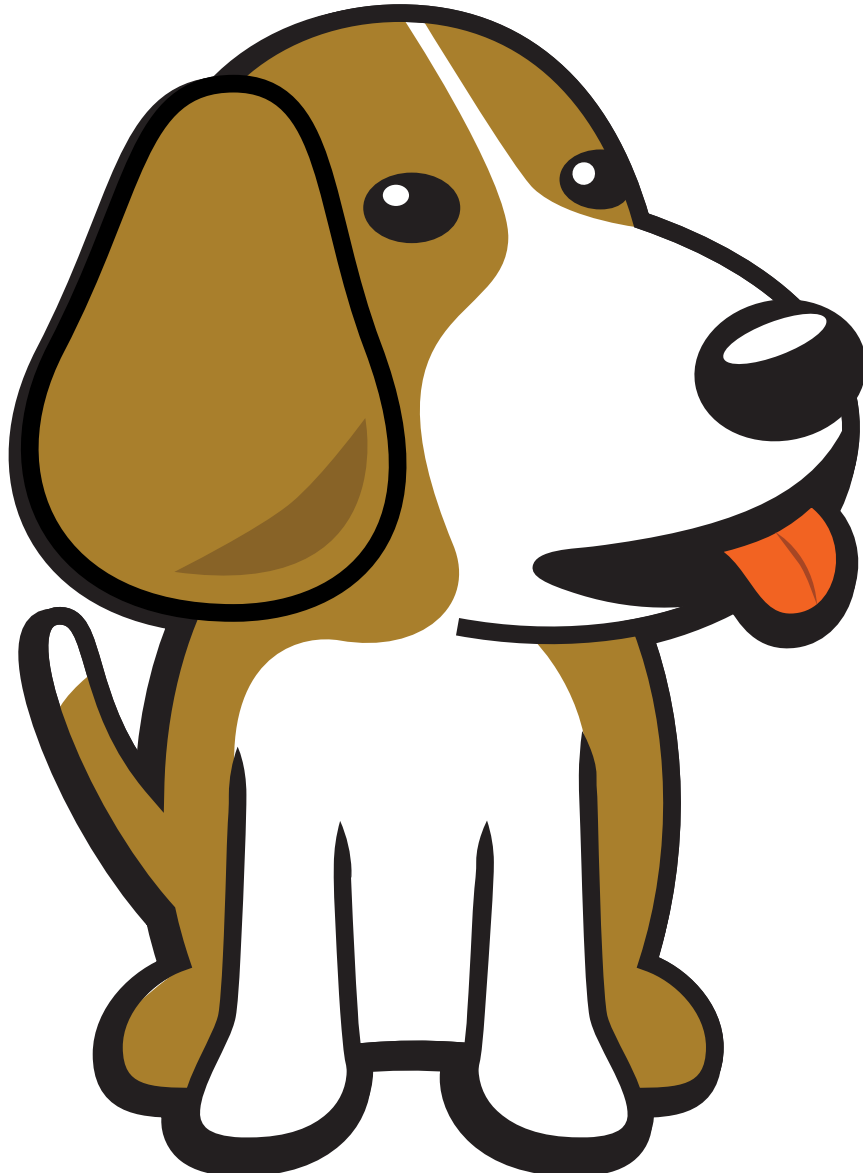


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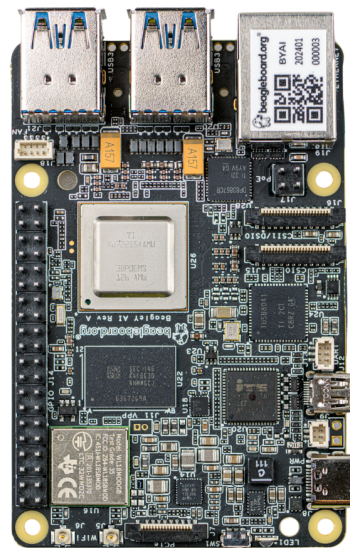
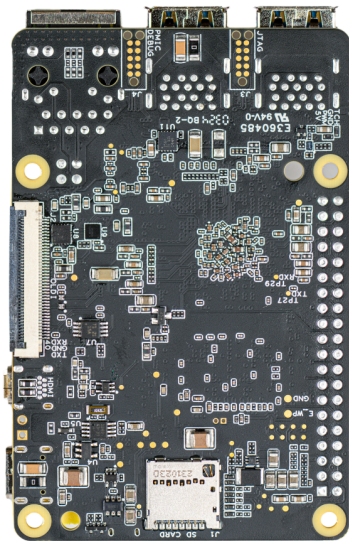
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Important: This is a work in progress, for latest documentation please visit <https://docs.beagleboard.org/latest/>

BeagleY-AI is an open-source single board computer based on the Texas Instruments AM67A Arm-based vision processor.

