Embedded Linux development with Buildroot training

On-site training, 3 days

Latest update: May 20, 2024

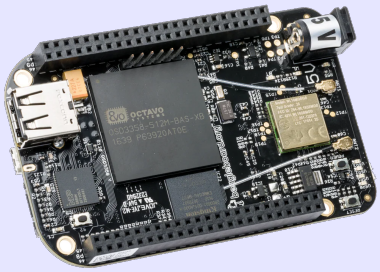
Title	**Embedded Linux development with Buildroot training**
Training objectives	• Be able to understand the role and principle of an embedded Linux build system, and compare Buildroot to other tools offering similar functionality. • Be able to create a simple embedded Linux system with Buildroot: create a configuration, run the build, install the result on an embedded platform. • Be able to adjust the Buildroot configuration to build an embedded Linux system tailored to specific needs: choice of the cross-compilation toolchain, management of the Linux kernel configuration, customization of the root filesystem contents, etc. • Be able to create new packages in Buildroot to integrate additional applications and libraries into the embedded Linux system. • Be able to use the tools offered by Buildroot to manage and analyze the build: security vulnerability tracking, license compliance, etc. • Be able to develop and debug Linux user-space applications in the context of Buildroot. • Be able to interact with the Buildroot open-source community, and to understand the internals of Buildroot.
Duration	**Three** days - 24 hours (8 hours per day)
Pedagogics	• Lectures delivered by the trainer: 40% of the duration • Practical labs done by participants: 60% of the duration • Electronic copies of presentations, lab instructions and data files. They are freely available at https://bootlin.com/doc/training/buildroot.
Trainer	One of the engineers listed on: `https://bootlin.com/training/trainers/`
Language	Oral lectures: English, French. Materials: English.
Audience	Companies already using or interested in using Buildroot to build their embedded Linux systems.

Prerequisites	• **Knowledge and practice of UNIX or GNU/Linux commands**: participants must be familiar with the Linux command line. Participants lacking experience on this topic should get trained by themselves, for example with our freely available on-line slides at bootlin.com/blog/command-line/. • **Minimal experience in embedded Linux development**: participants should have a minimal understanding of the architecture of embedded Linux systems: role of the Linux kernel vs. user-space, development of Linux user-space applications in C. Following Bootlin's *Embedded Linux* course at bootlin.com/training/embedded-linux/ allows to fulfill this pre-requisite. • **Minimal English language level: B1**, according to the *Common European Framework of References for Languages*, for our sessions in English. See bootlin.com/pub/training/cefr-grid.pdf for self-evaluation.
Required equipment	• Video projector • One PC computer on each desk (for one or two persons) with at least 8 GB of RAM, and Ubuntu Linux 22.04 installed in a **free partition of at least 30 GB** • Distributions other than Ubuntu Linux 22.04 are not supported, and using Linux in a virtual machine is not supported. • **Unfiltered and fast connection to Internet**: at least 50 Mbit/s of download bandwidth, and no filtering of web sites or protocols. • **PC computers with valuable data must be backed up** before being used in our sessions.
Certificate	Only the participants who have attended all training sessions, and who have scored over 50% of correct answers at the final evaluation will receive a training certificate from Bootlin.
Disabilities	Participants with disabilities who have special needs are invited to contact us at *training@bootlin.com* to discuss adaptations to the training course.

Hardware platform for practical labs, option #1

BeagleBone Black board

- An ARM AM335x (single Cortex-A8) processor from Texas Instruments
- USB powered
- 512 MB of RAM
- 2 or 4 GB of on-board eMMC storage
- USB host and device
- HDMI output
- 2 x 46 pins headers, to access UARTs, SPI buses, I2C buses and more.



