



# Embedded Linux system development training

## 5-day session

|                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Title</b>               | <b>Embedded Linux system development training</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Overview</b>            | <p>           Bootloaders<br/>           Kernel (cross) compiling and booting<br/>           Block and flash filesystems<br/>           C library and cross-compiling toolchains<br/>           Lightweight building blocks for embedded systems<br/>           Embedded system development tools<br/>           Embedded application development and debugging<br/>           Implementing real-time requirements in embedded Linux systems<br/>           Practical labs with the ARM based SAMA5D3 Xplained board from Atmel         </p> |
| <b>Materials</b>           | <p>Check that the course contents correspond to your needs:</p> <p><a href="http://free-electrons.com/doc/training/embedded-linux">http://free-electrons.com/doc/training/embedded-linux</a>.</p>                                                                                                                                                                                                                                                                                                                                            |
| <b>Duration</b>            | <p><b>Five</b> days - 40 hours (8 hours per day).<br/>           50% of lectures, 50% of practical labs.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Trainer</b>             | <p>One of the engineers listed on:</p> <p><a href="http://free-electrons.com/training/trainers/">http://free-electrons.com/training/trainers/</a></p>                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Language</b>            | <p>Oral lectures: English, French or Polish.<br/>           Materials: English.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Audience</b>            | <p>People developing devices using the Linux kernel<br/>           People supporting embedded Linux system developers.</p>                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Prerequisites</b>       | <p><b>Knowledge and practice of UNIX or GNU/Linux commands</b><br/>           People lacking experience on this topic should get trained by themselves, for example with our freely available on-line slides:<br/> <a href="http://free-electrons.com/blog/command-line/">http://free-electrons.com/blog/command-line/</a>.</p>                                                                                                                                                                                                              |
| <b>Alternative version</b> | <p>Reduced version of the Embedded Linux system development training (<b>4 days long</b>) with the following topics removed:</p> <ul style="list-style-type: none"> <li>• Flash file system</li> <li>• Real time</li> </ul> <p><a href="http://free-electrons.com/doc/training/embedded-linux/embedded-linux-4-days-agenda.pdf">http://free-electrons.com/doc/training/embedded-linux/embedded-linux-4-days-agenda.pdf</a>.</p>                                                                                                              |

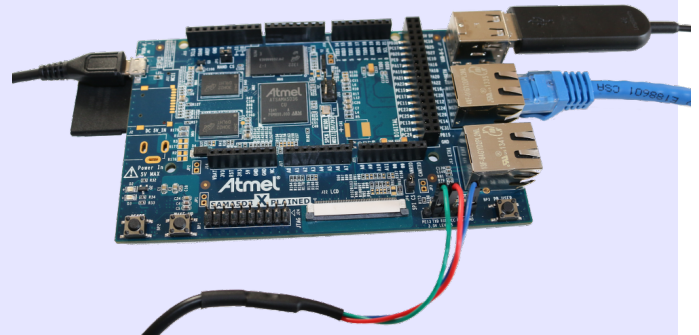


|                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Required equipment</b> | <p><b>For on-site sessions only</b><br/>Everything is supplied by Free Electronics in public sessions.</p> <ul style="list-style-type: none"> <li>• Video projector</li> <li>• PC computers with at least 4 GB of RAM, and Ubuntu Linux installed in a <b>free partition of at least 30 GB. Using Linux in a virtual machine is not supported</b>, because of issues connecting to real hardware.</li> <li>• We need Ubuntu Desktop 16.04 (32 or 64 bit, Xubuntu and Kubuntu variants are fine). We don't support other distributions, because we can't test all possible package versions.</li> <li>• <b>Connection to the Internet</b> (direct or through the company proxy).</li> <li>• <b>PC computers with valuable data must be backed up</b> before being used in our sessions. Some people have already made mistakes during our sessions and damaged work data.</li> </ul> |
| <b>Materials</b>          | <p>Print and electronic copies of presentations and labs.<br/>Electronic copy of lab files.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

## Hardware

Using the Atmel SAMA5D3 Xplained board in all practical labs SAMA5D36 (Cortex A5) CPU from Atmel, 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

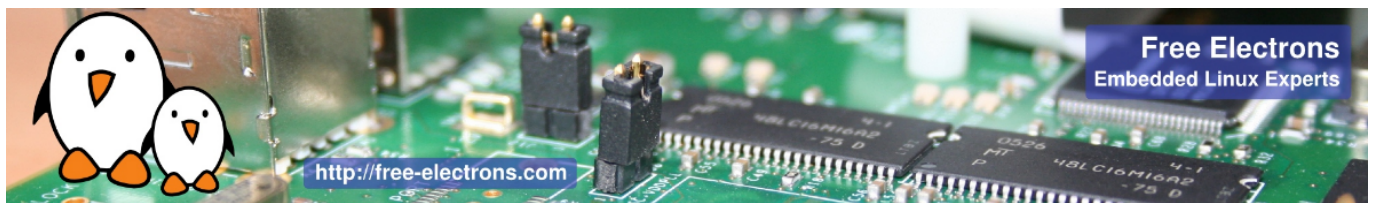


## Day 1 - Morning

### 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.

# Day 1 - Afternoon

## Lab - Cross compiling toolchain

- Configuring Crosstool-NG
- Executing it to build a custom uClibc toolchain.

