Upstream Embedded Linux on RISC-V SBCs:
The Past, Present and Future

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Speaking today

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ROLE

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TENURE

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PAST ENGAGEMENTS

Senior Linux Expert, System
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EDUCATION

MS Computer Science
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Contents

The Past

Revisiting Banana Pi BPI-F3

Banana Pi BPI–F3

- Industrial grade RISC-V development board

- SpacemiT K1 SoC, quad X60 64-bit RISC-V cores (RV64GCVB), RVA22, RVV1.0

- 2.0 TOPs AI accelerator

- 2/4/8/16 GB 32-bit 2400 MT/s LPDDR4/4X RAM

- 8/16/32/128 GB eMMC, micro SD card slot, optional 4 MB SPI NOR, 32 MB SPI NAND

- 2x GbE Ethernet
  RTL8852BS dual-band Wi-Fi 6 and Bluetooth 4.2

- 4x USB 3.0 host ports, 1x USB 2.0 OTG Type-C port

- 5-lane PCIe GEN2.1: mini-PCIe and M.2 M key

- IMG BXE-2-32 GPU @ up to 819 MHz, Vulkan 1.3, OpenGL ES 3.x/2.0/1.1, OpenCL 3.0

- HDMI and dual MIPI-CSI camera,
  4K decoding and encoding

- Starting at 60 bucks
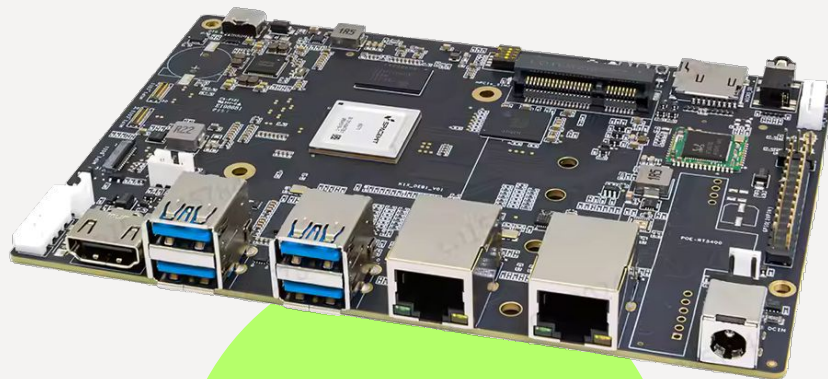
Banana Pi
open source
hardware

BTW: there are now many more SpacemiT K1 (or actually Ky X1, which is a derivative thereof) based boards available like the Orange Pi R2S and RV2, which my subsequent speaker Michael Opdenacker will cover in greater detail (;-p)

Downstream Bianbu v3.0.1

- V3.0.1 got released on Aug 15, 2025
- Bianbu-25.04-minimal-k1-v3.0.1-release-20250815180414.img.zip
- Booting e.g. from uSD card
- Downstream sources
  - from SpacemiT on gitee
  - from Banana Pi on github
- OpenSBI 1.3
- U-Boot 2022.10
- Linux kernel 6.6.63
- Based on Ubuntu 25.04 providing own APT source
  - http://archive.spacemit.com/bianbu/

Featuring

gcc 14.2

Llvm 18.1.8-11

Mesa 24.01

Ugly Chinese vendor downstream

Fedora-V Force (FVF) 42

- Latest FVF for BPI-F3 got released on Sep 27, 2025

- Fedora-Minimal-42-20250927113555.riscv64.SpacemiT-K1.raw.gz

- Booting e.g. from uSD card

- OpenSBI 1.3

- U-Boot 2022.10 SpacemiT

- Linux kernel 6.6.63

Featuring

gcc 15.1.1

Proper Fedora but still based on ugly Chinese vendor downstream

Upstream Status

- OpenSBI
  - "platform: generic: spacemit: add K1" got merged Oct 20, 2025
- U-Boot
  - Initial support got merged Dec 18, 2024 but was missing SPL support, later functionality to probe DRAM size got merged as I already talked about last year
  - Meanwhile reset and pinctrl support got merged and the UART compatible updated
  - Somebody worked on DRAM init rust code but still no U-Boot SPL integration
  - That changed Jan 17, 2026 with "[PATCH 00/17] Add board support for Spacemit K1 SoC in SPL"
    - Binary DDR firmware likely has to be moved out of U-Boot sources
    - Author did not describe how to install SPL binary to make patch testable
    - I gave it a try but did not get it to work yet

Upstream Status cont.

