Porting the Linux kernel to an ARM board

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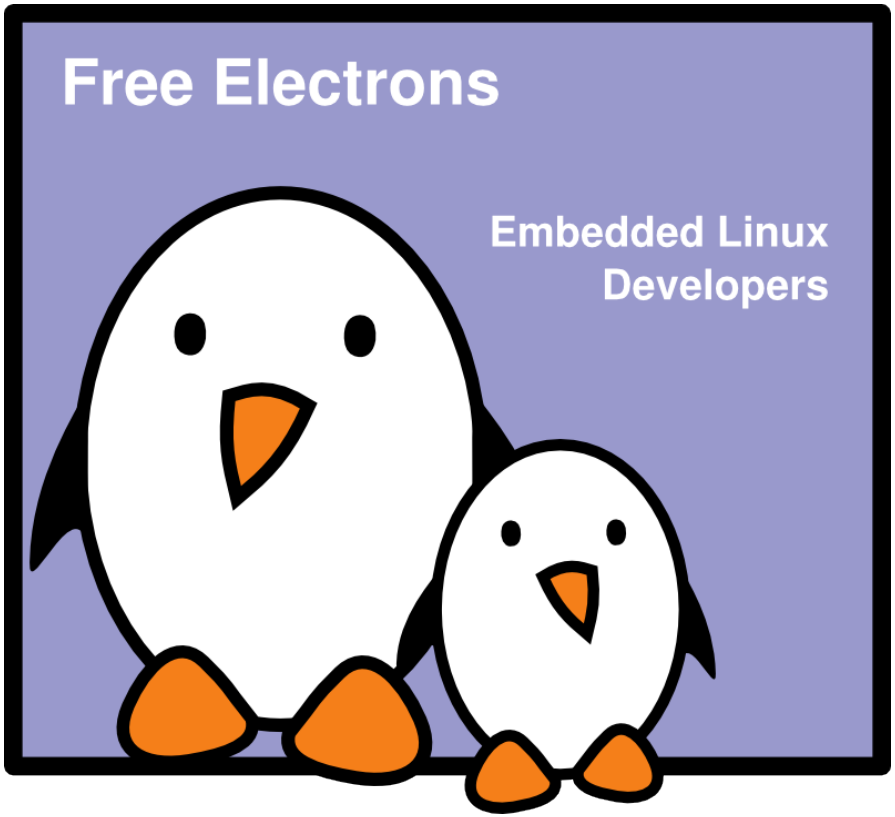

Latest update: Feb 17, 2010,
Document sources, updates and translations:
http://free-electrons.com/docs/kernel-porting
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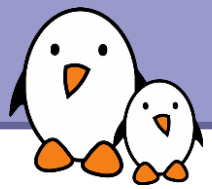
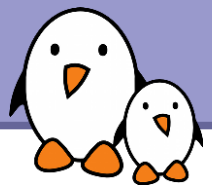


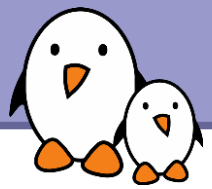
Porting the Linux kernel

- The Linux kernel supports a lot of different CPU architectures
- Each of them is maintained by a different group of contributors
  - See the `MAINTAINERS` file for details
- The organization of the source code and the methods to port the Linux kernel to a new board are therefore very architecture-dependent
- For example, PowerPC and ARM are very different
  - PowerPC relies on device trees to describe hardware details
  - ARM relies on source code only
- This presentation is focused on the ARM architecture only



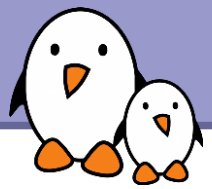
Architecture, CPU and machine

- In the source tree, each architecture has its own directory `arch/arm` for the ARM architecture
- This directory contains generic ARM code
  - `boot, common, configs, kernel, lib, mm, nwfpe, vfp, oprofile, tools`
- And many directories for different CPU families
  - `mach-*` directories : `mach-pxa` for PXA CPUs, `mach-imx` for Freescale iMX CPUs, etc.
  - Each of these directories contain
    - Support for the CPU
    - Support for several boards using this CPU
- Some CPU types share some code, in an entity called a *platform*
  - `plat-omap` contains common code from `mach-omap1` and `mach-omap2`



Source code for Calao USB A9263

- Taking the case of the Calao USB A9263 board, which uses a AT91SAM9263 CPU.
- `arch/`
  - `arm/`
    - `mach-at91/`
      - AT91 generic code
        `clock.c, leds.c, irq.c, pm.c`
      - CPU-specific code for the AT91SAM9263
        `at91sam9263.c, at91sam926x_time.c, at91sam9263_devices.c`
      - Board specific code
        `board-usb-a9263.c`
- For the rest of this presentation, we will focus on board support only