License Terms

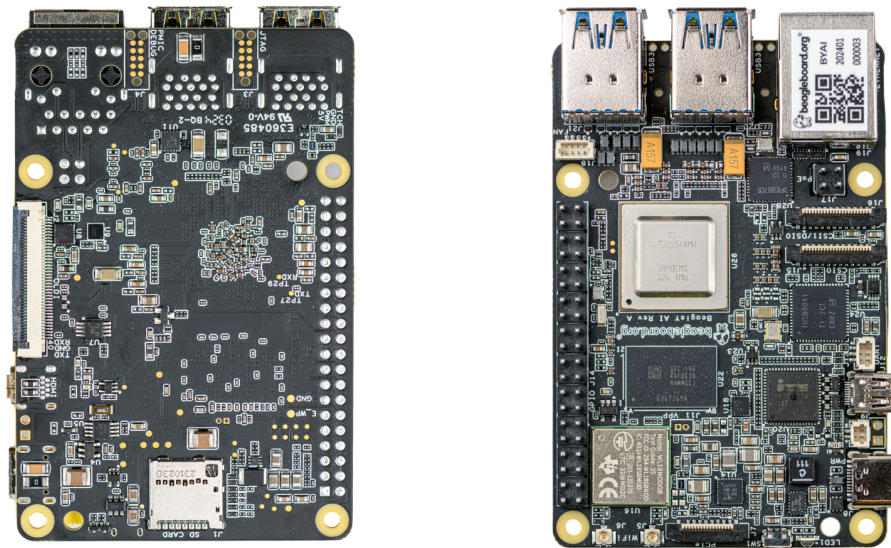
- This documentation is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](#)
 - Design materials and license can be found in the [git repository](#)
 - Use of the boards or design materials constitutes an agreement to the [boards-terms-and-conditions](#)
 - Software images and purchase links are available on the [board page](#)
 - For export, emissions and other compliance, see [Support](#)
 - All support for BeagleY-AI design is through the BeagleBoard.org community at [BeagleBoard.org forum](#).
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Chapter 1

Introduction

BeagleY-AI is an open-source single board computer designed for edge AI applications.



1.1 Detailed overview

BeagleY-AI is based on the Texas Instruments AM67A Arm-based vision processor. It features a quad-core 64-bit Arm®Cortex®-A53 CPU subsystem at 1.4GHz, Dual general-purpose C7x DSP with Matrix Multiply Accelerator (MMA) capable of 4 TOPs each, Arm Cortex-R5 subsystem for low-latency I/O and control, a 50 GFlop GPU, video and vision accelerators, and other specialized processing capability.

Table 1.1: BeagleY-AI features

Feature	Description
Processor	Texas Instruments AM67A, Quad 64-bit Arm® Cortex® -A53 @1.4 GHz, multiple cores including Arm/GPU processors, DSP, and vision/deep learning accelerators
RAM	4GB LPDDR4
Wi-Fi	Beagleboard BM3301, 802.11ax Wi-Fi
Bluetooth	Bluetooth Low Energy 5.4 (BLE)
USB Ports	4 x USB 3.0 TypeA ports supporting simultaneous 5Gbps operation, 1 x USB 2.0 TypeC, supports USB 2.0 device mode
Ethernet	Gigabit Ethernet, with PoE+ support (requires separate PoE HAT)
Camera/Display	2 x 4-lane MIPI camera connector (one connector muxed with DSI capability)
Display Output	1 x HDMI display, 1 x OLDI display, 1 x DSI MIPI Display
Real-time Clock (RTC)	Supports external coin-cell battery for power failure time retention
Debug UART	1 x 3-pin debug UART
Power	5V/3A DC power via USB-C
Power Button	On/Off included
PCIe Interface	PCI-Express® Gen3 x 1 interface for fast peripherals (requires separate M.2 HAT or other adapter)
Expansion Connector	40-pin header
Fan connector	1 x 4-pin fan connector, supports PWM control and fan speed measurement
Storage	microSD card slot with UHS-1 support
Tag Connect	1 x JTAG, 1 x External PMIC programming port

1.1.1 AM67A SoC

Todo: Add AM67A SoC details

1.1.2 Board components location

Front

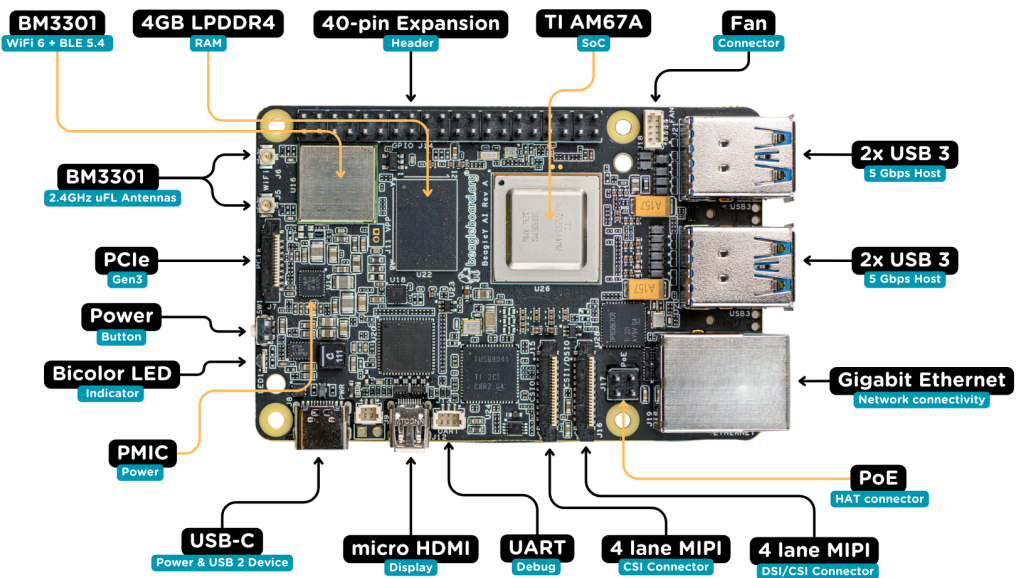


Table 1.2: BeagleY-AI board front components location

Feature	Description
WiFi/BLE	Beagleboard BM3301 with 802.11ax Wi-Fi & Bluetooth Low Energy 5.4 (BLE)
RAM	4GB LPDDR4
Expansion	40pin Expansion header compatible with HATs
SoC	TI AM67A Arm®Cortex®-A53 4 TOPS vision SoC with RGB-IR ISP for 4 cameras, machine vision, robotics, and smart HMI
Fan	4pin Fan connector
USB-A	4 x USB 3 TypeA ports supporting simultaneous 5Gbps operation host ports
Network Connectivity	Gigabit Ethernet
PoE	Power over Ethernet HAT connector
Camera/Display	1 x 4-lane MIPI camera/display transceivers, 1 x 4-lane MIPI camera
Debug UART	1 x 3-pin JST-SH 1.0mm debug UART port
Display Output	1 x HDMI display
USB-C	1 x Type-C port for power, and supports USB 2 device
PMIC	Power Management Integrated Circuit for 5V/5A DC power via USB-C with Power Delivery support
Bicolor LED	Indicator LED
Power button	ON/OFF button
PCIe	PCI-Express® Gen3 x 1 interface for fast peripherals (requires separate M.2 HAT or other adapter)

