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and LIfE Sciences

Politecnico
di Torino

Department of Control and
Computer Engineering

DAUIN

CUSTOM LINUX SYSTEMS

STEFANO DI CARLO

WHAT IS CUSTOM EMBEDDED LINUX ?

- A **tailored** Linux OS specifically designed for embedded systems
- Optimized for efficiency and built for **purpose**

- Key Characteristics
  - **Optimized Footprint**
    (Minimal resource usage)
  - **Hardware-Specific**
    (Built for the target hardware architecture like ARM)
  - **Feature-Centric**
    (Contains only the drivers, libraries, and apps needed)
  - **Secure and Stable**
    (Designed to enhance security and ensure reliability)

REAL-WORLD EXAMPLES

- IoT (Internet of Things)
- Automotive
- Industrial Automation
- Consumer Electronics
- Healthcare

- Why Use Linux for These Devices?
  - **Cost Efficiency**: Open-source nature lowers development costs
  - **Customizability**: Tailored for each use case.
  - **Hardware Optimization**: Ensures efficient use of system resources.
  - **Security**: Configurable to meet industry-specific compliance standards.

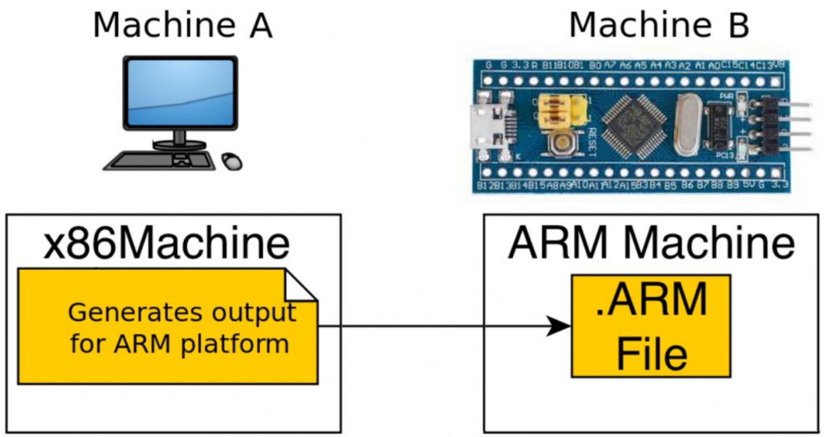
KEY ELEMENTS OF EMBEDDED LINUX SYSTEMS

- An embedded Linux system is built from several essential components, each playing a critical role in **booting**, **running**, and enabling the specific functionality of the device.

- The 4 Core Elements of Embedded Linux
  - Toolchain
  - bootloader
  - kernel
  - Root files
- one more element can be domain specific application

TOOLCHAIN

- A **toolchain** is a set of tools that allows developers to build, debug, and deploy software for embedded Linux systems. It is essential for creating binaries that run on the target device.



- Key Components of a Toolchain
  - Cross-Compiler

    Converts source code into executable binaries for the target hardware architecture (e.g., ARM, MIPS, x86).
  - Linker
  - Assembler
  - Libraries
  - Debugger
  - Build System

    Automates the process of compiling and linking.

