Embedded Linux Conference

Buildroot: what's new?

Thomas Petazzoni
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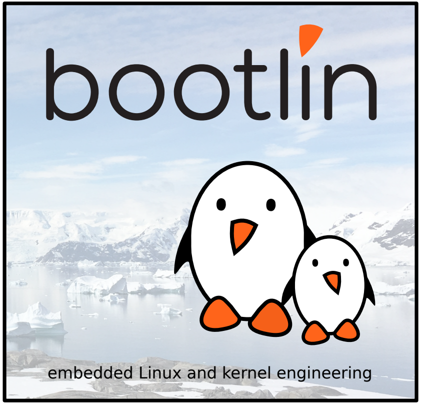

Thomas Petazzoni

- Co-owner and CEO at **Bootlin**
  - Embedded Linux experts
  - Engineering services: Linux BSP development, kernel porting and drivers, Yocto/Buildroot integration, real-time, boot-time, security, multimedia
  - Training services: Embedded Linux, Linux kernel drivers, Yocto, Buildroot, graphics stack, boot-time, real-time
- Co-maintainer of **Buildroot**, contributor since 2008, 5200+ patches contributed.
- Former contributor to the Linux kernel, 900+ patches contributed.
- Program committee member and regular speaker at the Embedded Linux Conference
- Living in **Toulouse**, south west of France
- thomas@bootlin.com

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Agenda

- What is Buildroot?
- Comparison with Yocto
- What's new between 2020.05 and 2022.05
  - Some numbers
  - LTS and security maintenance
  - Security vulnerability tracking
  - Security default settings
  - SELinux integration improvements
  - Vendoring support for Go/Rust
  - Python changes
  - Significant new packages
  - Testing improvements
  - Toolchain improvements
  - Architecture support

What is Buildroot?

- Is an **Embedded Linux build system**
  - Tool that **automates** the cross-compilation of a complete embedded Linux system from source
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- Very **active community** of developers/users, used by many companies: silicon vendors, embedded system manufacturers, hobbyists
- Oldest still maintained build system: started in 2001

Buildroot vs. Yocto

The one question that everybody asks!

Buildroot vs. Yocto

- What it builds
  - **Yocto**: builds a distribution, with binary packages and a package management system
  - **Buildroot**: builds a fixed functionality root filesystem, no binary packages
  - Note: binary packages are not necessarily a good thing for embedded!

Buildroot vs. Yocto

- What it builds
- Configuration
  - **Yocto**: flexible, powerful but complex configuration description
  - **Buildroot**: very simple configuration system, but sometimes limited

Buildroot vs. Yocto

- What it builds
- Configuration
- Build strategy
  - **Yocto**: complex and heavy logic, but with efficient caching of artifacts and “rebuild only what’s needed” features
  - **Buildroot**: simple but somewhat dumb logic, no caching of built artifacts, full rebuilds needed for some config changes

Buildroot vs. Yocto

- What it builds
- Configuration
- Build strategy
- Ecosystem
  - **Yocto**: (relatively) small common base in OpenEmbedded, lots of features supported in third party layers → lots of things, but varying quality
  - **Buildroot**: everything in one tree → perhaps less, but more consistent quality

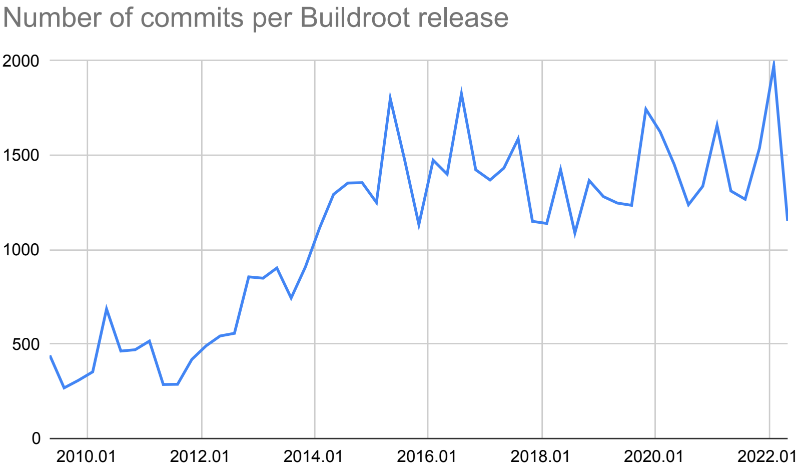
Buildroot vs. Yocto

- What it builds
- Configuration
- Build strategy
- Ecosystem
- Complexity/learning curve
  - **Yocto**: admittedly steep learning curve, *bitbake* remains a magic black box for most people
  - **Buildroot**: much smoother and shorter learning curve, tool is simple to approach, and reasonably simple to understand

