Embedded Linux Conference Europe 2017

Buildroot: what's new?

Thomas Petazzoni
Free Electrons
thomas.petazzoni@free-electrons.com

Free Electrons

Embedded Linux
Developers

Thomas Petazzoni

- CTO and Embedded Linux engineer at **Free Electrons**
  - Embedded Linux specialists.
  - Development, consulting and training.
  - `http://free-electrons.com`
- Contributions
  - **Kernel support for the Marvell Armada** ARM SoCs from Marvell
  - Major contributor to **Buildroot**, an open-source, simple and fast embedded Linux build system
- **Toulouse**, south west of France
- Windsurfing, snowboarding

Poll time

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- Who is already using Buildroot ?
- Who is using OpenEmbedded / Yocto Project ?
- Who is using OpenWRT / LEDE ?
- Who is using another build system ?

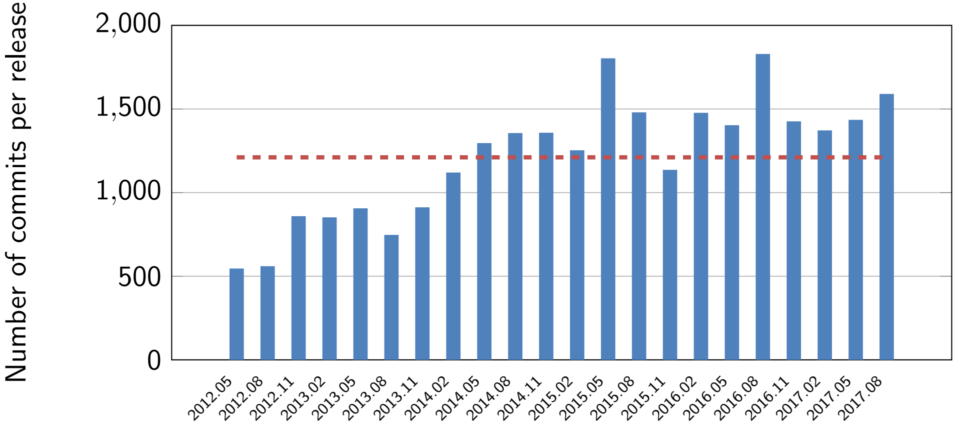
Buildroot at a glance

- Is an **embedded Linux build system**, builds from source:
  - cross-compilation toolchain
  - root filesystem with many libraries/applications, cross-built
  - kernel and bootloader images
- **Fast**, simple root filesystem in minutes
- **Easy** to use and understand: kconfig and make
- **Small** root filesystem, default 2 MB
- More than **2200 packages** available
- Generates filesystem images, not a distribution
- Vendor neutral
- Active community, stable releases every 3 months
- Started in 2001, oldest still maintained build system
- `http://buildroot.org`

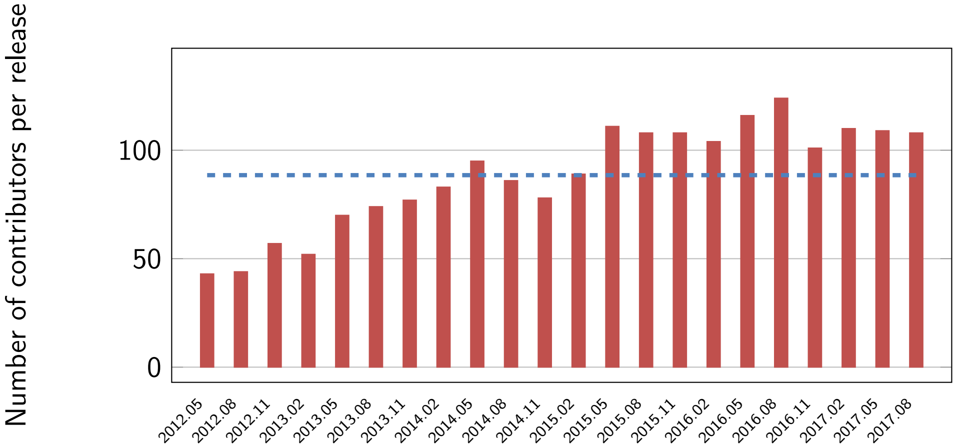
What's new?