Back

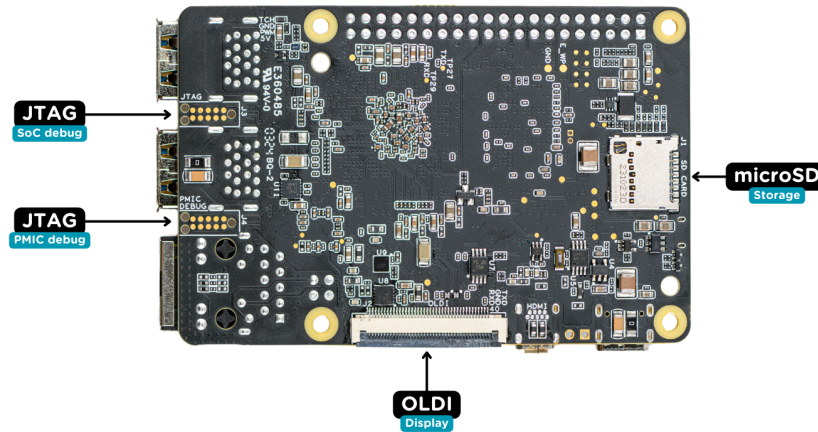


Table 1.3: BeagleY-AI board back components location

Feature	Description
Tag-Connect	1 x JTAG & 1 x Tag Connect for PMIC NVM Programming
Display output	1 x OLDI display
Storage	microSD card slot with support for high-speed SDR104 mode

Chapter 2

BeagleY-AI Quick Start

2.1 What's included in the box?

Todo: Update BeagleY-AI what's included in the box section as per production release.

When you purchase a BeagleY-AI, you'll get the following in the box:

1. BeagleY-AI
2. JST-SH cables
3. 2.4GHz antennas
4. Quick-start card

Tip: For board files, 3D model, and more, you can checkout the [BeagleY-AI repository on OpenBeagle](#).

Todo: Attaching antennas instructions for BeagleY-AI

Todo: BeagleY-AI unboxing video

2.2 Getting started

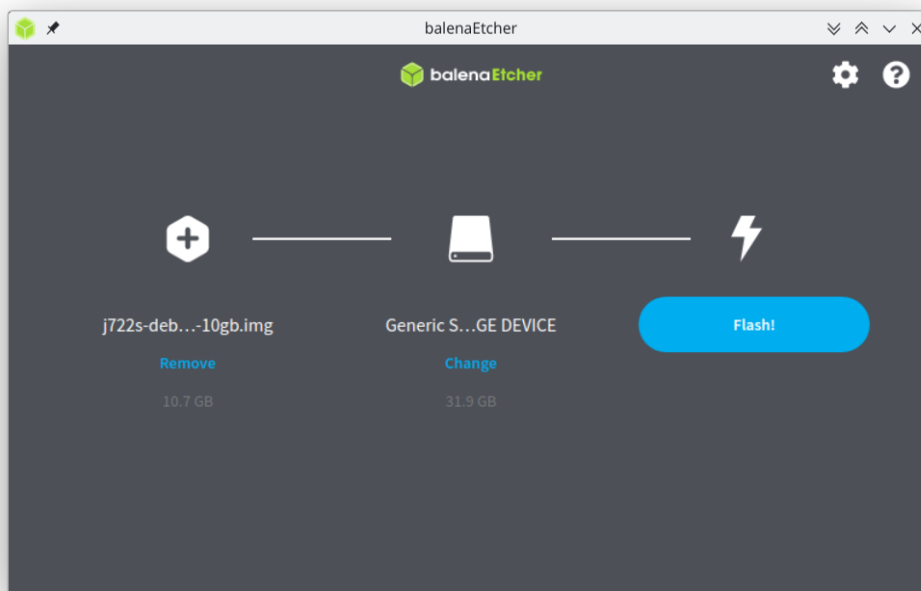
To get started you need the following:

