Power Management

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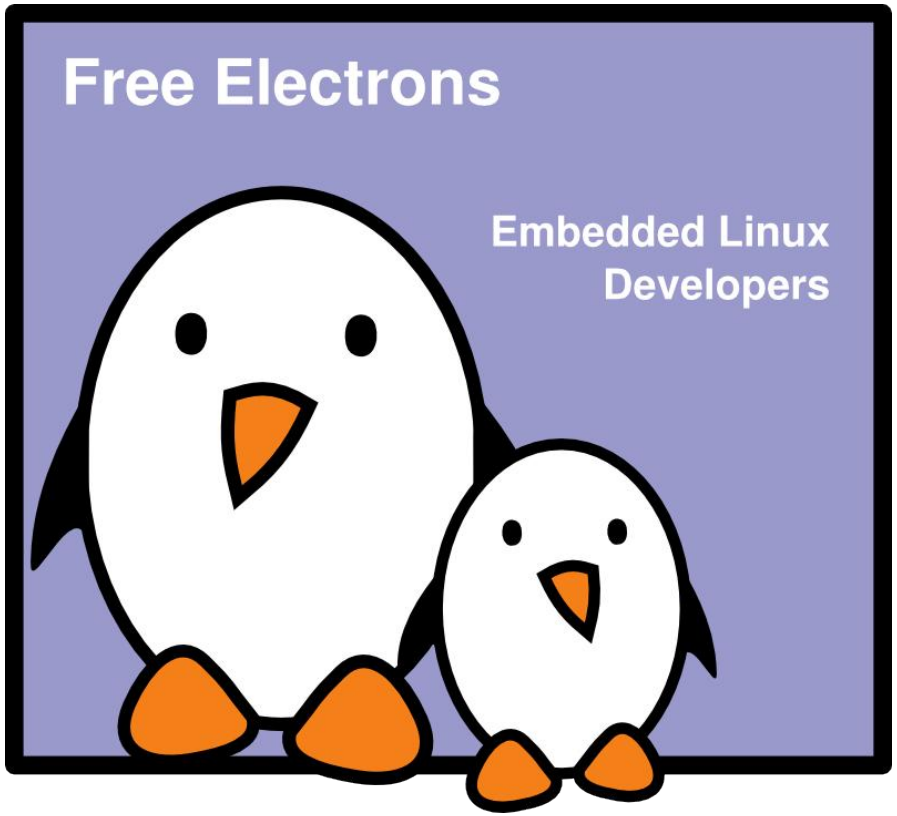
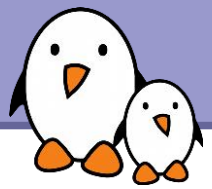


Linux

Latest update: Feb 21, 2011,
Document sources, updates and translations:
http://free-electrons.com/docs/power
Corrections, suggestions, contributions and translations are welcome!

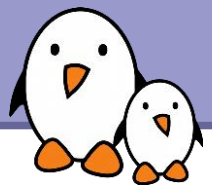


PM building blocks

Several power management « building blocks »

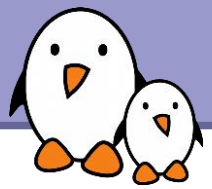
- Suspend and resume
- CPUidle
- Runtime power management
- Frequency and voltage scaling
- Applications

Independent « building blocks » that can be improved gradually during development



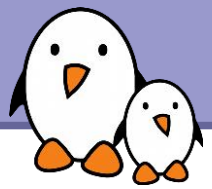
Clock framework (1)

- Generic framework to manage clocks used by devices in the system
- Allows to reference count clock users
  and to shutdown the unused clocks to save power
- Simple API described in
  http://free-electrons.com/kerneldoc/latest/DocBook/kernel-api/clk.html
  - `clk_get()` to get a reference to a clock
  - `clk_enable()` to start the clock
  - `clk_disable()` to stop the clock
  - `clk_put()` to free the clock source
  - `clk_get_rate()` to get the current rate



Clock framework (2)

- The clock framework API and the `clk` structure are usually implemented by each architecture (code duplication!)
  - See `arch/arm/mach-at91/clock.c` for an example
    This is also where all clocks are defined.
  - Clocks are identified by a name string specific to a given platform
- Drivers can then use the clock API.
  Example from `drivers/net/macb.c`:
  - `clk_get()` called from the `probe()` function, to get the definition of a clock for the current board, get its frequency, and run `clk_enable()`.
  - `clk_put()` called from the `remove()` function to release the reference to the clock, after calling `clk_disable()`.