- Last *What's new* talk at the *Embedded Linux Conference 2014*, i.e 3.5 years ago
- Lots of things have changed and improved in Buildroot since then, time for a new *What's new* talk!
- Main topics discussed
  - Project activity
  - Release schedule and LTS
  - Architecture support
  - Toolchain support
  - Infrastructure improvements
  - Testing improvements
  - Misc

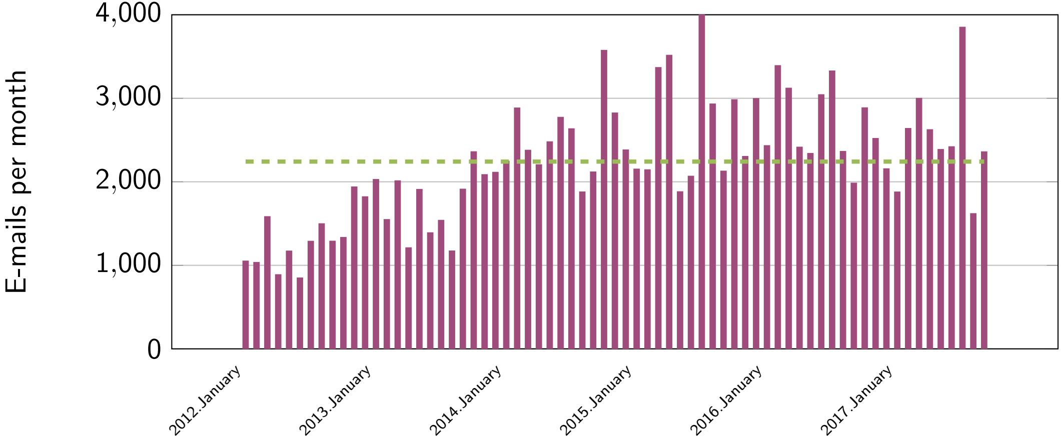
Project activity: per commits



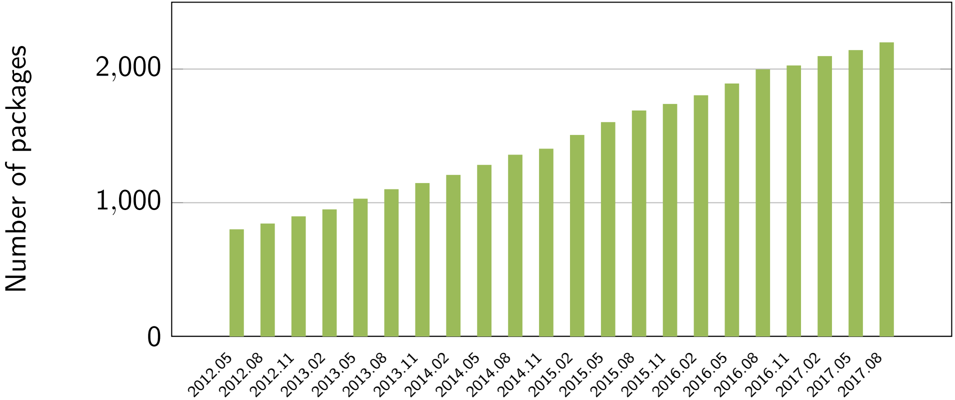
Project activity: contributors



Project activity: mailing list activity



Project activity: packages



Release schedule and LTS

- Since 2009, releases every **three months**: YYYY.02, YYYY.05, YYYY.08, YYYY.11
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- Since 2017.02: **LTS release**
  - Every YYYY.02 release will be **maintained for one year**, with security, build and bug fixes
  - Already did **6 point releases** for 2017.02, from 2017.02.1 to 2017.02.6: April, May, June, July (x2), September.
  - 526 commits, including **183 commits for security** updates/fixes
  - Effort done by Peter Korsgaard

Maintenance and physical meetings

- Used to have a single committer/project maintainer: Peter Korsgaard
- **Two additional committers** have been appointed in recent years:
  - Thomas Petazzoni (i.e, me)
  - Arnout Vandecappelle
- **Physical meetings**
  - One meeting before ELCE, was held last Saturday/Sunday
  - One meeting after FOSDEM, Brussels
  - One more private hackaton for the core team in the summer