1. USB type-A to type-C cable or type-C to type-C cable
2. 5V - 3A power supply
3. MicroSD Card
4. Boot media

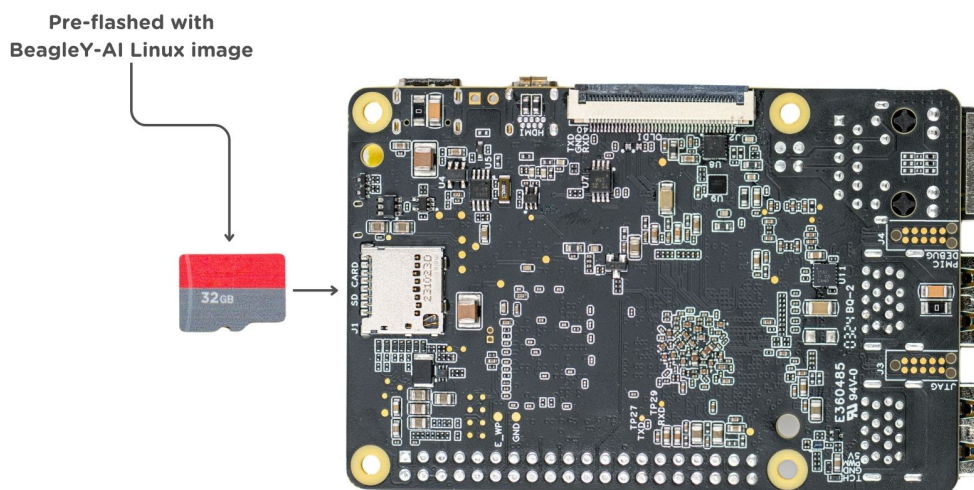
2.2.1 Boot Media

Download the boot media from <https://www.beagleboard.org/distros/beagle-y-ai-debian-xfce-12-5-2024-03-25> and flash it on a micro SD Card using using [Balena Etcher](#) following these steps:

1. Select downloaded boot media
2. Select SD Card
3. Flash!



Once flashed, you can insert the SD card into your BeagleY-AI as shown in the image below:



2.2.2 Power Supply

To power the board you can either connect it to a dedicated power supply like a mobile charger or a wall adapter that can provide $5V \geq 3A$. Checkout the [docs power supply](#) page for power supply recommendations.


```
[lorforlinux@fedora ~] $ ssh debian@192.168.7.2
Debian GNU/Linux 12

BeagleBoard.org Debian Bookworm Xfce Image 2024-03-25
Support: https://bbb.io/debian
default username is [debian] with a one time password of [tempwd]

debian@192.168.7.2's password:
You are required to change your password immediately (administrator enforced).
You are required to change your password immediately (administrator enforced).

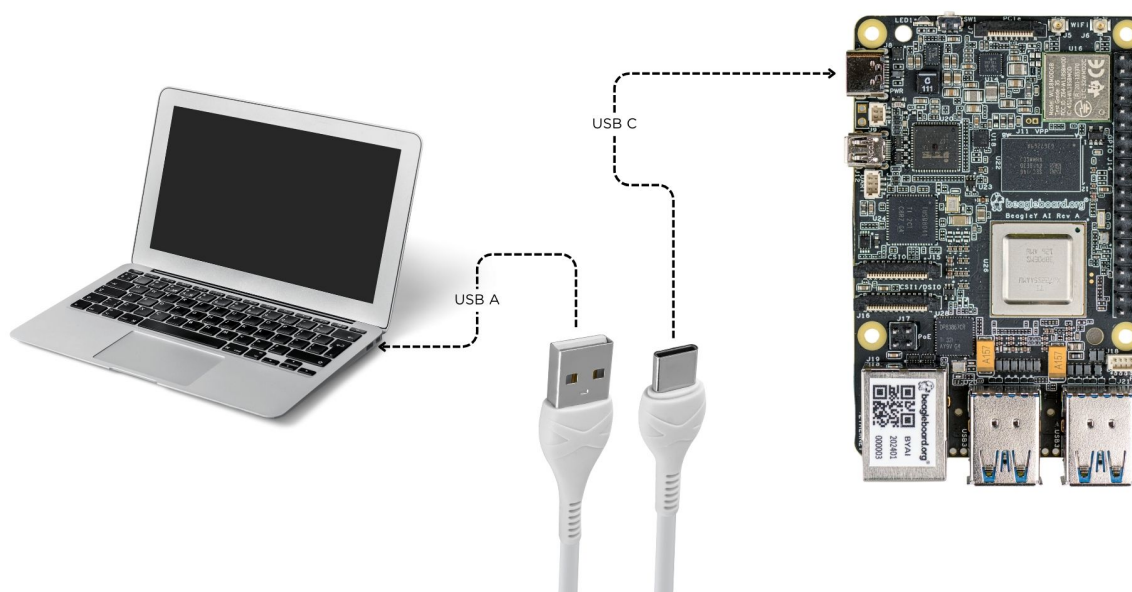
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Mon Mar 25 06:56:39 2024 from 192.168.7.1
WARNING: Your password has expired.
You must change your password now and login again!
Changing password for debian.
Current password: █
```