Clock disable implementation

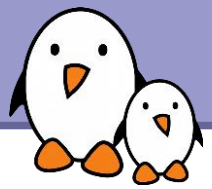
From arch/arm/mach-at91/clock.c: (2.6.36)

```
static void __clk_disable(struct clk *clk)
{
        BUG_ON(clk->users == 0);
        if (--clk->users == 0 && clk->mode)
                clk->mode(clk, 0);
        if (clk->parent)
                __clk_disable(clk->parent);
}
```

Call the hardware function switching off this clock

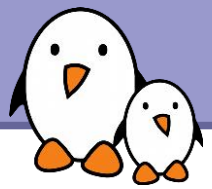
Example `mode` function (same file):

```
static void pmc_sys_mode(struct clk *clk, int is_on)
{
        if (is_on)
                at91_sys_write(AT91_PMC_SCER, clk->pmc_mask);
        else
                at91_sys_write(AT91_PMC_SCDR, clk->pmc_mask);
}
```



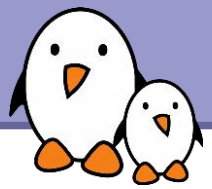
Suspend and resume

- Infrastructure in the kernel to support suspend and resume
- Platform hooks
  - `prepare()`, `enter()`, `finish()`, `valid()` in a `platform_suspend_ops` structure
  - Registered using the `suspend_set_ops()` function
  - See `arch/arm/mach-at91/pm.c`
- Device drivers
  - `suspend()` and `resume()` hooks in the `*_driver` structures (`platform_driver`, `usb_driver`, etc.)
  - See `drivers/net/macb.c`



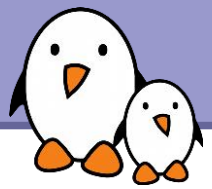
Board specific power management

- Typically takes care of battery and charging management.
- Also defines presuspend and postsuspend handlers.
- Example:
  `arch/arm/mach-pxa/spitz_pm.c`



arch/arm/mach-<cpu>/sleep.S

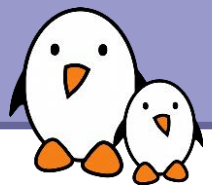
- Assembly code implementing CPU specific suspend and resume code. Note: only found on arm, just 3 other occurrences in other architectures, with other paths.
- First scenario: only a suspend function. The code goes in sleep state (after enabling DRAM self-refresh), and continues with resume code.
- Second scenario: suspend and resume functions. Resume functions called by the bootloader.
- Examples to look at:
  `arch/arm/mach-omap2/sleep24xx.S` (1st case)
  `arch/arm/mach-pxa/sleep.S` (2nd case)



Triggering suspend

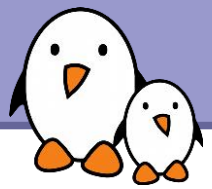
- Whatever the power management implementation, CPU specific `suspend_ops` functions are called by the `enter_state` function.
- `enter_state` also takes care of executing the suspend and resume functions for your devices.
- The execution of this function can be triggered from userspace. To suspend to RAM:
  `echo mem > /sys/power/state`
- Can also use the s2ram program from http://suspend.sourceforge.net/

Read `kernel/power/suspend.c`



Runtime power management

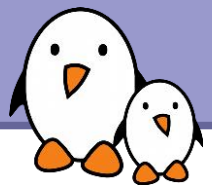
- According to the kernel configuration interface:
  Enable functionality allowing I/O devices to be put into energy-saving (low power) states at run time (or autosuspended) after a specified period of inactivity and woken up in response to a hardware-generated wake-up event or a driver's request.
- New hooks must be added to the drivers:
  `runtime_suspend()`, `runtime_resume()`, `runtime_idle()`
- API and details on
  Documentation/power/runtime_pm.txt
- See also Kevin Hilman's presentation at ELC Europe 2010:
  http://elinux.org/images/c/cd/ELC-2010-khilman-Runtime-PM.odp