- Linux kernel
  - Initial pinctrl support got merged Nov 12, 2024, followed by X60 core, CLINT/PLIC and an initial BPI-F3 device tree as I already talk about last year
  - Later Milk-V Jupiter board got added
  - And I2C, GPIO and clock support landed which I already tested and talked about last year
  - Followed by system heartbeat GPIO LED, reset, PWM, SDHCI (eMMC only), DMA, UART reset, Ethernet, EEPROM, QSPI, more I2C nodes and P2 PMIC support
  - And a lot of stuff on -next or still in-flight posted on the LKML

Upstream Status cont.

- RISC-V SpacemiT DT changes for 6.20 pull request from Jan 22, 2026

  - Disable Ethernet PHY auto sleep mode

  - Add pinctrl IO power support

  - Add K3 Pico-ITX board (I will talk more about the K3 later)

  - Add support for K3 SoC

  - Add DWC USB support

  - Add reset for eMMC(sdhci)/I2C

  - Add PCIe support

  - Support PMIC for Jupiter board

- [PATCH v2 0/3] pinctrl: spacemit: support I/O power domain configuration
  Applied via pinctrl (first two) and SoC (latter one) trees

- [PATCH net-next v3] net: spacemit: Remove broken flow control support
  Applied via net-next

Upstream Status cont.

- [PATCH net v3] net: spacemit: Check for netif_carrier_ok() in emac_stats_update()
  Applied via net (and conflicts...)

- [PATCH] gpio: spacemit-k1: Use PDR for pin direction, not SDR/CDR
  Applied via brgl

- [PATCH v6 0/2] i2c: spacemit: introduce pio for k1

- [PATCH v5 0/3] spacemit: fix P1 sub-device Kconfig defaults and dependencies

- [PATCH v3 0/3] riscv: dts: spacemit: Add USB 3.0 support for K1

- [PATCH 1/2] riscv: dts: spacemit: add common board dtsi for OrangePi

- [PATCH 2/2] riscv: dts: spacemit: add fixed regulators for OrangePi

- [PATCH v2 0/4] regulator: spacemit-p1: Fix voltage ranges and support board power tree

- [PATCH net v3] net: spacemit: k1-emac: fix jumbo frame support

Upstream Status cont.

- Yocto project aka meta-riscv

  - Remember, I had a functional patch set last year but using downstream U-Boot and Linux kernel from the SoC vendor tree

  - On Jan 6, 2026 Michael's merge request using mainline U-Boot (only U-BOOT SPL with DRAM training from the SoC vendor tree) and Linux kernel got applied

  - I found and fixed an issue with missing openssl/evp.h include

  - Suggests using NFS rootfs via Ethernet (which works great BTW)

  - eMMC is supported (which also works great BTW)

  - No micro SD card support yet (that controller has a completely different configuration)

  - Michael initiated some further discussion on the LKML

    - [PATCH 0/2] Attempt to enable MMC on SpacemiT K1 boards

  - Patches welcome (;-p)

Upstream Status cont.

- Freedesktop-SDK

    - Merge requests !24432 from my co-worker Matteo Martelli last updated 11 months ago which I already talked about last year is still open

    - I tried to re-base it on top of latest master, however, downstream vendor OpenSBI fails to build with later GCC

    - Tried upstream OpenSBI as well, but downstream vendor U-Boot would need it as an .itb rather than a .bin

    - Unfortunately needs more work...

The Present

Banana Pi
BPI-RV2

Banana Pi BPI–RV2

- Siflower SF21H8898 SoC, quad XuanTie C908 1.25 GHz 64-bit RISC-V cores (RV64GCB[V]), RVA22, RVV1.0, TSMC 12 nm FFC process

- Dedicated network processing accelerator (NPU), 20 Gbps switching capacity

- 512 MB 16-bit DDR3 RAM, 128 MB SPI NAND and 16 MB SPI NOR (NAND/NOR boot and NOR wp jumpers)

- 5x Gigabit ports and 1× 2.5GbE port

- M.2 Key B with USB 2.0, PCIe GEN2 and NanoSIM slot, Mini-PCIe slot with USB 2.0 and 1-lane PCIe GEN2

- 1x USB 2.0 Type-A host port through USB hub, USB Type-C serial console UART (HT42B534-2 chip)

- PCF8563-compatible RTC (CR1220 battery)