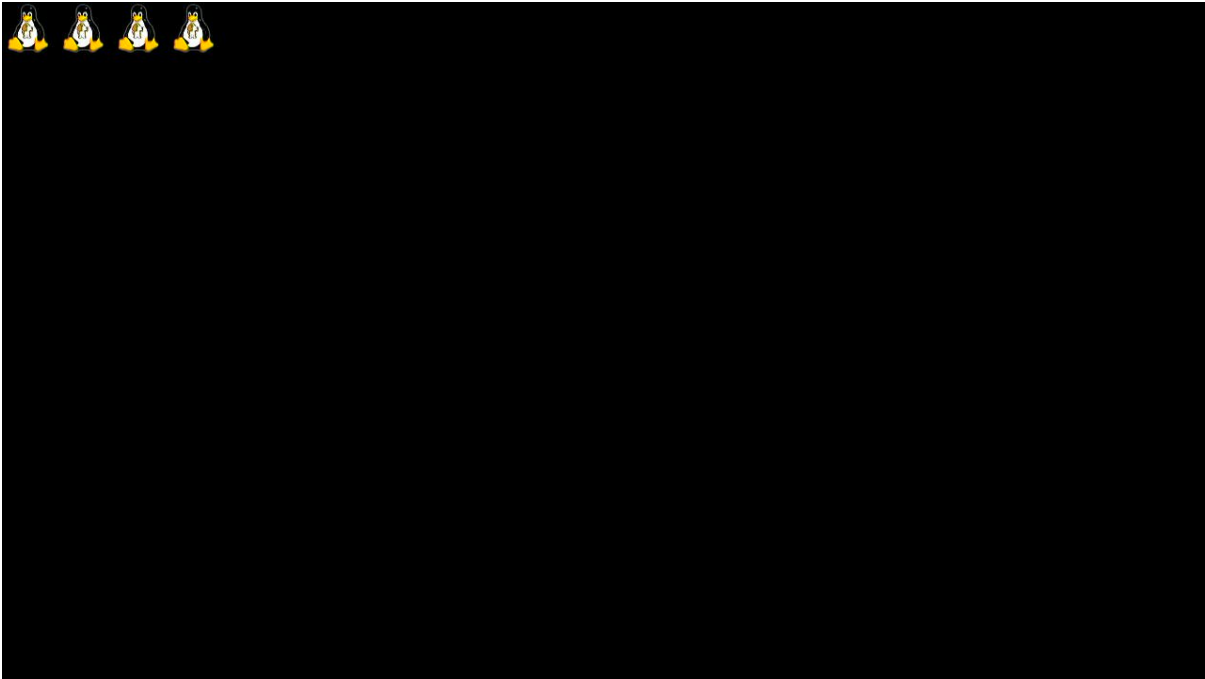
2.2.5 Using BeagleY-AI

To setup your BeagleY-AI for normal usage, connect the following:

1. 5V \geq 3A power supply
2. HDMI monitor using micro HDMI to full-size HDMI cable
3. Ethernet cable from the board to your router
4. Wireless or wired keyboard & mice

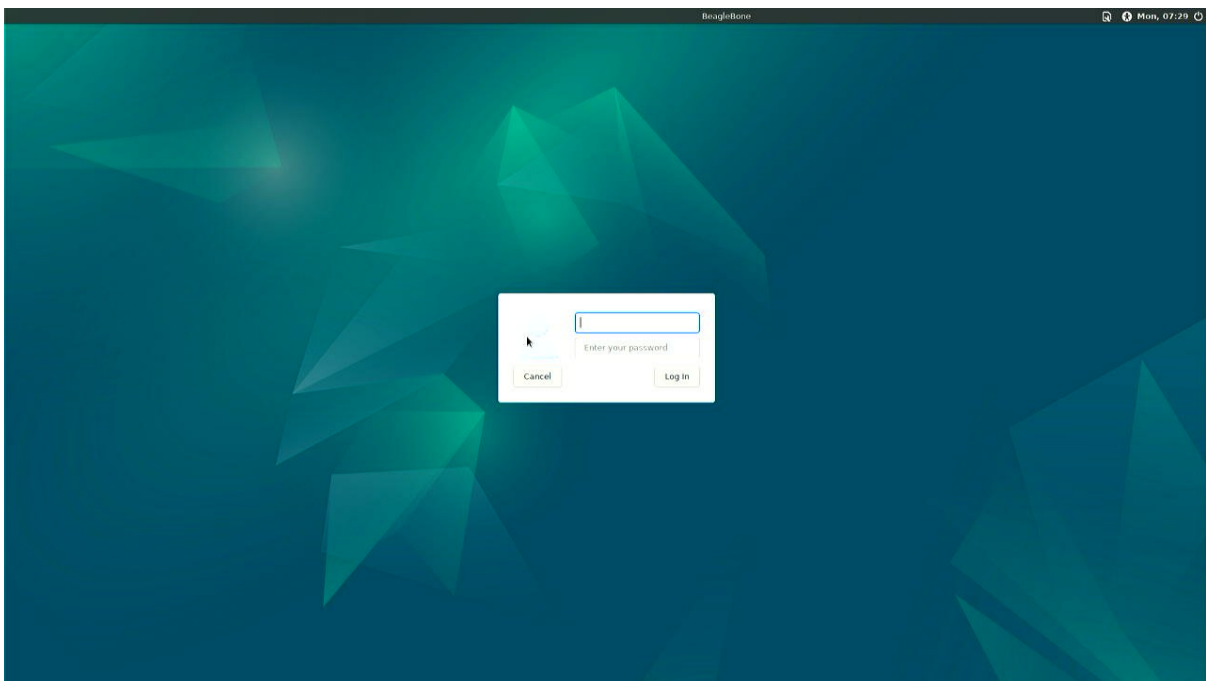


If everything is connected properly you should see four penguins on your monitor.