Buildroot vs. Yocto

- What it builds
- Configuration
- Build strategy
- Ecosystem
- Complexity/learning curve
- And also a matter of personal taste/preference, as often when choosing tools

Community vitality: some numbers



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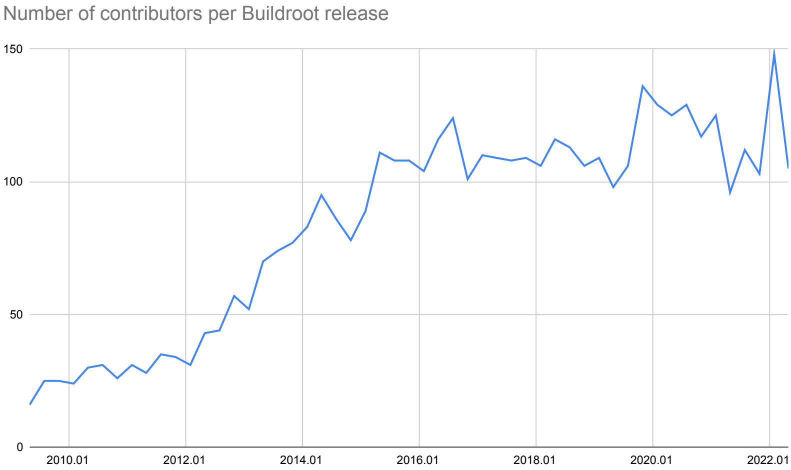

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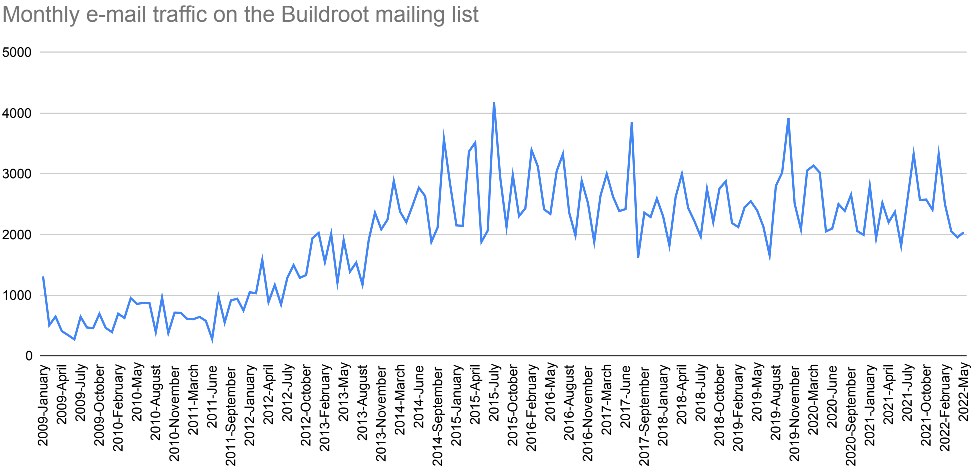