- 26-pin GPIO MikroBUS header (I2C, PCM, PWM, SPI, UART)

- Reset button, CPU, Key B and mini-PCIe LEDs

Banana Pi
open source
hardware

- DCIN (5521) 12V/2A (max 18 volts) or 802.3at/af PoE on 2.5GbE port

- Size 148 × 100.5 mm

- Starting at less than 40 bucks

Downstream OpenWrt 24.10

- BPI-RV2-SF21H8898-OPENWRT-24.10-BSP got released on Dec 2, 2025

- Booting only from SPI NAND supported

- Downstream sources

  - U-boot-2022.01.tgz on Baidu cloud or Google drive

  - OpenWrt from Banana Pi on BPI-SINOVOIP github

- OpenSBI 1.x

- U-Boot 2022.01
  But only booting from SPI NAND

- Linux kernel 6.6.110

- Very limited documentation so far

Featuring

gcc 13.3

Recovery only via SPI NAND flasher

Upstream Status

- OpenSBI
  - Nothing yet
- U-Boot
  - Nothing yet
- Linux kernel
  - Siflower vendor prefix got merged Jan 24, 2025
  - [PATCH 0/2] gpio: add support for GPIO controller on Siflower SoCs
  - [PATCH v2] riscv: add Siflower RISC-V SoC family Kconfig support
  - Both require re-work
  - But no more progress since January last year

Upstream Status cont.

- OpenWrt

  - Initial support got merged Oct 8, 2024
    (Note: siflower's sf19 is MIPS while sf21 is RISC-V)

  - Relies on the downstream vendor boot chain being present on the board

  - Booting from SPI NAND only

- Yocto Project aka meta-riscv

  - I do have a branch building OpenWrt-based 6.12 kernel on my github

  - But found out that downstream vendor U-Boot only supports booting from SPI NAND

  - Not even the USB 2.0 host port is supported!

  - Flashing something into SPI NAND, it also boots from, seems slightly risky

  - I need to first make sure I can recovery flash it somehow

ESWIN Computing EBC77

ESWIN Computing EBC77

- EIC7700X SoC, quad SiFive HiFive Premier P550 1.8 GHz 64-bit RISC-V cores (RV64GC), RVA20

- 20 TOPS NPU

- 16 GB 64-bit 6400 MT/s LPDDR5X RAM

- 8 MB SPI NOR Flash (W25Q64DW)

- Dual 4-lane MIPI CSI/DSI interfaces, vision DSP

- 4-lane PCIe GEN3 FPC connector (proprietary)

- 40-pin GPIO header (I2C, I2S, UART)

- Gigabit Ethernet (RTL8211F RGMII PHY) Ampak AP6256 dual-band Wi-Fi 5, Bluetooth 5.0

- 2x USB 3.2 GEN1 host ports (one recovery boot capable), 2x USB 2.0 host ports

- Micro SD slot and micro HDMI output

- IMG AXM-8-256 3D GPU (supports OpenGL-ES 3.2, EGL 1.4, OpenCL 1.2/2.1 EP2, Vulkan 1.2)
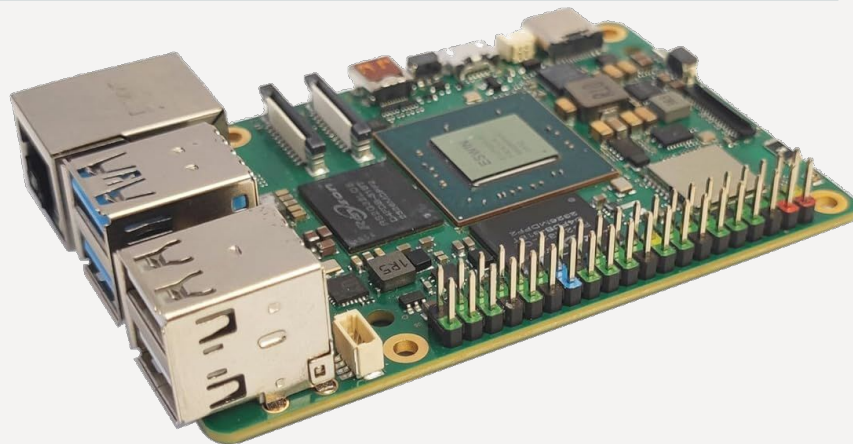
- 8K multimedia decode/encode

- PCF85063 RTC

- Micro USB debug UART connector (via CH341)

- Fan connector

- USB-C power delivery (up to 45 watts)