## Lecture - Bootloaders

- Available bootloaders
- Bootloader features
- Installing a bootloader
- Detailed study of U-Boot

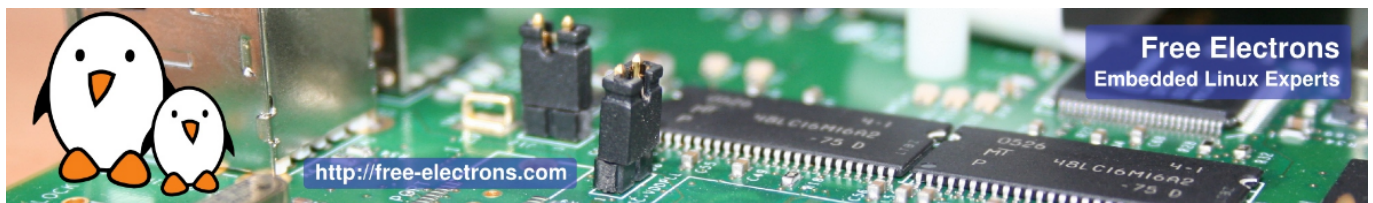
## Lab - Bootloader and U-boot

### *Using the Atmel 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.

## Lecture - Linux kernel

- 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



## Day 2 - Morning

### Lab - Kernel sources

- Downloading kernel sources
- Apply kernel patches

### Lecture – Configuring and compiling a Linux kernel

- Kernel configuration.
- Useful settings for embedded systems.
- Native compiling.
- Generated files.
- Using kernel modules

### Lecture - Kernel cross-compiling

- Kernel cross-compiling setup.
- Using ready-made configuration files for specific architectures and boards.
- Cross-compiling Linux

### Lab - Kernel cross-compiling and booting

#### *Using the Atmel 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.

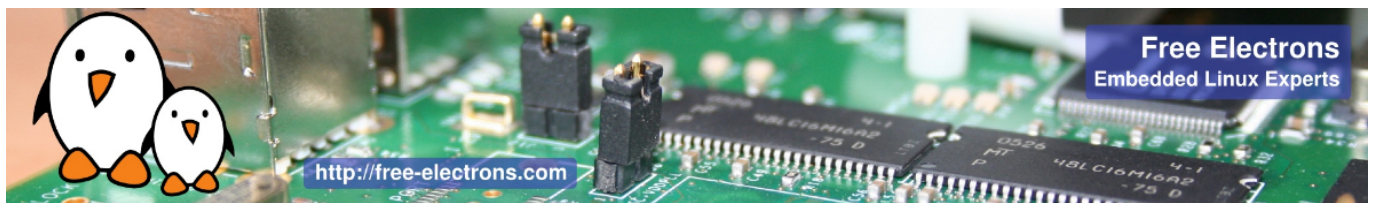
## Day 2 - Afternoon

### 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.



## Lab – Tiny root filesystem built from scratch with BusyBox

*Using the Atmel 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.

## Day 3 - Morning

### Lab – Tiny root filesystem built from scratch with BusyBox

Continued from the previous afternoon.

#### 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.

#### Lab - 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.





## Day 3 - Afternoon

### 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.

### Lab – 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.

### 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.

## Day 4 - Morning

### 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.

### Lab – Cross-compiling applications and libraries

#### *If enough time left*

- 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.



## Day 4 - Afternoon

### Lecture - Embedded system building tools

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

### Lab - System build with Buildroot

*Using the Atmel 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.

## Day 5 - Morning

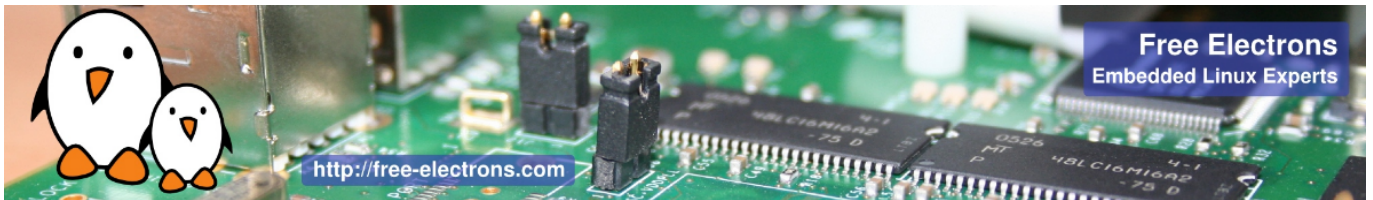
### Lecture - Application development and debugging

- 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.

### Lab – Application development and debugging

*On the Atmel 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.



## Day 5 - Afternoon

---

### 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.

### Lab - 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.