Saving power in the idle loop

- The idle loop is what you run
  when there's nothing left to run in the system.
- Implemented in all architectures
  in `arch/<arch>/kernel/process.c`
- Example to read: look for `cpu_idle` in
  `arch/arm/kernel/process.c`
- Each ARM cpu defines its own `arch_idle` function.
- The CPU can run power saving HLT instructions, enter NAP mode, and even disable the timers (tickless systems).

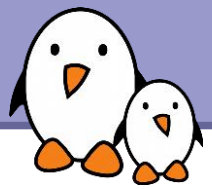
See also http://en.wikipedia.org/wiki/Idle_loop



Managing idle

Adding support for multiple idle levels

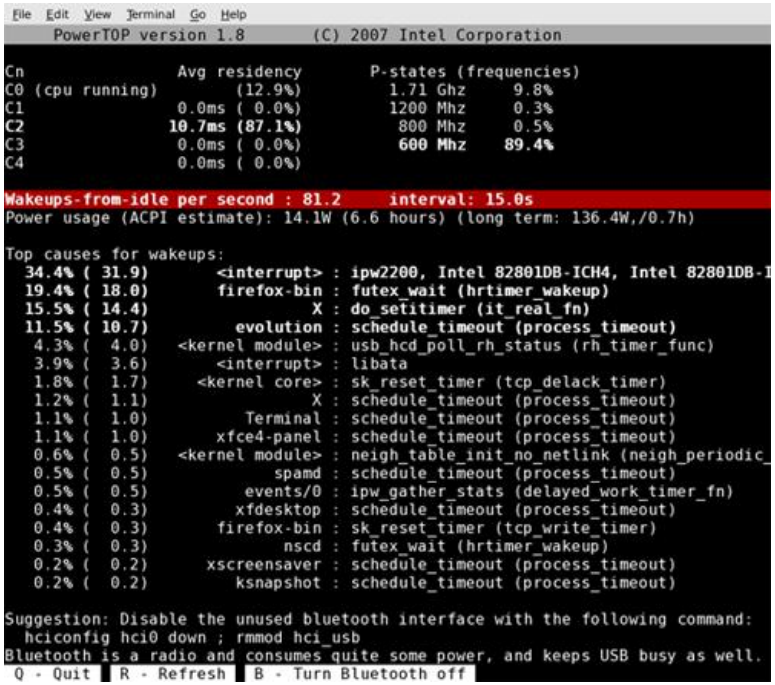
- Modern CPUs have several sleep states offering different power savings with associated wake up latencies
- Since 2.6.21, the dynamic tick feature allows to remove the periodic tick to save power, and to know when the next event is scheduled, for smarter sleeps.
- CPUidle infrastructure to change sleep states
  - Platform-specific driver defining sleep states and transition operations
  - Platform-independent governors (ladder and menu)
  - Available for x86/ACPI, not supported yet by all ARM cpus. (look for `cpuidle*` files under `arch/arm/`)
  - See `Documentation/cpuidle/` in kernel sources.

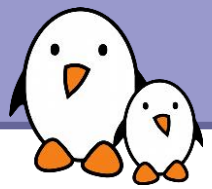


PowerTOP

http://www.lesswatts.org/projects/powertop/

- With dynamic ticks, allows to fix parts of kernel code and applications that wake up the system too often.
- PowerTOP allows to track the worst offenders
- Now available on ARM cpus implementing CPUidle
- Also gives you useful hints for reducing power.

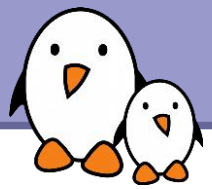




Frequency and voltage scaling (1)

Frequency and voltage scaling possible through the *cpufreq* kernel infrastructure.