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  - ARC, ARM(eb,nommu), ARM64(eb), Blackfin, C-Sky, m68k, Microblaze(el), mips(64)(el), nios2, OpenRISC, PowerPC(64)(le), SuperH, Sparc(64), x86(_64), Xtensa

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- **ARM Cortex M3/M4 noMMU** support
- Merge of **ARM/ARM64** options, to select ARM64 cores
- **PowerPC64 little endian and big endian** support, contributions from IBM
- **MIPS improvements**: MIPS32r6 and MIPS64r6 support, MIPS core selection, NaN/FP32 selection, contributions from Imagination Technologies
- **OpenRISC**, **C-Sky**, **Sparc64** support
- Re-enabling of **m68k** both Coldfire (noMMU) and 68k (MMU)
- **Blackfin** and **Microblaze** improved with uClibc-ng support
- SH64 and AVR32 support removed

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- Internal toolchain improvements
  - Support for **musl** C library added
  - Moved from uClibc to **uClibc-ng**
  - **Regular updates**: gcc up to 7.x (default is 6.x), binutils 2.29 (default 2.28), gdb 8.0 (default 7.12), glibc 2.26, uClibc-ng 1.0.26, musl 1.1.16.
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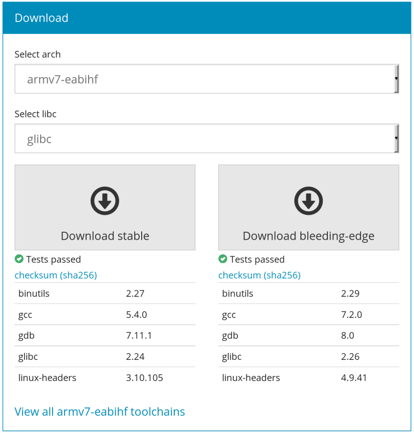
  - **LTO** and **Fortran** support
  - Toolchain **wrapper** also used for the internal back-end: allows sanity checks
  - eglibc removed
- External toolchain improvements
  - Logic split in **multiple packages**, one per external toolchain family
  - Include/library paths **sanity checking** in the wrapper
  - Numerous **updates**: Linaro/Sourcery toolchains, new Imagination Technologies toolchains, removed old toolchains

toolchains.free-electrons.com

- Side project, but Buildroot related
- Freely available **pre-built toolchains** for a wide range of architectures and configurations
- **34 different architecture**/variants
- glibc/uClibc-ng/musl, as available
- Two versions: stable and bleeding-edge
- Built by Buildroot, on Gitlab CI
- **Tested** by building a Linux kernel and minimal userspace, and if supported, booting under QEMU
- `http://toolchains.free-electrons.com`



Download

Select arch: armv7-eabihf

Select libc: glibc

Download stable

✓ Tests passed

checksum (sha256)

binutils	2.27
gcc	5.4.0
gdb	7.11.1
glibc	2.24
linux-headers	3.10.105

Download bleeding-edge

✓ Tests passed

checksum (sha256)

binutils	2.29
gcc	7.2.0
gdb	8.0
glibc	2.26
linux-headers	4.9.41

View all armv7-eabihf toolchains

Infrastructure: relocatable SDK

- `output/host` contains
  - The native tools, including the cross-compiler
  - The toolchain *sysroot*, with all libraries and headers
- Can be used as an SDK
  - Allows application developers to build applications targeting the root filesystem without having to use Buildroot
- `output/host` is now **relocatable**, which makes it easier to use as an SDK
- `make sdk` prepares the SDK
  - Replaces absolute *RPATH* in native binaries by relative ones
  - Installs a `relocate-sdk.sh` script that users of the SDK must run to fix up the remaining absolute paths
- Related work:
  - `output/host/usr/*` moved to `output/host/`
  - *RPATH* in target binaries are now cleaned up

Infrastructure: hashes

- Each package now has a `<pkg>.hash` file that contains hashes
  - For the tarball being downloaded
  - For the patches being downloaded, if any
  - For the license files included in the upstream source code
- Tarball/patch hashes are checked when the package is extracted, i.e at every build
- License files hashes are checked when generating the licensing report (`make legal-info`)
- Allows
  - check the integrity of what is downloaded,
  - ensure that tarballs stored locally have not been modified
  - detect if license terms are changed upstream
  - detect if upstream messes up and re-uploads a new (but different) tarball
- Almost all packages have a hash file now: 2166 packages out of 2232 packages

```
# Verified from http://ftp.isc.org/isc/bind9/9.11.1-P3/bind-9.11.1-P3.tar.gz.sha256.asc
sha256 52426e75432e46996dc90f24fca027805a341c38fbbb022b60dc9acd2677ccf4 bind-9.11.1-P3.tar.gz
sha256 d3906dfe153e2c48440d3ca1d5319f5e89b4b820cdfc5d0779c23d7ac2b175e9 COPYRIGHT
```