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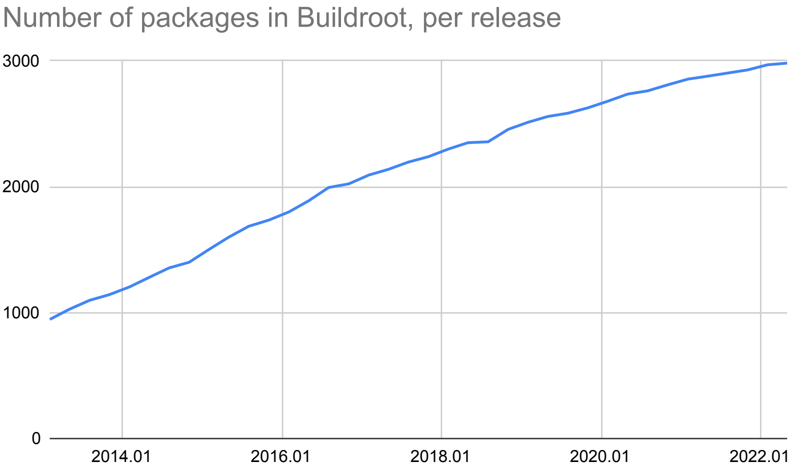
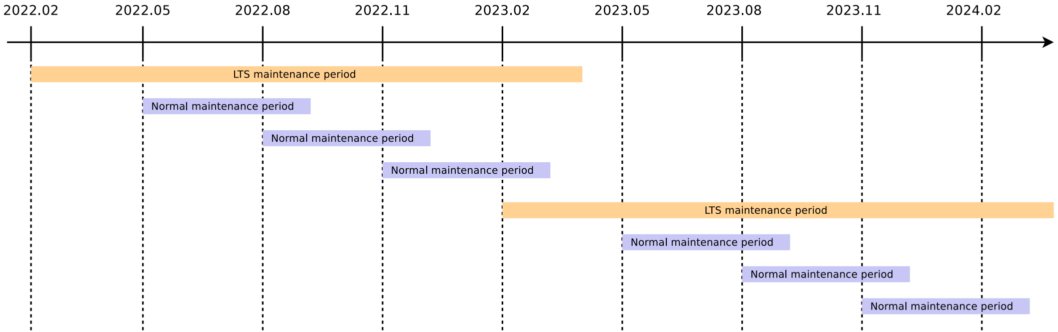


LTS and security maintenance


2022.02
2022.05
2022.08
2022.11
2023.02
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2023.11
2024.02
LTS maintenance period
Normal maintenance period
Normal maintenance period
Normal maintenance period
LTS maintenance period
Normal maintenance period
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Normal maintenance period

- Maintenance: security fixes, bug fixes
- *YYYY.02* releases maintained for slightly over 12 months
- *YYYY.{05,08,11}* releases maintained for slightly over 3 months

LTS and security maintenance

- Process started with 2019.02.x
- Process now works well: review of all commits in *master* and decision if applicable to the current LTS branch
- **2020.02.x** LTS branch
  - 1219 commits
  - 228 directly security related (probably more in reality)
  - 12 point releases: 2020.02.1 → 2020.02.12
  - End of life
- **2021.02.x** LTS branch
  - 751 commits
  - 110 directly security related (same, probably more in reality)
  - 12 point releases: 2021.02.1 → 2021.02.12
  - End of life on April 6, 2022
- **2022.02.x** LTS branch, current
  - Started in February 2022
  - End of life planned on April 2023

Security vulnerability tracking

- `make pkg-stats` matches your package set with the *NIST* security vulnerability database
  - CVE database: *Common Vulnerability and Exposure*
  - CPE database: *Common Platform Enumeration*
  - HTML and JSON output

Security vulnerability tracking

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  - CVE database: *Common Vulnerability and Exposure*
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- Checks if packages...
  - are affected by known CVEs
  - have a CPE identifier known in the CPE database

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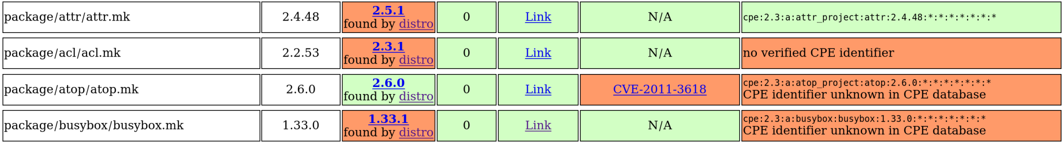
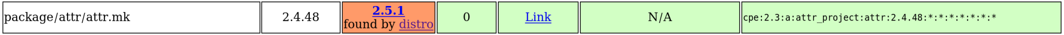
  - HTML and JSON output
- Checks if packages...
  - are affected by known CVEs
  - have a CPE identifier known in the CPE database
- Helped with metadata from the package `.mk` file
  - `<pkg>_IGNORE_CVES` to ignore matching CVEs if they are fixed locally by a security fix backport
  - `<pkg>_CPE_ID_...` to override the default CPE identifier for the package `cpe:2.3:a:<pkg>_project:<pkg>:<pkg-version>:*:*:*:*:*:*`