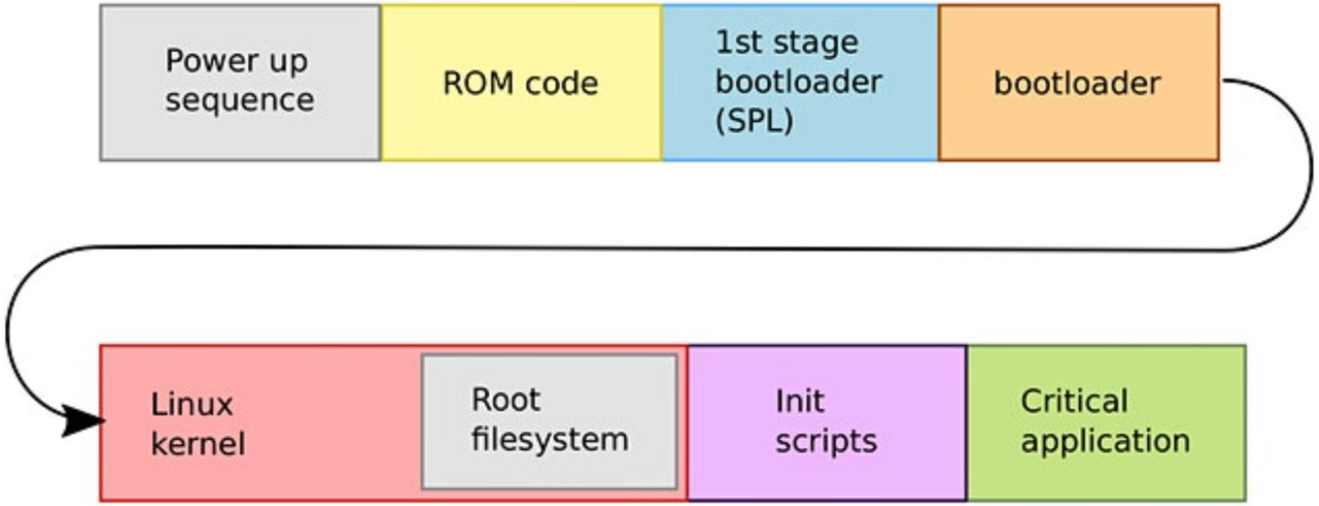
BOOTLOADER

- A **bootloader** is a small program that runs before the operating system kernel and is responsible for initializing hardware and loading the kernel into memory.
- Key functions
  - Hardware Initialization
  - Kernel Loading
  - System Configuration
  - Optional Features

- Examples of Common Bootloaders
  - U-Boot (Universal Bootloader)
    - Most widely used in embedded Linux.
    - Highly customizable and supports a wide range of architectures.
  - GRUB (GRand Unified Bootloader)
    - More common in desktops but supports embedded use cases.
    - Advanced configuration options.
  - Barebox
    - Lightweight and fast bootloader for embedded systems.

BOOTLOADER (CONT.)

- Bootloader Phases
  - Stage 1 (Primary Bootloader)
    - Minimal functionality to initialize hardware and load the secondary bootloader.
  - Stage 2 (Secondary Bootloader)
    - Loads and executes the Linux kernel with a full set of configurations.



KERNEL

- The **kernel** is the heart of an embedded Linux system, acting as the **bridge** between the hardware and software. It manages resources and ensures that the system runs smoothly and efficiently.
  - System Resource Management
  - Hardware Abstraction
  - Process Scheduling

- Key Components of a kernel
  - Device Drivers

    Drivers for various hardware components (e.g., sensors, displays, network interfaces).Linker
  - Networking Stack
  - File System Support
  - Customizability

    Non-essential features and drivers can be removed to optimize size and performance.

ROOT FILESYSTEM

- Directory structure that contains all the files, libraries, binaries, and configuration files needed for the system to function.
- Typically mounted at the root (/) of the device and is the foundation for the Linux operating system.
- contains the files necessary for booting the system and providing user-level functions.

- Key Components of Root Filesystem
  - Libraries
  - Binaries
  - Configuration Files
- The root filesystem can be customized to include only the **necessary components** for the embedded device, optimizing **memory** and **storage** usage.

DOMAIN-SPECIFIC APPLICATIONS (OPTIONAL ELEMENT)

- Applications designed and developed for the specific function or industry of an embedded device.
- Purpose
  - Implement Device Functionality
  - Optimized for Performance

- Key Components
  - Tailored to Specific Needs
    - highly customized to suit the exact requirements of the industry, ensuring optimal performance and reliability.
  - Integration with Kernel
    - integrated directly with kernel-level features, such as device drivers and network stacks.

EMBEDDED LINUX BUILD TOOLS

- Building a custom embedded Linux system requires robust tools that **simplify** the process of **configuring**, **building**, and **deploying** the system.
- Buildroot is a popular tool in this space, offering simplicity and flexibility for embedded Linux development.

- Key features
  - Minimalistic Approach
  - Fast Build Times
  - Cross-Compilation Support
  - Extensive Configuration Options