Infrastructure: licensing report

- Packages include a description of the license and paths to license files

```
DBUS_LICENSE = AFL-2.1 or GPL-2.0+ (library, tools), GPL-2.0+ (tools)
DBUS_LICENSE_FILES = COPYING
```

- Collected by `make legal-info`: source tarballs, patches, license files, manifests
- Improvements
  - **SPDX license codes** used to describe the licensing of all packages
  - **Hashes** added for license files, in order to detect changes
  - Storage of source code for binary artifacts such as pre-built toolchains, using `<pkg>_ACTUAL_SOURCE`
  - Many **more packages have license details**: 2143 out of 2232 packages

Infrastructure: BR2_EXTERNAL

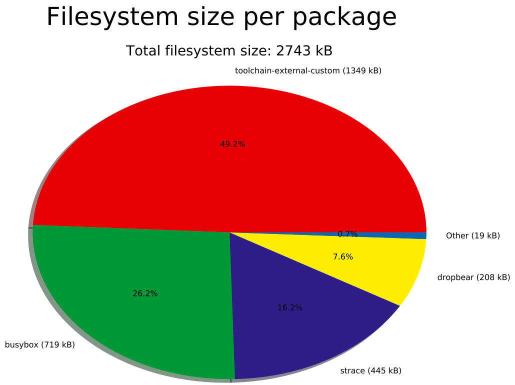
- BR2_EXTERNAL allows to implement packages, store *defconfigs* and other build-related files outside of the Buildroot tree
- Allows separating the upstream Buildroot from project/company-specific packages and data
- Simplified form of *layer* concept found in Yocto/OE/OpenWRT
- Available since 2014.02
- Improvements
  - Support for multiple BR2_EXTERNAL directories
  - Support for implementing bootloader packages and filesystem image formats in BR2_EXTERNAL

Infrastructure: package infrastructures

- Base infrastructure: `generic-package`
- Specialized infrastructures for specific build systems: `autotools-package`, `cmake-package`, `python-package`
- Improvements
  - `python-package` extended to support Python 3.x
  - New `perl-package` infrastructure for **Perl** packages
  - New `virtual-package` infrastructure for **virtual** packages such as OpenGL, jpeg, udev
  - New `waf-package` infrastructure for **Waf** based packages
  - New `rebar-package` infrastructure for **Erlang** packages
  - New `kconfig-package` infrastructure, used by Linux, BusyBox, uClibc-ng, Barebox, U-Boot, etc.
  - New `kernel-module` infrastructure to help building kernel modules

Infrastructure: graphing

- Already existing:
  - `make graph-depends`, `make <pkg>-graph-depends`, to generate dependency graphs
  - `make graph-build`, graph of the build time per package
- Improvements
  - `make graph-size`, size of the filesystem, split by package
  - `make <pkg>-graph-rdepends`, graph of the reverse dependencies



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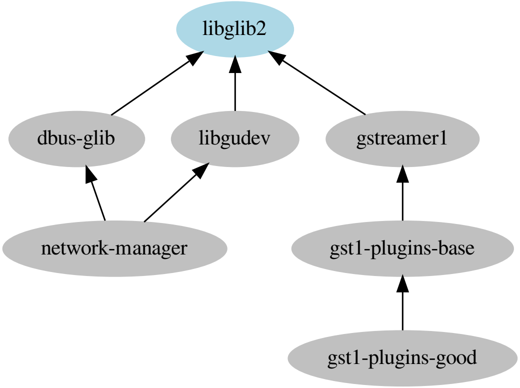