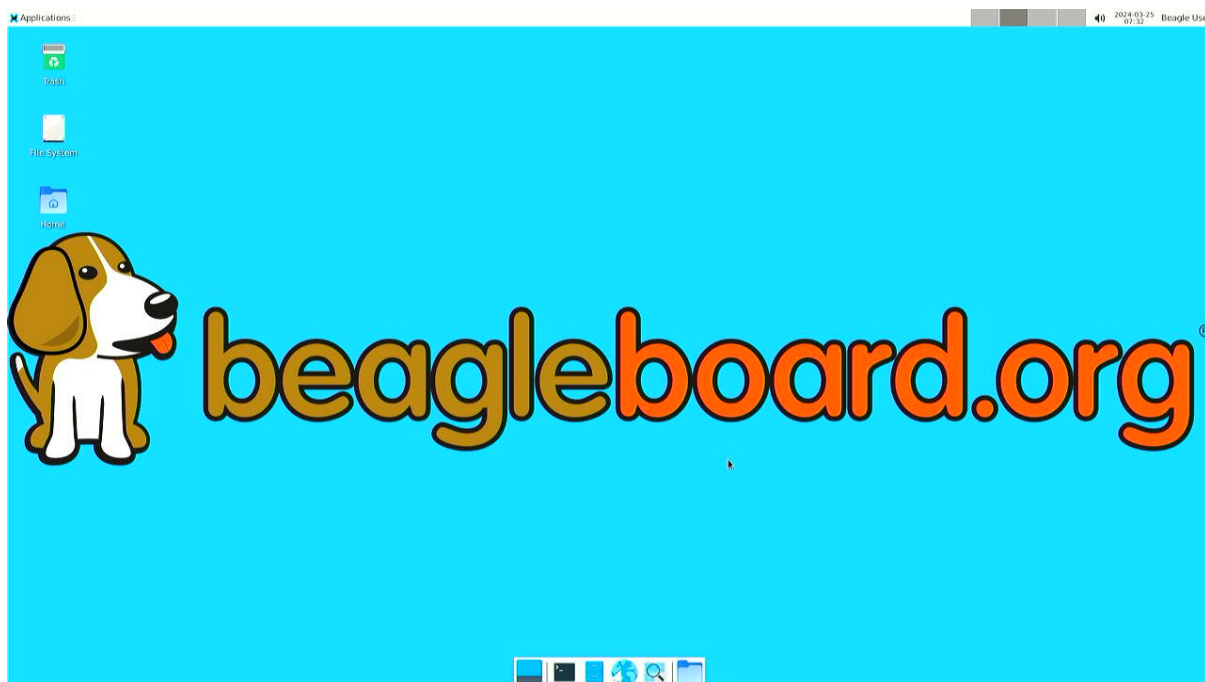


When prompted, log in using the updated login credentials you updated during the USB tethering step.

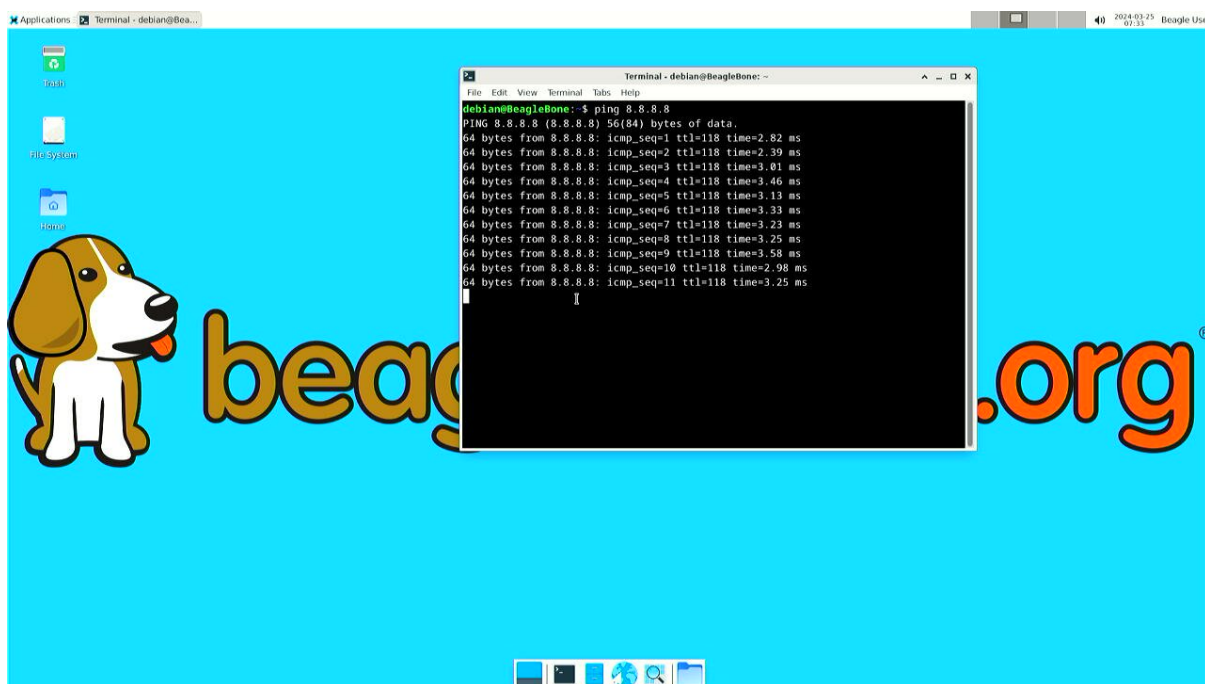
Note: You can not update login credentials at this step, you must update them during USB tethering step!