pkg-stats output details



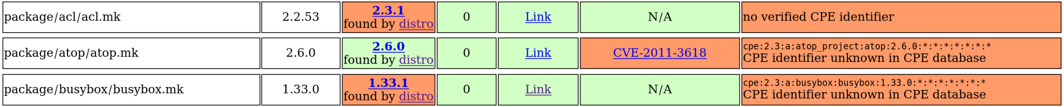
package/attr/attr.mk	2.4.48	**2.5.1** found by distro	0	Link	N/A	`cpe:2.3:a:attr_project:attr:2.4.48:*:*:*:*:*:*:*`
package/acl/acl.mk	2.2.53	**2.3.1** found by distro	0	Link	N/A	no verified CPE identifier
package/atop/atop.mk	2.6.0	**2.6.0** found by distro	0	Link	CVE-2011-3618	`cpe:2.3:a:atop_project:atop:2.6.0:*:*:*:*:*:*:*` CPE identifier unknown in CPE database
package/busybox/busybox.mk	1.33.0	**1.33.1** found by distro	0	Link	N/A	`cpe:2.3:a:busybox:busybox:1.33.0:*:*:*:*:*:*:*` CPE identifier unknown in CPE database

pkg-stats output details



package/attr/attr.mk	2.4.48	2.5.1 found by distro	0	Link	N/A	cpe:2.3:a:attr_project:attr:2.4.48:*:*:*:*:*:*

- some <pkg>_CPE_ID_* variables defined → CPE information verified
- CPE identifier exists in the CPE dictionary
- no known CVEs



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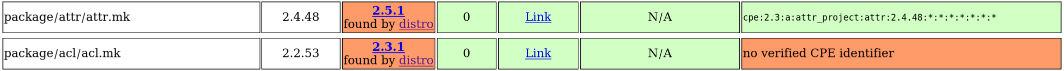

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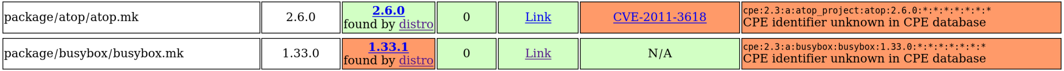
- no `<pkg>_CPE_ID_*` variable → don't know if the default CPE identifier is correct
- based on this default CPE identifier → no known CVE



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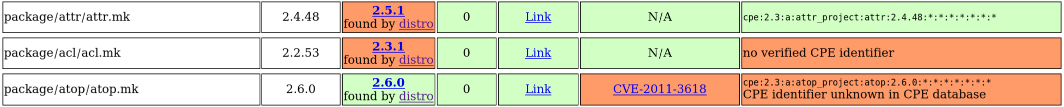

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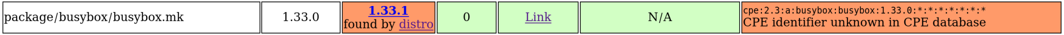
- some `<pkg>_CPE_ID_*` variables defined → CPE information verified
- no entry in CPE dictionary → version 2.6.0 not known by NVD
- CVE-2011-3618 applicable: NVD database indicates it applies to all versions.



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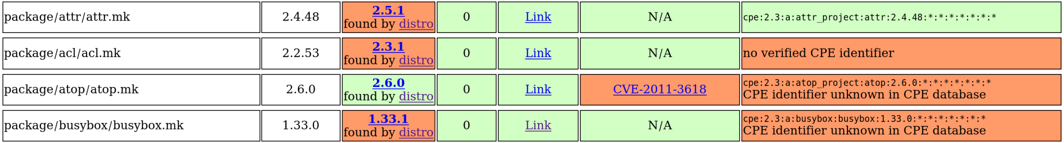

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- no entry in CPE dictionary → version 1.33.0 not known by NVD
- no known CVEs