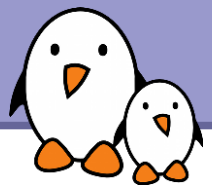


Configuration

- A configuration option must be defined for the board, in `arch/arm/mach-at91/Kconfig`

```
config MACH_USB_A9263
        bool "CALAO USB-A9263"
        depends on ARCH_AT91SAM9263
        help
          Select this if you are using a Calao Systems USB-A9263.
          <http://www.calao-systems.com>
```

- This option must depend on the CPU type option corresponding to the CPU used in the board
  - Here the option is `ARCH_AT91SAM9263`, defined in the same file
- A default configuration file for the board can optionally be stored in `arch/arm/configs/`. For our board, it's `usb-a9263_defconfig`



Compilation

- The source files corresponding to the board support must be associated with the configuration option of the board
- This is done in `arch/arm/mach-at91/Makefile`

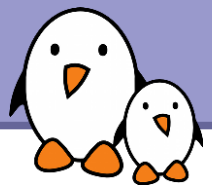
```
obj-$(CONFIG_MACH_USB_A9263)    += board-usb-a9263.o
```

- The Makefile also tells which files are compiled for every AT91 CPU

```
obj-y                := irq.o gpio.o
obj-$(CONFIG_AT91_PMC_UNIT)     += clock.o
obj-y                           += leds.o
obj-$(CONFIG_PM)                += pm.o
obj-$(CONFIG_AT91_SLOW_CLOCK)   += pm_slowclock.o
```

- And which files for our particular CPU, the AT91SAM9263

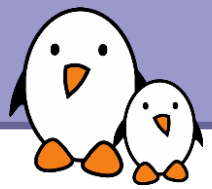
```
obj-$(CONFIG_ARCH_AT91SAM9263)  += at91sam9263.o at91sam926x_time.o
at91sam9263_devices.o sam9_smc.o
```



Machine structure

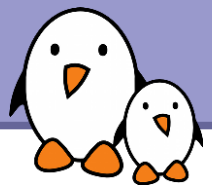
- Each board is defined by a machine structure
  - The word « machine » is quite confusing since every `mach-*` directory contains several machine definitions, one for each board using a given CPU type
- For the Calao board, at the end of `arch/arm/mach-at91/board-usb-a9263.c`

```
MACHINE_START(USB_A9263, "CALAO USB_A9263")
        /* Maintainer: calao-systems */
        .phys_io        = AT91_BASE_SYS,
        .io_pg_offst    = (AT91_VA_BASE_SYS >> 18) & 0xfffc,
        .boot_params    = AT91_SDRAM_BASE + 0x100,
        .timer          = &at91sam926x_timer,
        .map_io         = ek_map_io,
        .init_irq       = ek_init_irq,
        .init_machine   = ek_board_init,
MACHINE_END
```



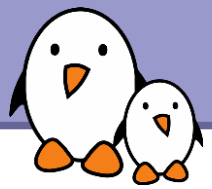
Machine structure macros

- `MACHINE_START` and `MACHINE_END`
  - Macros defined in `arch/arm/include/asm/mach/arch.h`
  - They are helpers to define a `struct machine_desc` structure stored in a specific ELF section
  - Several `machine_desc` structures can be defined in a kernel, which means that the kernel can support several boards.
  - The right structure is chosen at boot time



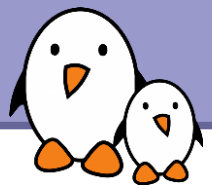
Machine type number

- In the ARM architecture, each board type is identified by a machine type number
- The latest machine type numbers list can be found at http://www.arm.linux.org.uk/developer/machines/download.php
- A copy of it exists in the kernel tree in `arch/arm/tools/mach-types`
  - For the Calao board
    ```
    usb_a9263  MACH_USB_A9263 USB_A9263 1710
    ```
- At compile time, this file is processed to generate a header file, `include/asm-arm/mach-types.h`
  - For the Calao board
    ```
    #define MACH_TYPE_USB_A9263 1710
    ```
  - And a few other macros in the same file



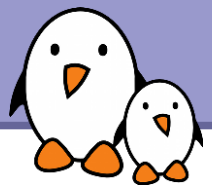
Machine type number

- The machine type number is set in the `MACHINE_START()` definition
  `MACHINE_START(USB_A9263, "CALAO USB_A9263")`
- At run time, the machine type number of the board on which the kernel is running is passed by the bootloader in register *r1*
- Very early in the boot process (`arch/arm/kernel/head.S`), the kernel calls `__lookup_machine_type` in `arch/arm/kernel/head-common.S`
- `__lookup_machine_type` looks at all the `machine_desc` structures of the special ELF section
  - If it doesn't find the requested number, prints a message and stops
  - If found, it knows the machine descriptions and continues the boot process