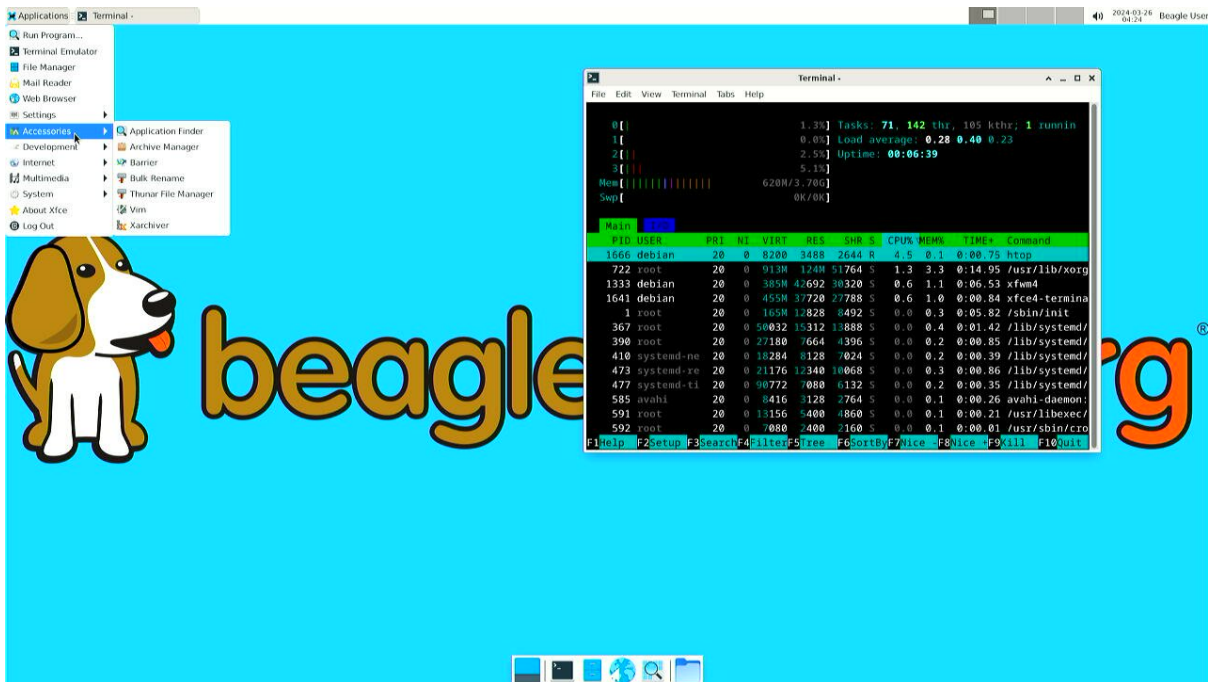
Once logged in you should see the splash screen shown in the image below:



Test network connection by running ping 8.8.8.8



Explore and build with your new BeagleY-AI board!



2.2.6 Connecting to WiFi

Connect 2x antennas to your BeagleY-AI board if not pre-attached.

After successfully attaching the antenna, power up the board. Once booted you can follow the commands below to connect to any WiFi access point,

- To list the wireless devices attached, (you should see wlan0 listed)

```
iwctl device list
```

- Scan WiFi using,

```
iwctl station wlan0 scan
```

- Get networks using,

```
iwctl station wlan0 get-networks
```

- Connect to your wifi network using,

```
iwctl --passphrase "<wifi-pass>" station wlan0 connect "<wifi-name>"
```

- Check wlan0 status with,

```
iwctl station wlan0 show
```

- To list the networks with connected WiFi marked you can again use,

```
iwctl station wlan0 get-networks
```

- Test connection with ping command,

```
ping 8.8.8.8
```


2.3 Demos and Tutorials

- [Booting from NVMe Drives](#)

Chapter 3

Design and specifications

Chapter 4

Expansion

Todo: Describe how to build expansion hardware for BeagleY-AI

4.1 PCIe

For software reference, you can see how PCIe is used on NVMe HATs.

- [Booting from NVMe Drives](#)
- beagley-ai-imx219-csi-cameras
- beagley-ai-rtc

Chapter 5

Demos and tutorials

5.1 Booting from NVMe Drives

Todo: remove notes about work-in-progress. they just make the site more janky.

Note: This page is a work in progress. Further drive testing and images will be added soon

BeagleY-AI supports a PCI-Express x1 interface which enables data rates of up to 1GB/s for high speed expansion.

Note: While the SoC supports PCI-e Gen 3, the flat-flex connector required by HATs is only rated for PCI-e Gen 2, so, as is the case with other similar boards in this form factor, actual transfer speeds may be limited to Gen 2, depending on a variety of layout and environmental factors

This enables it to take advantage of standard PC NVMe drives which offer exponentially higher random and sequential read/write speeds as well as improved endurance over SD cards or traditional eMMC storage.

While the boot-ROM on the AM67 SoC does not support direct boot-to-NVMe, we can use a method where we boot U-Boot from the SD Card and then use it to load the Linux filesystem from external NVMe storage.

5.1.1 Verified HATs and Drives

Most/All HATs and NVMe drives should work, but the following have been verified to work as part of writing this guide:

HATs:

1. [Geekworm X1001 PCIe to M.2 Key-M](#)
2. [Geekworm X1000 PCIe M.2 Key-M](#)

NVMe drives:

1. [Kingston OM3PDP3512B \(512GB 2230\)](#)
2. [Kingston NV2 \(512GB 2280\)](#)

Drive Adapters (3D Printable):

The X1000 above uses the slightly uncommon 2242 drive size, so, an adapter may be required to mount a 2230 drive.

1. A simple adapter from @eliasjonsson on Printables works great - <https://www.printables.com/model/578236-m2-ssd-2230-to-2242>
2. Similar adapters exist for 2230 to 2280 for example such as this one from @nzalog - <https://www.printables.com/model/217264-2230-to-2280-m2-adapter-ssd>

5.1.2 Step by step

Note: This article was written using the [BeagleY-AI Debian XFCE 12.5 2024-03-25 image](#).

Step 1. Boot from SD Normally

Grab the latest BeagleY-AI SD Image from ([BeagleBoard.org/distros](https://beagleboard.org/distros).)

