Embedded Linux system development training

On-line seminar

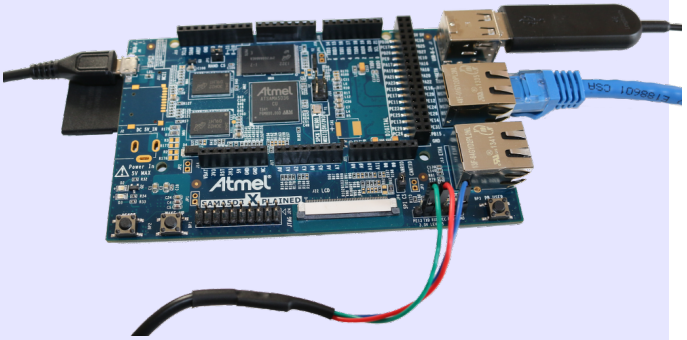
Title	**Embedded Linux system development training**
Overview	Bootloaders Kernel (cross) compiling and booting Block and flash filesystems C library and cross-compiling toolchains Lightweight building blocks for embedded systems Embedded system development tools Embedded application development and debugging Implementing real-time requirements in embedded Linux systems Practical demos with the ARM based SAMA5D3 Xplained board from Microchip
Materials	Check that the course contents correspond to your needs: `https://bootlin.com/doc/training/embedded-linux`.
Duration	**Seven** half days - 28 hours (4 hours per half day). 80% of lectures, 20% of practical demos.
Trainer	One of the engineers listed on: `https://bootlin.com/training/trainers/`
Language	Oral lectures: English Materials: English.
Audience	People developing devices using the Linux kernel People supporting embedded Linux system developers.
Prerequisites	**Familiarity with UNIX or GNU/Linux commands** People lacking experience on this topic should get trained by themselves, for example with our freely available on-line slides: `https://bootlin.com/blog/command-line/`.

Required equipment	• Computer with the operating system of your choice, provided it is supported by Zoom (`https://zoom.us` for videoconferencing • Webcam and microphone (preferably from an audio headset) • High speed access to the Internet
Materials	Electronic copies of presentations, demo instructions and data.

Hardware

Using the Microchip SAMA5D3 Xplained board in all practical demos, with a SAMA5D36 (Cortex A5) CPU from Microchip, which features:

- USB powered
- 256 MB DDR2 RAM
- 256 MB NAND flash
- 2 Ethernet ports (Gigabit + 100 Mbit)
- 2 USB 2.0 host ports
- 1 USB device port
- 1 MMC/SD slot
- 3.3 V serial port (like Beaglebone Black)
- Arduino R3-compatible header
- Misc: JTAG, buttons, LEDs



Half day 1

Lecture - Introduction to embedded Linux

- Advantages of Linux versus traditional embedded operating systems. Reasons for choosing Linux.
- Global picture: understanding the general architecture of an embedded Linux system. Overview of the major components in a typical system.

The rest of the course will study each of these components in detail.

Lecture - Embedded Linux development environment

- Operating system and tools to use on the development workstation for embedded Linux development.
- Desktop Linux usage tips.

Lecture - Cross-compiling toolchain and C library

- What's inside a cross-compiling toolchain
- Choosing the target C library
- What's inside the C library
- Ready to use cross-compiling toolchains
- Building a cross-compiling toolchain with automated tools.

Demo - Cross compiling toolchain	Lecture - Bootloaders
• Configuring Crosstool-NG • Executing it to build a custom uClibc toolchain.	• Available bootloaders • Bootloader features • Installing a bootloader • Detailed study of U-Boot

Half day 2

Demo - Bootloader and U-boot	Lecture - Linux kernel
Using the Microchip SAMA5D3 Xplained board • Set up serial communication with the board. • Configure, compile and install the first-stage bootloader and U-Boot on the Xplained board. • Become familiar with U-Boot environment and commands. • Set up TFTP communication with the board. Use TFTP U-Boot commands.	• Role and general architecture of the Linux kernel • Features available in the Linux kernel, with a focus on features useful for embedded systems • Kernel user interface • Getting the sources • Understanding Linux kernel versions. • Using the patch command

Demo - Kernel sources	Lecture – Configuring and compiling a Linux kernel
• Downloading kernel sources • Apply kernel patches	• Kernel configuration. • Using ready-made configuration files for specific architectures and boards. • Kernel compilation. • Generated files. • Using kernel modules

Demo - Kernel cross-compiling and booting

Using the Microchip Xplained board

- Configuring the Linux kernel and cross-compiling it for the ARM board.
- Downloading your kernel on the board through U-boot's tftp client.
- Booting your kernel from RAM.
- Copying the kernel to flash and booting it from this location.
- Storing boot parameters in flash and automating kernel booting from flash.