Infrastructure: *skeleton* restructuring

- **Skeleton**: base of the root filesystem, main directory hierarchy and basic config files
- Initially a single set of files copied to `TARGET_DIR` at the beginning of the build
- Now:
  - `skeleton` is a virtual package, that depends on `skeleton-init-sysv`, `skeleton-init-systemd`, `skeleton-init-none` or `skeleton-custom`
  - Common base: `skeleton-init-common`
  - Core init scripts moved in `initscripts`
  - Allows to avoid SysV cruft in systemd systems and vice-versa
  - Allowed to implement read-only rootfs support with *systemd*
  - Support for merged `/usr`, used by *systemd* support

Filesystem support

- Support for generating filesystem images in a large number of formats
- Improvements
  - `ext2`, `ext3` and `ext4` images now generated by `mkfs.ext<X>` instead of `genext2fs`, to better support ext3/ext4
  - Support for AXFS added
  - ISO9660 support re-written, to support Grub2 and Isolinux as bootloaders, initramfs and pure ISO9660 scenarios
  - Usage of *genimage* to generate complete SD card/MMC images in many *defconfigs*
  - Ability to specify a custom script to run within the *fakeroot* environment when creating filesystem images

Reproducible builds

- Idea: get binary identical results for repeated builds of a given configuration
- Option `BR2_REPRODUCIBLE` added
- Various things already fixed:
  - Sets `SOURCE_DATE_EPOCH`, used by gcc and various packages
  - Date/time of files in the filesystem
  - Build date, user, host name in the Linux kernel build and BusyBox
  - Remove timestamps in Python `.pyc` files
  - ...
- A lot more remains to be done. Unfortunately, the developers who started this work are no longer active.

Packages

- By far where most of the contributions go: updating existing packages and adding new packages
- Almost **1000 packages** added between 2014.05 and 2017.08
- Significant updates/additions
  - SELinux support
  - Qt 5.9 (including Qt WebEngine), Gtk 3.x, EFL updates
  - OpenCV 3.0
  - Kodi
  - Go, Mono
  - Python modules (many!), Perl modules, Erlang modules
  - Docker, aufs
  - System upgrade: SWupdate, RAUC
  - HW support: AMD Catalyst, Freescale i.MX, NVidia, TI
  - Apache, ClamAV, Dovecot, MariaDB, Nginx
  - Glib C++ stack: glibmm, atkmm, cairomm, gtkmm, etc.
  - ... and SuperTuxKart!

Testing: runtime testing infrastructure

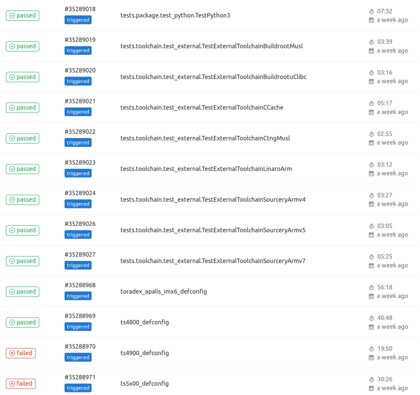
- Run-time test infrastructure added in `support/testing/`
- Test cases written in Python
- Build a given Buildroot configuration, boot under QEMU, run commands and check results
- Tests for filesystem images, packages, core functionality, init systems

```
class TestDropbear(infra.basetest.BRTest):
    config = infra.basetest.BASIC_TOOLCHAIN_CONFIG + \
        """
        BR2_SYSTEM_DHCP="eth0"
        BR2_PACKAGE_DROPBEAR=y
        BR2_TARGET_ROOTFS_CPIO=y
        # BR2_TARGET_ROOTFS_TAR is not set
        """

    def test_run(self):
        img = os.path.join(self.builddir,"images","rootfs.cpio")
        self.emulator.boot(arch="armv5",
                           kernel="builtin",
                           options=["-initrd", img,
                                    "-net", "nic"])
        self.emulator.login("testpwd")
        cmd = "netstat -ltn 2>/dev/null | grep 0.0.0.0:22"
        _, exit_code = self.emulator.run(cmd)
        self.assertEqual(exit_code, 0)
```

Testing: CI

- Already existing: http://autobuild.buildroot.org
  - Set of 50 architecture/toolchain configurations
  - Choose a random architecture/toolchain configuration, a random selection of packages, and build
  - Results reported on a Web page, e-mailed to the mailing list
- Improvements
  - All **defconfigs** are built on *Gitlab CI*
  - **Run-time tests** are executed on *Gitlab CI*
  - Preparation on autobuild.b.o to support **testing multiples branches** (master, next, LTS)
  - Notifications from autobuild.b.o sent to relevant developers