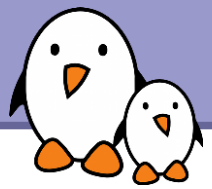
Early debugging and boot parameters

- Early debugging
  - `phys_io` is the physical address of the I/O space
  - `io_pg_offset` is the offset in the page table to remap the I/O space
  - These are used when `CONFIG_DEBUG_LL` is enabled to provide very early debugging messages on the serial port
- Boot parameters
  - `boot_params` is the location where the bootloader has left the boot parameters (the kernel command line)
  - The bootloader can override this address in register *r2*
  - See also `Documentation/arm/Booting` for the details of the environment expected by the kernel when booted



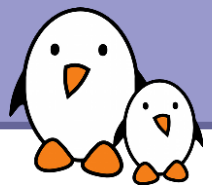
System timer

- The timer field point to a `struct sys_timer` structure, that describes the system timer
  - Used to generate the periodic tick at HZ frequency to call the scheduler periodically
- On the Calao board, the system timer is defined by the `at91sam926x_timer` structure in `at91sam926x_time.c`
- It contains the interrupt handler called at HZ frequency
- It is integrated with the `clockevents` and the `clocksource` infrastructures
  - See `include/linux/clocksource.h` and `include/linux/clockchips.h` for details



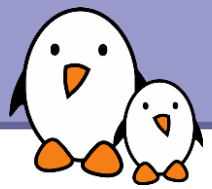
map_io()

- The `map_io()` function points to `ek_map_io()`, which
  - Initializes the CPU using `at91sam9263_initialize()`
    - Map I/O space
    - Register and initialize the clocks
  - Configures the debug serial port and set the console to be on this serial port
  - Called at the very beginning of the C code execution
    - `init/main.c: start_kernel()`
    - `arch/arm/kernel/setup.c: setup_arch()`
    - `arch/arm/mm/mmu.c: paging_init()`
    - `arch/arm/mm/mmu.c: devicemaps_init()`
      - `mdesc->map_io()`



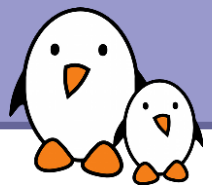
init_irq()

- `init_irq()` to initialize the IRQ hardware specific details
- Implemented by `ek_init_irq()`, which calls `at91sam9263_init_interrupts()` in `at91sam9263.c`, which mainly calls `at91_aic_init()` in `irq.c`
  - Initialize the interrupt controller, assign the priorities
  - Register the IRQ chip (`irq_chip` structure) to the kernel generic IRQ infrastructure, so that the kernel knows how to ack, mask, unmask the IRQs
- Called a little bit later than `map_io()`
  - `init/main.c: start_kernel()`
  - `arch/arm/kernel/irq.c: init_IRQ()`
  - `init_arch_irq()` (equal to `mdesc->init_irq`)



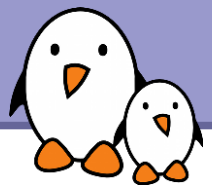
init_machine()

- `init_machine()` completes the initialization of the board by registering all platform devices
- Called by `customize_machines()` in `arch/arm/kernel/setup.c`
- This function is an `arch_initcall` (list of functions whose address is stored in a specific ELF section, by levels)
- At the end of kernel initialization, just before running the first userspace program init:
  - `init/main.c: kernel_init()`
  - `init/main.c: do_basic_setup()`
  - `init/main.c: do_initcalls()`
  - Calls all initcalls, level by level