- Form factor of 85mm x 56mm

- Starting at less than 130 bucks

Downstream Ubuntu 24.04.3 LTS

- Version 2025.10.30 (R01A12) released on Dec 12, 2025

- sbc-ubuntu-24.04-preinstalled-server-riscv64_20251211_0111_41.img.zst

- Booting from SPI NOR, Root File System on uSD card

- Downstream sources on https://github.com/eswincomputing

- OpenSBI 1.3

- U-Boot 2024.01

- Linux kernel 6.6.92

- Based on Ubuntu 24.04.3 LTS providing Ubuntu APT source

Featuring

gcc 13.3

Backed by Canonical

Upstream Status

- OpenSBI
    - "platform: generic: eswin: add EIC7700" got merged Dec 21, 2025
- U-Boot:
    - Nothing yet
- Linux kernel
    - Cache controller support for ESWIN EIC7700 got merged Apr 7, 2025
    - Since then CLINT (timer), pinctrl, AHCI/ATA, Ethernet/stmmac, MMC/SDHCI/dwcmshc, reset, USB/dwc3 and SiFive HiFive Premier P550 board support got added
    - And a lot of stuff on -next or still in-flight posted on the LKML

Upstream Status con.

- LKML

  - [PATCH v9 0/3] Add driver support for ESWIN eic700 SoC clock controller

  - [PATCH v9 0/2] Add driver support for Eswin EIC7700 SoC PCIe controller

  - [PATCH v3 00/22] riscv: Memory type control for platforms with physical memory aliases
    Only got partially merged?

- Yocto project aka meta-riscv

  - My initial downstream and mainline machines got merged Jan 17, 2026

  - Latter based on Linux kernel v6.19-rc5 incl. 22 patches straight from the LKML and two further device tree patches inspired by downstream vendor kernel

  - Boots from a micro SD card given EBC77 had latest downstream U-Boot installed in its SPI NOR flash it boots from

  - Pull request updating to v6.19-rc7 from Jan 28, 2026

Upstream Status con.

- Freedesktop-SDK
  - My merge request !30486 using same Linux kernel v6.19-rc7 with the 24 patches
  - EFI loader just hangs without any output at all (req. debugging, first on QEMU?)
  - Luckily works with EFI/Grub from downstream Ubuntu
    - First, I copy dtb, initrd and kernel from EFI partition to rootfs/boot
    - Then, I replace EFI partition with Ubuntu one and copy over Ubuntu's rootfs/boot/{efi/grub}
    - Last but not least, I edit rootfs/boot/grub/grub.cfg fixing its UUID (blkid)
    - And finally, I boot manually as follows:
      - grub rescue> set boot=(hd0,gpt2)
      - grub rescue> set prefix=(hd0,gpt2)/boot/grub
      - grub rescue> insmod normal
      - grub rescue> normal

The Future

RVA23

Milk-V Titan
Milk-V Jupiter 2

Milk-V Titan

- UltraRISC UR-DP1000, eight core, 12 nm

- Technically not fully RVA23 as it is missing V (vector) extension

- Claim to be most powerful RISC-V mini-ITX

- Starting at 235 bucks

- Pre-ordered mine getting an additional discount (but don't forget shipping cost)

- Supposedly shipping within 45 days

- Already got 64 GB (2× 32 GB) of DDR4-3200 memory waiting for it (thanks to AI this ain't cheap anymore)

- Latest news: reliability issues with revision 3 boards now producing further batches at different manufacturers, let's see...

Upstream Status

- [PATCH v6 0/4] Add UltraRISC DP1000 PLIC support

Milk-V Jupiter 2

- SpacemiT K3 SoC, eight X100 64-bit 2.4 GHz RISC-V cores, 130 KDMIPS, RVA23

- Dual RT24 64-bit RISC-V real-time processing cores, 2x RT I/O FPC

- Eight A100 cores, 60 TOPs AI accelerator, dedicated TCM and DMA acceleration channels, 1024-bit RVV1.0

- Up to 32 GB 64-bit 6400 MT/s LPDDR5 RAM

- Up to 256 GB UFS

- M.2 key B 2242/2230 2-lane PCIe GEN3, USB and NanoSIM

- M.2 key M 2280 4-lane PCIe GEN3

- 1x GbE Ethernet, 1× 10GbE SFP+

- Dual-band Wi-Fi 6 and Bluetooth 5.2

- 4x USB 2.0 host ports, 2x USB 3.2 GEN1 Type-C ports

- IMG BXM-4-64-MC1 GPU, Vulkan 1.3, OpenGL ES 3.2/2.0/1.1, OpenCL 3.0

- Dimension 100 × 86 mm

- Pricing unknown

- Supposedly ships April 2026

- USB Type-C DP Alt Mode up to 4K@60Hz, eDP up to 2.5K@90Hz, audio codec/connector