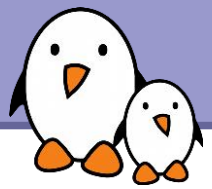
- Generic infrastructure
  `drivers/cpufreq/cpufreq.c`
  `include/linux/cpufreq.h`
- Generic governors, responsible for deciding frequency and voltage transitions
  - `performance`: maximum frequency
  - `powersave`: minimum frequency
  - `ondemand`: measures CPU consumption to adjust frequency
  - `conservative`: often better than `ondemand`.
    Only increases frequency gradually when the CPU gets loaded.
  - `userspace`: leaves the decision to an userspace daemon.
- This infrastructure can be controlled from
  `/sys/devices/system/cpu/cpu<n>/cpufreq/`



Frequency and voltage scaling (2)

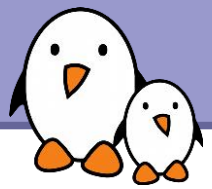
- CPU support code in architecture dependent files.
  Example to read: `arch/arm/plat-omap/cpu-omap.c`
- Must implement the operations of the `cpufreq_driver` structure and register them using `cpufreq_register_driver()`
  - `init()` for initialization
  - `exit()` for cleanup
  - `verify()` to verify the user-chosen policy
  - `setpolicy()` or `target()`
    to actually perform the frequency change

See `Documentation/cpu-freq/` for useful explanations



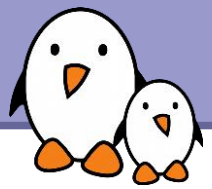
PM QoS

- PM QoS is a framework developed by Intel introduced in 2.6.25
- It allows kernel code and applications to set their requirements in terms of
  - CPU DMA latency
  - Network latency
  - Network throughput
- According to these requirements, PM QoS allows kernel drivers to adjust their power management
- See `Documentation/power/pm_qos_interface.txt` and Mark Gross' presentation at ELC 2008
- Still in very early deployment (only 4 drivers in 2.6.36).



Regulator framework

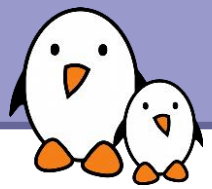
- Modern embedded hardware have hardware responsible for voltage and current regulation
- The regulator framework allows to take advantage of this hardware to save power when parts of the system are unused
  - A consumer interface for device drivers (i.e users)
  - Regulator driver interface for regulator drivers
  - Machine interface for board configuration
  - *sysfs* interface for userspace
- Merged in Linux 2.6.27.
  See `Documentation/power/regulator/` in kernel sources.
- See Liam Girdwood's presentation at ELC 2008
  http://free-electrons.com/blog/elc-2008-report#girdwood



BSP work for a new board

In case you just need to create a BSP for your board, and your CPU already has full PM support, you should just need to:

- Create clock definitions and bind your devices to them.
- Implement PM handlers (suspend, resume) in the drivers for your board specific devices.
- Implement runtime PM handlers in your drivers.
- Implement board specific power management if needed (mainly battery management)
- Implement regulator framework hooks for your board if needed.
- All other parts of the PM infrastructure should be already there: suspend / resume, cpuidle, cpu frequency and voltage scaling.