init_machine() for Calao

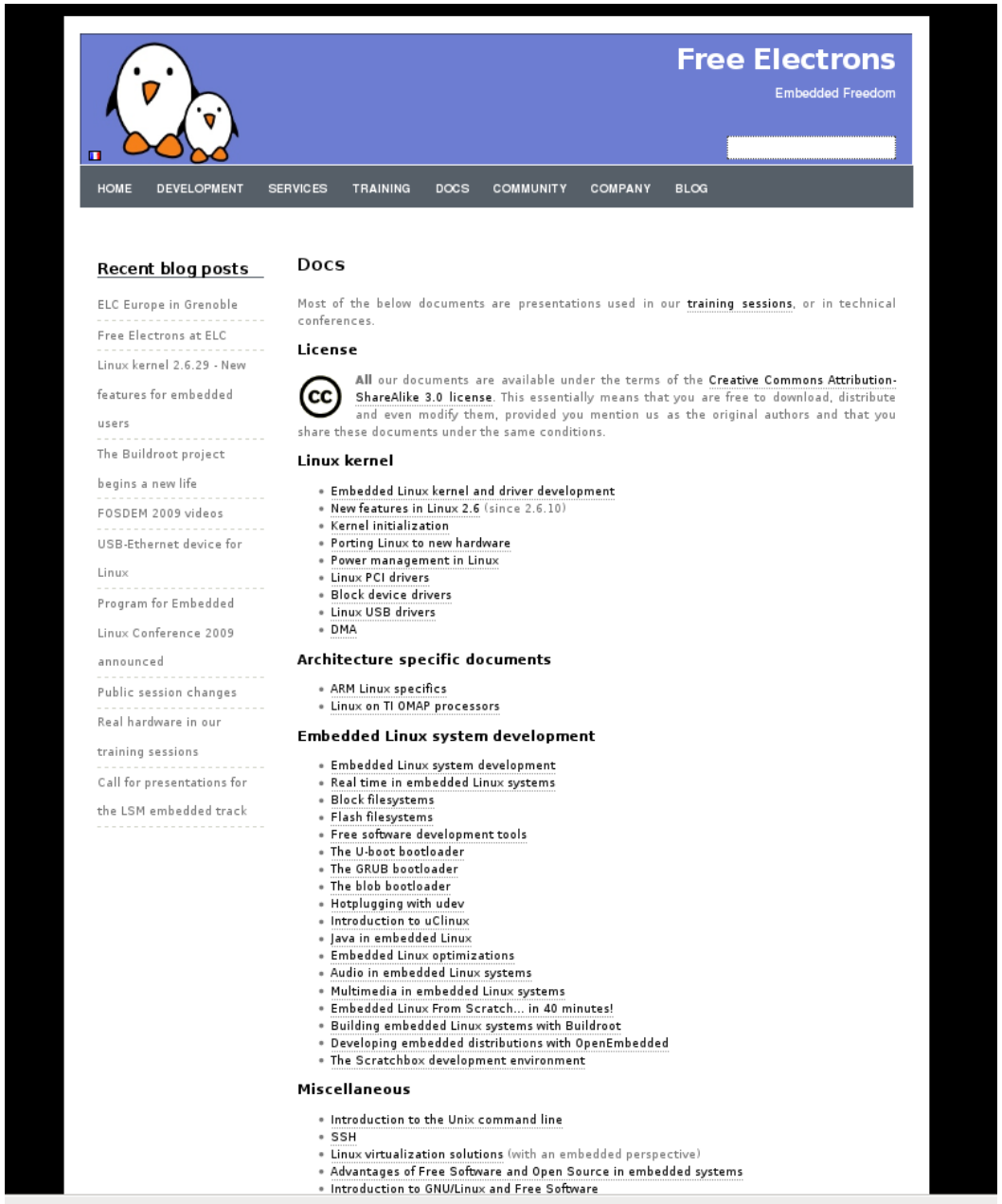
- For the Calao board, implement in `ek_board_init()`
  - Registers serial ports, USB host, USB device, SPI, Ethernet, NAND flash, 2IC, buttons and LEDs
  - Uses `at91_add_device_*()` helpers, defined in `at91sam9263_devices.c`
  - These helpers call `platform_device_register()` to register the different `platform_device` structures defined in the same file
  - For some devices, the board specific code does the registration itself (buttons) or passes board-specific data to the registration helper (USB host and device, NAND, Ethernet, etc.)



Drivers

- The `at91sam9263_devices.c` file doesn't implement the drivers for the platform devices
- The drivers are implemented at different places of the kernel tree
- For the Calao board
  - USB host, driver `at91_ohci`, `drivers/usb/host/ohci-at91.c`
  - USB device, driver `at91_udc`, `drivers/usb/gadget/at91_udc.c`
  - Ethernet, driver `macb`, `drivers/net/macb.c`
  - NAND, driver `atmel_nand`, `drivers/mtd/nand/atmel_nand.c`
  - I2C on GPIO, driver `i2c-gpio`, `drivers/i2c/busses/i2c-gpio.c`
  - SPI, driver `atmel_spi`, `drivers/spi/atmel_spi.c`
  - Buttons, driver `gpio-keys`, `drivers/input/keyboard/gpio_keys.c`
- All these drivers are selected by the ready-made configuration file

Related documents



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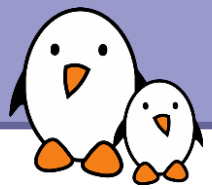

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