Security default settings

- Default configuration settings changed to enable more security-hardening features
- *PIC/PIE* (position independent) → needed for some other security features
- *SSP* (Stack Smashing Protection) enabled by default: `-fstack-protector`
- *RELRO* (RELocation Read Only) enabled by default, making additional ELF sections read-only
- *FORTITY_SOURCE* enabled by default, adds additional checks in the C library for buffer overflows

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- Contributions to upstream SELinux refpolicy to make it work with Buildroot

Vendoring support for Go/Rust (1)

- Go and Rust have **language-specific package managers**
- These package managers automatically download the dependencies
  - Described by `go.mod` in Go
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Vendoring support for Go/Rust (1)

- Go and Rust have **language-specific package managers**
- These package managers automatically download the dependencies
  - Described by `go.mod` in Go
  - Described by `Cargo.toml` in Rust
- They break fundamental features of build systems
  - Integration into a download infrastructure: caching, local backup site
  - Legal/license information collection: source code, license files
  - Reproducibility

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- After downloading the main package source code, ability to run custom logic to finalize the download
  - `support/download/go-post-process`
  - `support/download/cargo-post-process`
- Runs the Go or Rust specific tools to retrieve the dependencies
- Makes sure that
  - The tarball contains the full source code, dependencies included
  - The hash used by Buildroot to validate the tarball covers also the dependencies
  - All source code and license files are available in the tarball

Vendoring support for Go

- Existing `golang-package` infrastructure
- Extended to use the *post-download* helper

package/tinifier/tinifier.mk

```
TINIFIER_VERSION = 3.4.0
TINIFIER_SITE = $(call github,tarampampam,tinifier,v$(TINIFIER_VERSION))
TINIFIER_LICENSE = MIT
TINIFIER_LICENSE_FILES = LICENSE
TINIFIER_GOMOD = ./cmd/tinifier

$(eval $(golang-package))
```

Vendoring support for Rust

- Newly added `cargo-package` infrastructure
- Uses a *post-download* helper

package/bat/bat.mk

```
BAT_VERSION = 0.19.0
BAT_SITE = $(call github,sharkdp,bat,v$(BAT_VERSION))
BAT_LICENSE = Apache-2.0 or MIT
BAT_LICENSE_FILES = LICENSE-APACHE LICENSE-MIT

$(eval $(cargo-package))
```

Python changes: Python 2.x removed

- Python 2.x EOL upstream in January 2020
- Kept for some time in Buildroot, marked deprecated, to help migration
- Finally removed in *2022.02*
- Allowed to remove a lot of complexity that was needed to support Python 2.x and Python 3.x in parallel

Python changes: PEP517 build system support

- Standard replacement for `setup.py`
- Uses a `pyproject.toml` file
- For now Buildroot supports `flit` based PEP517 build systems
- Needs `<pkg>_SETUP_TYPE = flit`

package/python-cssselect2/python-cssselect2.mk

```
PYTHON_CSSSELECT2_VERSION = 0.6.0
PYTHON_CSSSELECT2_SOURCE = cssselect2-$(PYTHON_CSSSELECT2_VERSION).tar.gz
PYTHON_CSSSELECT2_SITE = https://files.pythonhosted.org/packages/68/62/[...]
PYTHON_CSSSELECT2_SETUP_TYPE = flit
PYTHON_CSSSELECT2_LICENSE = BSD-3-Clause
PYTHON_CSSSELECT2_LICENSE_FILES = LICENSE

$(eval $(python-package))
```

Significant new packages

- ≈ 290 new packages added between 2020.05 and 2022.05
- GNU Octave
- Tracing: bpftool, uftrace, ply, babeltrace2
- ARM Mali GPU drivers
- Zabbix
- liburing
- WirePlumber
- OpenCV 4
- libvirt
- OpenZFS
- PostGIS
- Additional Qt5 modules: Qt5Knx, Qt5Coap, Qt5Mqtt, Qt5Lottie
- 63 additional Python packages

CI testing improvements

- Already existing
  - **Build-time** testing of semi-random configurations, `autobuild.buildroot.org`
  - Suite of **run-time tests**, `support/testing`, tested in Gitlab CI
  - Defconfigs build tested, and if possible boot tested, in Gitlab CI