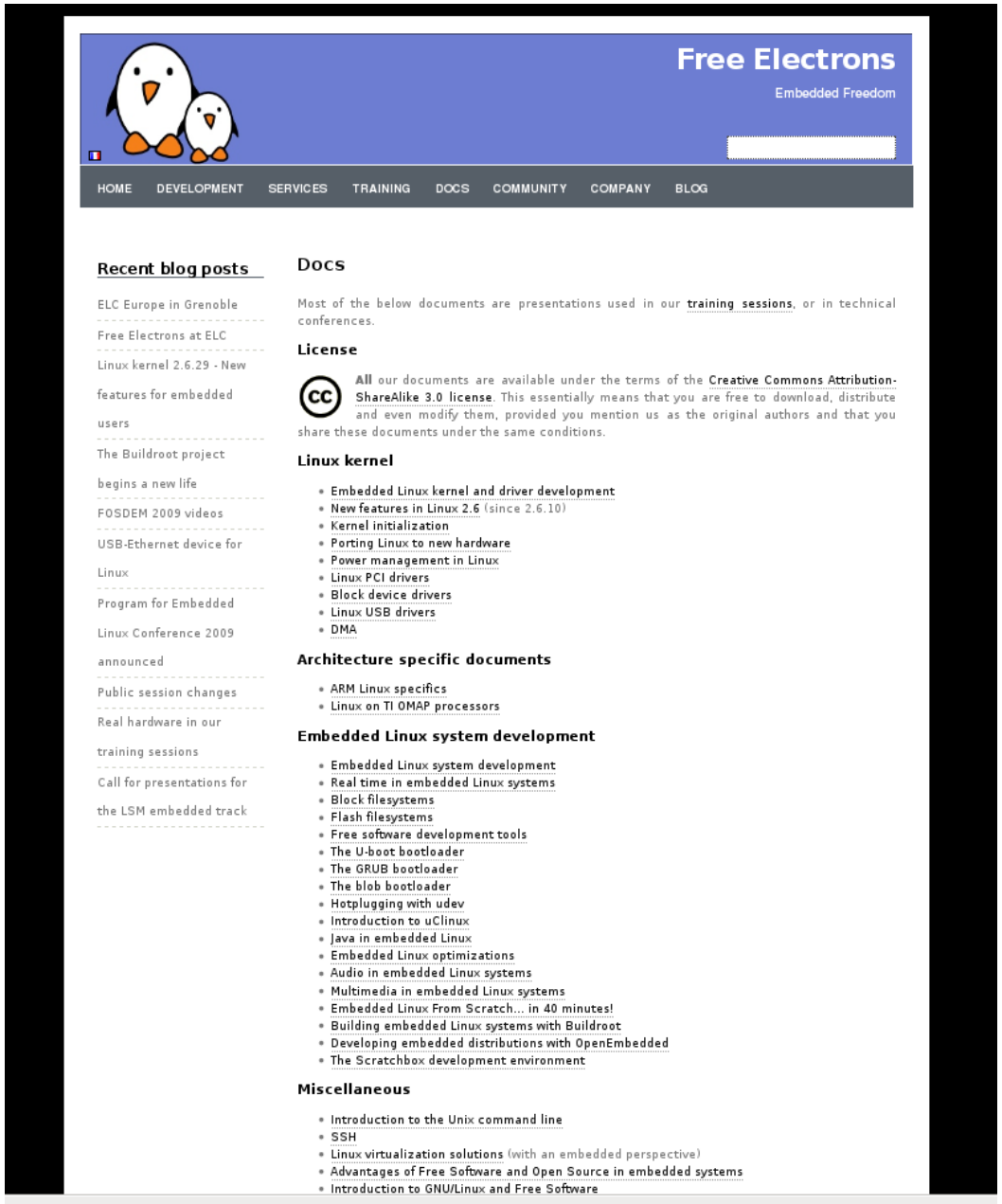
Useful resources

- `Documentation/power/` in the Linux kernel sources.
  Will give you many useful details.
- http://lesswatts.org
  Intel effort trying to create a Linux power saving community.
  Mainly targets Intel processors.
  Lots of useful resources.
- http://wiki.linaro.org/WorkingGroups/PowerManagement/
  Ongoing developments on the ARM platform.
- Tips and ideas for prolonging battery life:
  http://j.mp/fVdxKh

Practical lab – Power management

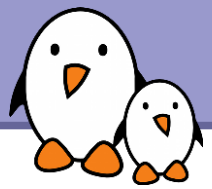
- Suspend and resume your Linux system
- Change the CPU frequency of your system

Related documents



All our technical presentations on http://free-electrons.com/docs

- Linux kernel
- Device drivers
- Architecture specifics
- Embedded Linux system development



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- By adding links on your website to our on-line materials, to increase their visibility in search engine results.

Linux kernel

Linux device drivers
Board support code
Mainstreaming kernel code
Kernel debugging

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