HOW BUILDROOT WORKS

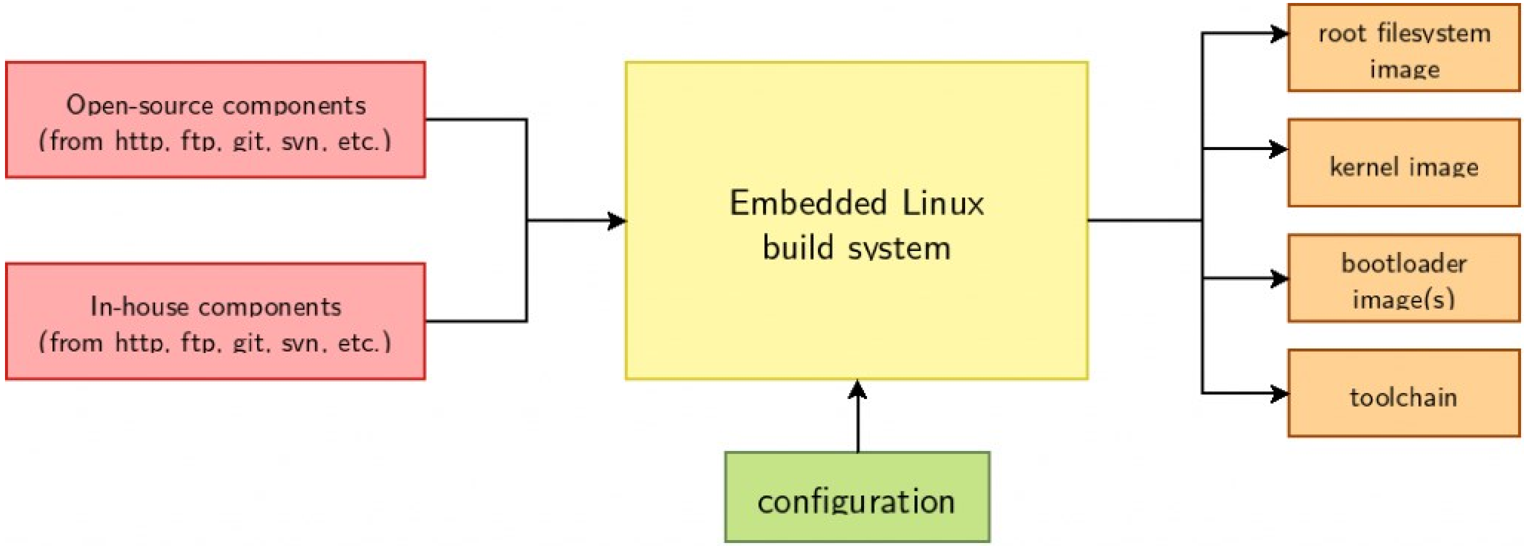
- Buildroot is a set of **Makefiles** designed to simplify the process of building custom Linux-based embedded systems. It automates the downloading, configuration, compilation, and **integration** of software packages into a functional system image.

- Each directory in Buildroot contains at least two files:
  - **something.mk:** The Makefile that downloads, configures, compiles, and installs a package.
  - **Config.in:** Describes configuration options for the package.

- Key Components/Directories of Buildroot
  - **Toolchain:** Makefiles for building the cross-compilation toolchain
  - **Arch:** definitions for processor architectures supported by Buildroot (e.g., ARM)
  - **Package:** Makefiles for user-space tools and libraries to be compiled and added to the target root filesystem
  - **Boot:** Manages the Makefiles and files for the supported bootloaders (e.g., U-Boot)
  - **System:** Provides support for system integration (e.g., target filesystem skeleton, init system)
  - **Fs:** files related to the generation of the target root filesystem image

BUILDROOT WORKFLOW

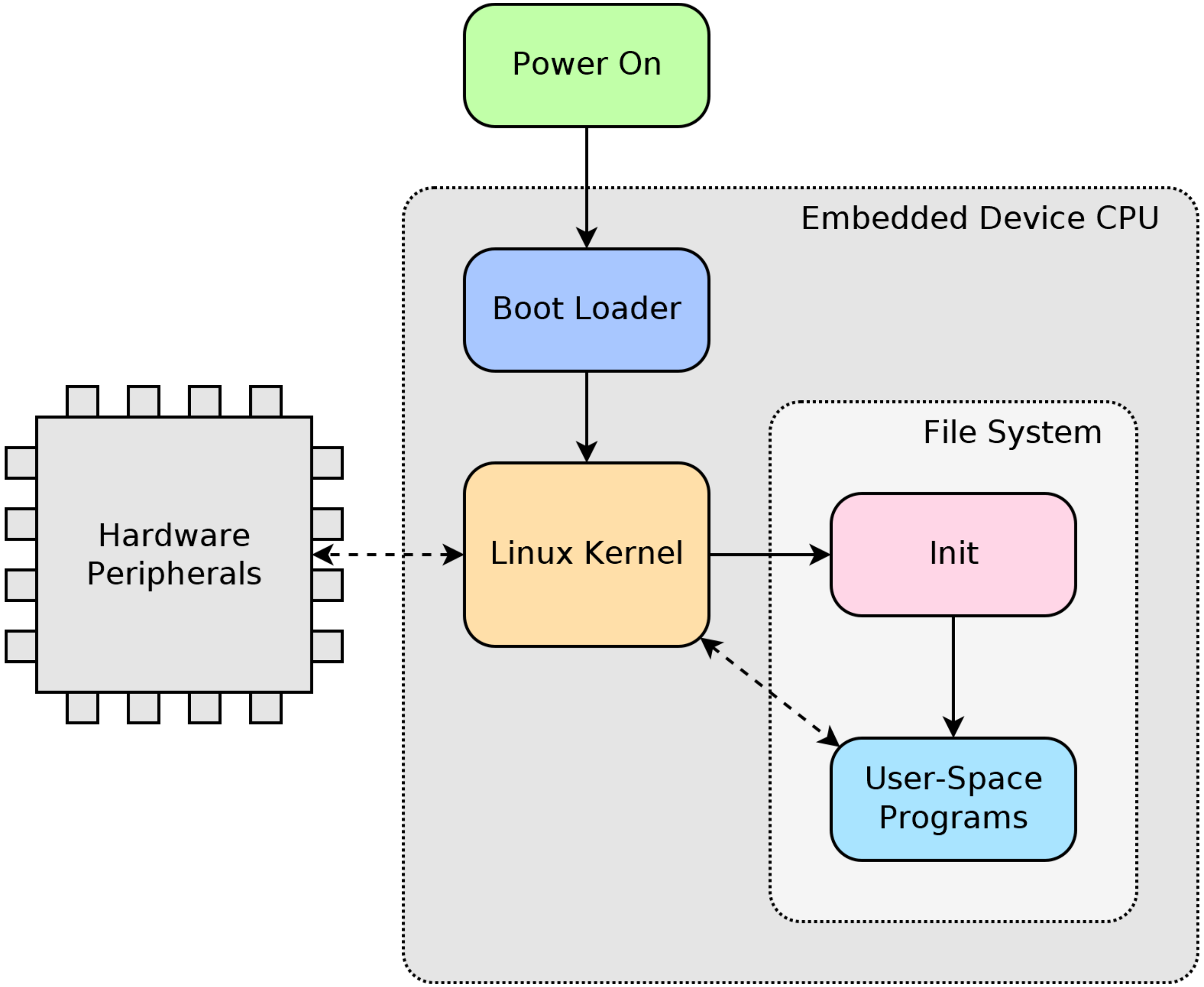
- **Input Data:** Configuration files and package selections.
- **Output Product:** A fully built Linux-based embedded system, including the Linux kernel, root filesystem, bootloader, and device tree, ready for deployment on the target hardware.