Hardware platform for practical labs, option #2

STMicroelectronics STM32MP157D Discovery Kit 1 board

- STM32MP157D (dual Cortex-A7) processor from STMicroelectronics
- USB powered
- 512 MB DDR3L RAM
- Gigabit Ethernet port
- 4 USB 2.0 host ports
- 1 USB-C OTG port
- 1 Micro SD slot
- On-board ST-LINK/V2-1 debugger
- Arduino compatible headers
- Audio codec, buttons, LEDs

Day 1 - Morning

Lecture - Embedded Linux and build system introduction

- The general architecture of an embedded Linux system
- Build systems vs. binary distributions
- Role of a build system
- Comparison of existing build systems

Lecture - Introduction to Buildroot

- Key facts about the project
- Getting Buildroot
- Basic configuration of Buildroot
- Doing a first build

Lab - Basic Buildroot usage

- Getting and setting up Buildroot
- Configuring and building a basic system with Buildroot for an embedded platform
- Flash and test the generated system on the embedded platform

Lecture - Managing the build and configuration

- Out of tree build
- Using and creating *defconfigs*
- Defconfig fragments
- Other building tips

Day 1 - Afternoon

Lecture - Buildroot source and build trees

- Details about the Buildroot source code organization
- Details about the Buildroot build tree

Lecture - Toolchains in Buildroot

- The different choices for using toolchains in Buildroot
- Overview of the toolchain options
- Using existing binary toolchains, such as Bootlin toolchains, understanding *multilib* capabilities and integration of toolchains in Buildroot
- Generating custom toolchains with *Crosstool-NG*, and re-use them as external toolchains

Lecture - Managing the Linux kernel configuration

- Loading, changing and saving the kernel configuration

Lecture - Root filesystem construction in Buildroot

- Understand how Buildroot builds the root filesystem: *skeleton*, installation of packages, overlays, *post-build* and *post-image* scripts.
- Customization of the root filesystem contents
- System configuration: *console* selection, various `/dev` management methods, the different `init` implementations, etc.
- Understand how Buildroot generates filesystem images

Lab - Root filesystem customization

- Explore the build output
- Customize the root filesystem using a *rootfs overlay*
- Customize the kernel with patches and additional configuration options
- Add more packages
- Use *defconfig* files and *out of tree* build

Day 2 - Morning

Lecture - Download infrastructure in Buildroot

- Downloading logic
- Primary site and backup site, doing offline builds
- VCS download, integrity checking
- Download-related *make* targets

Lecture - GNU Make 101

- Basics of make rules
- Defining and referencing variables
- Conditions, functions
- Writing recipes

Lecture - Integrating new packages in Buildroot

- How to integrate new packages in the Buildroot configuration system
- Understand the different package infrastructures: for *generic*, *autotools*, *CMake*, *Python* packages and more.
- Writing a package `Config.in` file: how to express dependencies on other packages, on toolchain options, etc.
- Details on writing a package recipe: describing the package source code location, download method, configuration, build and installation steps, handling dependencies, etc.

Lab - New packages in Buildroot

- Create a new package for *nInvaders*
- Understand how to add dependencies
- Add patches to *nInvaders* for *Nunchuk* support

Day 2 - Afternoon

Lecture - Advanced package aspects

- Licensing report
- Patching support: patch ordering and format, global patch directory, etc.
- User, permission, device tables
- Init scripts and systemd unit files
- Config scripts
- Understanding *hooks*
- Overriding commands
- Legacy handling
- Virtual packages

Lab - Advanced packages

- Package an application with a mandatory dependency and an optional dependency
- Package a library, hosted on GitHub
- Use *hooks* to tweak packages
- Add a patch to a package

Day 3 - Morning

Lecture - Analyzing the build: licensing, dependencies, build time

- Usage of the legal information infrastructure
- Graphing dependencies of packages
- Collecting and graphing build time information

Lecture - Advanced topics

- `BR2_EXTERNAL` to store customizations outside of the Buildroot sources
- Package-specific targets
- Understanding rebuilds
- Tips for building faster

Lab - Advanced aspects

- Use build time graphing capabilities
- Use dependency graphing capabilities
- Use licensing report generation, and add licensing information to your own packages
- Use `BR2_EXTERNAL`

Day 3 - Afternoon

Lecture - Application development with Buildroot

- Using Buildroot during application development
- Usage of the Buildroot environment to build applications outside of Buildroot
- Generate an SDK for other developers
- Remote debugging with Buildroot

Lab - Application development with Buildroot

- Build and run your own application
- Remote debug your application
- Use `<pkg>_OVERRIDE_SRCDIR`

Lecture - Understanding Buildroot internals

- Detailed description of the Buildroot build process: toolchain, packages, root filesystem construction, stamp files, etc.
- Understanding virtual packages.

Lecture - Getting support and contributing

- Getting support: *Bugzilla*, *mailing list*, *IRC*
- Contributing: understanding the development process, how to submit patches