✓ passed	#35289018 triggered	tests.package.test_python.TestPython3	07:32 a week ago
✓ passed	#35289019 triggered	tests.toolchain.test_external.TestExternalToolchainBuildrootMusl	03:39 a week ago
✓ passed	#35289020 triggered	tests.toolchain.test_external.TestExternalToolchainBuildrootuClibc	03:16 a week ago
✓ passed	#35289021 triggered	tests.toolchain.test_external.TestExternalToolchainCCache	05:17 a week ago
✓ passed	#35289022 triggered	tests.toolchain.test_external.TestExternalToolchainCtngMusl	02:55 a week ago
✓ passed	#35289023 triggered	tests.toolchain.test_external.TestExternalToolchainLinaroArm	03:12 a week ago
✓ passed	#35289024 triggered	tests.toolchain.test_external.TestExternalToolchainSourceryArmv4	03:27 a week ago
✓ passed	#35289026 triggered	tests.toolchain.test_external.TestExternalToolchainSourceryArmv5	03:05 a week ago
✓ passed	#35289027 triggered	tests.toolchain.test_external.TestExternalToolchainSourceryArmv7	05:25 a week ago
✓ passed	#35288968 triggered	toradex_apalis_imx6_defconfig	56:18 a week ago
✓ passed	#35288969 triggered	ts4800_defconfig	40:48 a week ago
⊗ failed	#35288970 triggered	ts4900_defconfig	19:50 a week ago
⊗ failed	#35288971 triggered	ts5x00_defconfig	30:26 a week ago

Tooling

- DEVELOPERS file and associated get-developers tool
  - Much like MAINTAINERS in the Linux kernel
  - Used when sending patches
  - Used to report build failures per package or per-architecture to the relevant developers
- check-package script to detect obvious mistakes in packages
- test-pkg to build test a package with a large number of architecture/toolchain configurations
- scanpypi script to generate Python packages
  - Connects to *Pypi*, analyzes the metadata, and produces a Buildroot *package*

DEVELOPERS

```
N:      Waldemar Brodkorb <wbx@openadk.org>
F:      arch/Config.in.bfin
F:      arch/Config.in.m68k
F:      arch/Config.in.or1k
F:      arch/Config.in.sparc
F:      package/glibc/
F:      package/mksh/
F:      package/uclibc/
F:      package/uclibc-ng-test/
```

test-pkg

```
  armv5-ctng-linux-gnueabi [ 1/49]: OK
armv7-ctng-linux-gnueabihf [ 2/49]: OK
          br-aarch64-glibc [ 3/49]: OK
             br-arcle-hs38 [ 4/49]: SKIPPED
              br-arm-basic [ 5/49]: OK
    br-arm-cortex-a9-glibc [ 6/49]: OK
               ...........

       49 builds, 27 skipped,
       0 build failed, 0 legal-info failed
```

Misc improvements

- **Linux extensions** infrastructure, to support building packages that need kernel patching: Xenomai, RTAI, specific drivers
- **Linux tools** infrastructure, to build user-space tools part of the kernel tree: *perf*, *gpio*, *iio*, *cpupower*, *tmon*, *self-tests*
- Complete revamp of the *gettext* handling, option `BR2_SYSTEM_ENABLE_NLS` to control native language support
- Checks on the architecture of cross-compiled binaries, to detect packages that do not cross-compile to the correct architecture

Features on the radar

- Git download cache
  - Avoid re-cloning an entire Git repository every time the version/tag of a Git-fetched package is changed
- Per-package out of tree build
  - Avoids *rsync* when using *local* packages or `<pkg>_OVERRIDE_SRCDIR` and improves debugging experience
  - Avoids extracting the source code twice when building host and target variants
- Top-level parallel build
  - Building different packages in parallel
  - Requires per-package staging and host directories
- *Go* and *Meson* package infrastructures

Conclusion

- Active project
- LTS releases with security updates
- Relocatable SDK
- Rich and up-to-date package set
- Good and increasing testing effort
- Interesting new features on the roadmap

Questions? Suggestions? Comments?

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http://free-electrons.com/pub/conferences/2017/elce/petazzoni-buildroot-whats-new/