Half day 3

Lecture – Root filesystem in Linux

- Filesystems in Linux.
- Role and organization of the root filesystem.
- Location of the root filesystem: on storage, in memory, from the network.
- Device files, virtual filesystems.
- Contents of a typical root filesystem.

Lecture - BusyBox

- Detailed overview. Detailed features.
- Configuration, compiling and deploying.

Demo – Tiny root filesystem built from scratch with BusyBox

Using the Microchip Xplained board

- Now build a basic root filesystem from scratch for your ARM system
- Setting up a kernel to boot your system on a workstation directory exported by NFS
- Passing kernel command line parameters to boot on NFS
- Creating the full root filesystem from scratch. Populating it with BusyBox based utilities.
- Creating device files and booting the virtual system.
- System startup using BusyBox /sbin/init
- Using the BusyBox http server.
- Controlling the target from a web browser on the PC host.
- Setting up shared libraries on the target and compiling a sample executable.

Half day 4

Lecture - Block filesystems

- Filesystems for block devices.
- Usefulness of journaled filesystems.
- Read-only block filesystems.
- RAM filesystems.
- How to create each of these filesystems.
- Suggestions for embedded systems.

Demo - Block filesystems

Using the Xplained ARM board

- Creating partitions on your block storage
- Booting a system with a mix of filesystems: SquashFS for applications, ext3 for configuration and user data, and tmpfs for temporary system files.

Lecture - Flash filesystems

- The Memory Technology Devices (MTD) filesystem.
- Filesystems for MTD storage: JFFS2, Yaffs2, UBIFS.
- Kernel configuration options
- MTD storage partitions.
- Focus on today's best solution, UBI and UBIFS: preparing, flashing and using UBI images.

Demo – Flash filesystems

Using the SAMAD3 Xplained ARM board

- Defining partitions in U-Boot for your internal flash storage instead of using raw offsets.
- Sharing these definitions with Linux.
- Creating a UBI image on your workstation, flashing it from U-Boot and booting your system on one of the UBI volumes with UBIFS.

Half day 5

Lecture – Leveraging existing open-source components in your system

- Reasons for leveraging existing components.
- Find existing free and open source software components.
- Choosing the components.
- The different free software licenses and their requirements.
- Overview of well-known typical components used in embedded systems: graphical libraries and systems (framebuffer, Gtk, Qt, etc.), system utilities, network libraries and utilities, multimedia libraries, etc.
- System building: integration of the components.

Lecture – Cross-compiling applications and libraries

- Configuring, cross-compiling and installing applications and libraries.
- Details about the build system used in most open-source components.
- Overview of the common issues found when using these components.

Demo – Cross-compiling applications and libraries

- Building a system with audio libraries and a sound player application.
- Manual compilation and installation of several free software packages.
- Learning about common techniques and issues.

Half day 6

Lecture - Embedded system building tools

- Review of existing system building tools.
- Buildroot example.

Demo - System build with Buildroot

Using the Microchip Xplained board

- Using Buildroot to rebuild the same system as in the previous lab.
- Seeing how easier it gets.
- Optional: add a package to Buildroot.

Lecture - Application development and debugging

- Programming languages and libraries available.
- Overview of the C library features for application development.
- Build system for your application, how to use existing libraries in your application.
- Source browsers and Integrated Development Environments (IDEs).
- Debuggers. Debugging remote applications with gdb and gdbserver. Post-mortem debugging with core files.
- Code checkers, memory checkers, profilers.

Demo – Application development and debugging

On the Microchip Xplained board

- Develop and compile an application relying on the ncurses library
- Using strace, ltrace and gdbserver to debug a crappy application on the remote system.
- Do post-mortem analysis of a crashed application.

Half day 7

Lecture - Linux and real-time

Very useful for many kinds of devices, industrial or multimedia systems.

- Understanding the sources of latency in standard Linux.
- Soft real-time solutions for Linux: improvements included in the mainline Linux version.
- Understanding and using the latest RT preempt patches for mainline Linux.
- Real-time kernel debugging. Measuring and analyzing latency.
- Xenomai, a hard real-time solution for Linux: features, concepts, implementation and examples.

Demo - Linux latency tests

- Tests performed on the Xplained ARM board.
- Latency tests on standard Linux, with preemption options.
- Latency tests using the `PREEMPT_RT` kernel patchset.
- Setting up Xenomai.
- Latency tests with Xenomai.

Questions and Answers

- Questions and answers with the audience about the course topics
- Extra presentations if time is left, according what most participants are interested in.