- UART, I2C, I2S, EtherCAT/CAN-FD, PWM, GPIOs

- RTC battery and fan connectors

- 2-pin 12V ATX or USB Type-C 65 W USB-PD

Upstream Status

- [PATCH 0/8] riscv: spacemit: Add SpacemiT K3 SoC and K3 Pico-ITX board

- [PATCH v5 0/5] Add clock support for SpacemiT K3 SoC

- [PATCH v3 0/2] riscv: spacemit: add gpio support for K3 SoC

- [PATCH v3 0/4] pinctrl: spacemit: add support for K3 SoC

- [PATCH 0/4] reset: spacemit: Add support for SpacemiT K3 SoC

- [PATCH] riscv: defconfig: spacemit: k3: enable clock support

- [PATCH net-next v3 0/3] riscv: spacemit: Add ethernet support for K3

- [PATCH 0/6] iommu/riscv: Add HPM support for RISC-V IOMMU

Upcoming RVA23 Boards/IPs/Chips

- Andes Technology AX66 and Cuzco cores (both preliminary)

- ESWIN Computing S500 64-bit general-purpose processor, high energy-efficient 64-bit RISC-V application-level CPU IP product, meets RVA23 profile

- ESWIN Computing S516 64-bit AI acceleration processor, high energy-efficient RISC-V application-level CPU IP product, meets RVA23 profile

- Nuclei System Technology UX1030H (fully compliant with RVA23 profile)

- SiFive Performance P800-Series (related to ESWIN's stuff, I guess we don't know)

- SpacemiT VitalStone V100 server CPU, X100 cores, K3 SoC

- Tenstorrent TT-Ascalon (IP only)

- XiangShan: An Open-Source High-Performance RISC-V Processor and Infrastructure for Architecture Research (sounds very interesting indeed)

- Zhihe A210 SoC (not yet RVA23?), A600 SoC

Live Demo

Live Demo

- This year I let you choose

  - Banana Pi BPI-F3 running Yocto project image with mainline Linux kernel (missing micro SD support)

  - Banana Pi BPI-RV2 running upstream OpenWrt 2025.12.0-rc3 with mainline Linux kernel 6.12 LTS (OpenWrt-patched)

  - ESWIN EBC77 running Yocto project image with mainline Linux kernel (Yocto-patched)

  - ESWIN EBC77 running Freedesktop-SDK image with mainline Linux kernel (fdsdk-patched)

References

- Banana Pi BPI-F3
  https://docs.banana-pi.org/en/BPI-F3/BananaPi_BPI-F3

- Bianbu v3.0.1
  https://archive.spacemit.com/image/k1/version/bianbu/v3.0.1

- Fedora-V Force (FVF)
  https://www.fedoravforce.org

- Freedesktop-SDK: bpi-f3: add support for SinoVoip BPI-F3 RISC-V board
  https://gitlab.com/freedesktop-sdk/freedesktop-sdk/-/merge_requests/24432

- Banana Pi BPI-RV2
  https://docs.banana-pi.org/en/BPI-RV2/BananaPi_BPI-RV2

- OpenWrt
  https://git.openwrt.org/?p=openwrt/openwrt.git;a=commitdiff;h=b8a8bf53e94c07b4c2cb85005d9598f9f6d7b87e

- ESWIN Computing
  https://www.eswincomputing.com/en

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- EBC77 SBC Ubuntu
  https://github.com/eswincomputing/ebc7700-sbc-ubuntu

- Freedesktop-SDK: Draft: Add eswin ebc77 support
  https://gitlab.com/freedesktop-sdk/freedesktop-sdk/-/merge_requests/30486

- Yocto Project: meta-riscv
  https://github.com/riscv/meta-riscv

- Milk-V Titan
  https://milkv.io/titan

- Milk-V Jupiter 2
  https://milkv.io/jupiter2

- First Ever RVA23 Mainline Contribution
  https://lore.kernel.org/all/20251216-k3-basic-dt-v1-0-a0d256c9dc92@riscstar.com

Thank You.

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