Open-source components (from http, ftp, git, svn, etc.)
In-house components (from http, ftp, git, svn, etc.)
Embedded Linux build system
configuration
root filesystem image
kernel image
bootloader image(s)
toolchain

GOAL

- A fully functional, self-contained embedded Linux operating system
- Running domain-specific applications
- Including all essential components required for the device to operate effectively.



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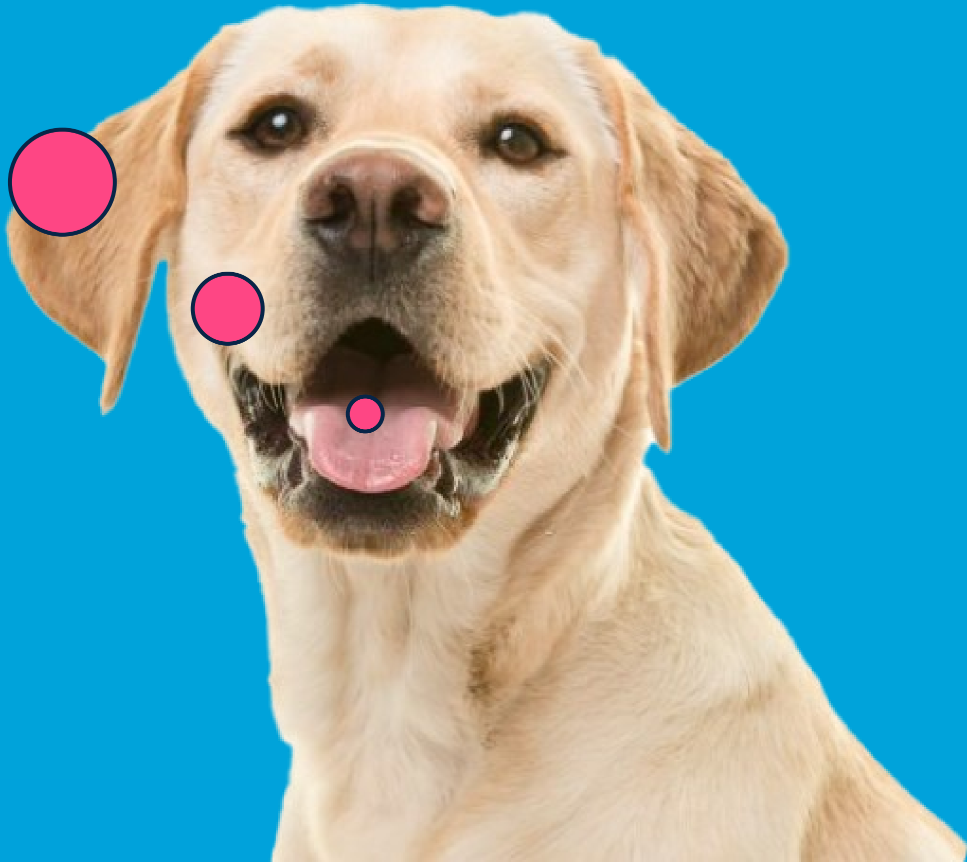
QUESTIONS?



THANK YOU!