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- Improvement
  - Switch to **fully random configurations** for build-time testing
  - Architecture/toolchain config used to be taken from a set of pre-defined config
  - Only package set was randomized
  - Now the full configuration is randomized
  - Allowed to **detect many corner cases**, and fix them
  - Still on-going

Architecture support

- Buildroot already **supports more CPU architectures** than any other build system
  - Synopsys ARC (LE/BE), AArch64 (LE/BE), ARM (LE/BE, including no-MMU Cortex-M), C-SKY, x86 (32-bit/64-bit), m68k, Microblaze (LE/BE), MIPS (32-bit/64-bit, LE/BE), NIOSII, OpenRISC, PowerPC, Power64 (LE/BE), RISC-V (32-bit/64-bit), SuperH, SPARC (32-bit/64-bit), Cadence Xtensa

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- Addition of support for the **S390x** CPU architecture
  - Contributed and maintained directly by IBM

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  - Synopsys ARC (LE/BE), AArch64 (LE/BE), ARM (LE/BE, including no-MMU Cortex-M), C-SKY, x86 (32-bit/64-bit), m68k, Microblaze (LE/BE), MIPS (32-bit/64-bit, LE/BE), NIOSII, OpenRISC, PowerPC, Power64 (LE/BE), RISC-V (32-bit/64-bit), SuperH, SPARC (32-bit/64-bit), Cadence Xtensa
- Addition of support for the **S390x** CPU architecture
  - Contributed and maintained directly by IBM
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- Removal of NDS32 happening soon
  - Follows removal of NDS32 from upstream Linux

Toolchain support

- Two choices in Buildroot for the toolchain/compiler:
  - **Internal toolchain**: Buildroot builds the full toolchain from source, i.e binutils, C library, kernel headers, gcc, gdb
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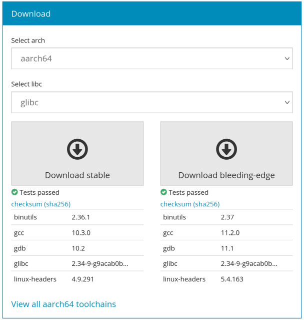
- Improvements
  - **Internal toolchain**: mainly updates to follow the latest upstream release of all components
  - **External toolchain**: main change is the direct support for 198 pre-built toolchains from toolchains.bootlin.com



Download

Select arch: aarch64

Select libc: glibc

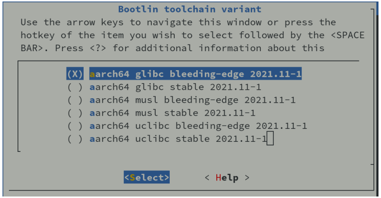
Download stable — ✓ Tests passed — checksum (sha256)

binutils	2.36.1
gcc	10.3.0
gdb	10.2
glibc	2.34-9-g9acab0b...
linux-headers	4.9.291

Download bleeding-edge — ✓ Tests passed — checksum (sha256)

binutils	2.37
gcc	11.2.0
gdb	11.1
glibc	2.34-9-g9acab0b...
linux-headers	5.4.163

View all aarch64 toolchains



```
                    Bootlin toolchain variant
 Use the arrow keys to navigate this window or press the
 hotkey of the item you wish to select followed by the <SPACE
 BAR>. Press <?> for additional information about this

            (X) aarch64 glibc bleeding-edge 2021.11-1
            ( ) aarch64 glibc stable 2021.11-1
            ( ) aarch64 musl bleeding-edge 2021.11-1
            ( ) aarch64 musl stable 2021.11-1
            ( ) aarch64 uclibc bleeding-edge 2021.11-1
            ( ) aarch64 uclibc stable 2021.11-1

                   <Select>      < Help >
```

Buildroot training course

- Bootlin has a full training course on Buildroot
- Taught by your speaker
- Training materials are freely available
    - Like for all Bootlin training courses
- Next public on-line course September 5-9, 2022

Online training course
Embedded System Development with Buildroot

bootlin
Embedded Linux and kernel engineering

https://bootlin.com/training/buildroot/

Questions? Suggestions? Comments?

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thomas.petazzoni@bootlin.com

https://bootlin.com/pub/conferences/2022/elc/petazzoni-buildroot-whats-new/