Once logged in and at the terminal, make sure your system is up to date (a reboot is also recommended after updating)

```
sudo apt-get update && sudo apt-get full-upgrade -y
sudo reboot
```

Step 2. Verify that your NVMe drive is detected

The command `lspci` will list the attached PCI Express devices on the system:

```
debian@BeagleY:~$ lspci
```

You should see an output similar to the following, where the first entrance is the SoC internal PCI Express bridge device and the second device listed is your NVMe drive, in this case, a Kingston OM3PDP3 drive.

```
00:00.0 PCI bridge: Texas Instruments Device b010
01:00.0 Non-Volatile memory controller: Kingston Technology Company, Inc.
↳OM3PDP3 NVMe SSD (rev 01)
```

Now that we know the PCIe device is detected, let's see if it's recognized as a Storage Device:

The command `lsblk` will list the attached storage devices on the system:

```
debian@BeagleY:~$ lsblk
NAME            MAJ:MIN RM   SIZE RO TYPE MOUNTPOINTS
mmcblk0         179:0    0  59.7G  0 disk
├─mmcblk0p1     179:1    0   256M  0 part /boot/firmware
└─mmcblk0p2     179:2    0  59.4G  0 part /
nvme0n1         259:0    0 476.9G  0 disk
└─nvme0n1p1     259:1    0 476.9G  0 part
```

Here we see that two devices are connected, `mmcblk0` corresponds to our SD card, and `nvme0n1` corresponds to our NVMe drive, so everything is ready to go!

If your drives aren't listed as expected, please check the Troubleshooting section at the end of this document.

Step 3. Copy your filesystem and modify `extlinux.conf` for NVMe boot

A variety of useful scripts are available in `/opt/`, one of them enables us to move our micro-sd contents to NVMe and make BeagleY-AI boot from there directly.

The following 3 commands will change your U-boot prompt to boot from NVMe by default, but the serial boot menu will still enable you to fall back to SD boot or other modes if something happens.

Note: This will copy the entire contents of your SD card to the NVMe drive, so expect it to take upwards of 15 minutes. This only needs to be run one time

```
sudo cp -v /opt/u-boot/bb-u-boot-beagle-y-ai/beagle-y-microsd-to-nvme /etc/
↳default/beagle-flasher
sudo beagle-flasher-boot-emmc-rootfs-nvme
sudo reboot
```

Enjoy NVMe speeds!

Now that we've run the scripts above, you should see that lsblk now reports that our / or root filesystem is on the nvme0n1p1 partition, meaning we are successfully booting from the NVMe drive.

It's subtle, but the change can be seen by running lsblk again.

```
debian@BeagleY:~$ lsblk
NAME                MAJ:MIN RM   SIZE RO TYPE MOUNTPOINTS
mmcblk0             179:0    0  59.7G  0 disk
├─mmcblk0p1         179:1    0   256M  0 part /boot/firmware
└─mmcblk0p2         179:2    0  59.4G  0 part
nvme0n1             259:0    0 476.9G  0 disk
└─nvme0n1p1        259:1    0 476.9G  0 part /
```

Congratulations!

5.1.3 Troubleshooting

While most setups should work, it is possible that a combination of Software, Hardware or both can result in minor issues. Here are some ideas for troubleshooting on your own:

Check that your cables are plugged in and oriented correctly

The flat-flex ribbon cable will only connect correctly one way, so ensure the orientation is correct with your expansion HAT manual and that the ribbon cable is correctly seated.

A note on power-hungry drives

While most drives can be powered as-is with only the ribbon cable, some drives, especially high end full-size 2280 drives may consume more power than normal for an M.2 connector. For such cases, some HAT expansions will provide a means of providing external supplemental power. If your drive is not detected, it may be worthwhile to try using a drive from a different manufacturer as a troubleshooting step.

As a side note, since 2230 drives are normally designed to run in Laptops, they tend to also consume less power than their desktop counterparts and as such, are a "safer" option.

Check the Linux Kernel Logs for PCI:

You should see something similar to below without further errors:

```
debian@BeagleY:~$ dmesg | grep "PCI"
[ 0.005276] PCI/MSI: /bus@f0000/interrupt-controller@1800000/msi-
↳controller@1820000 domain created
[ 0.158546] PCI: CLS 0 bytes, default 64
[ 3.674209] j721e-pcie-host f102000.pcie: PCI host bridge to bus 0000:00
```

(continues on next page)

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```
[ 3.742406] pci 0000:01:00.0: 7.876 Gb/s available PCIe bandwidth,
↳limited by 8.0 GT/s PCIe x1 link at 0000:00:00.0 (capable of 31.504 Gb/s
↳with 8.0 GT/s PCIe x4 link)
[ 4.915630] pci 0000:00:00.0: PCI bridge to [bus 01]
```

Still having issues?

Post questions on the [forum](#) under the tag “beagle-ai”.

Chapter 6

Support

All support for BeagleY-AI design is through BeagleBoard.org community at [BeagleBoard.org](https://beagleboard.org/forum) forum.

6.1 Production board boot media

Todo: Add production boot media link in `_static/epilog/production.image` and reference it here.

6.2 Certifications and export control

6.2.1 Export designations

- HS: 8471504090
- US HS: 8543708800
- UPC: 640265311062
- EU HS: 8471707000
- COO: CHINA

6.2.2 Size and weight

- Bare board dimensions: **TBD**
- Bare board weight: **TBD**
- Full package dimensions: **TBD**
- Full package weight: **TBD**

6.3 Additional documentation

6.3.1 Hardware docs

For any hardware document like schematic diagram PDF, EDA files, issue tracker, and more you can checkout the [BeagleY-AI design repository](#).

6.3.2 Software docs

For BeagleY-AI specific software projects you can checkout all the [BeagleY-AI project repositories group](#).

6.3.3 Support forum

For any additional support you can submit your queries on our forum, <https://forum.beagleboard.org/tag/beagle-y-ai>

6.3.4 Pictures

6.4 Change History

Note: This section describes the change history of this document and board. Document changes are not always a result of a board change. A board change will always result in a document change.

6.4.1 Board Changes

For all changes, see <https://openbeagle.org/beagle-y-ai/beagle-y-ai>. Versions released into production are noted below.

Table 6.1: BeagleY-AI board change history

Rev	Changes	Date	By