Runtime Power Management on SuperH Mobile

Upstream Implementation and Status

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Outline

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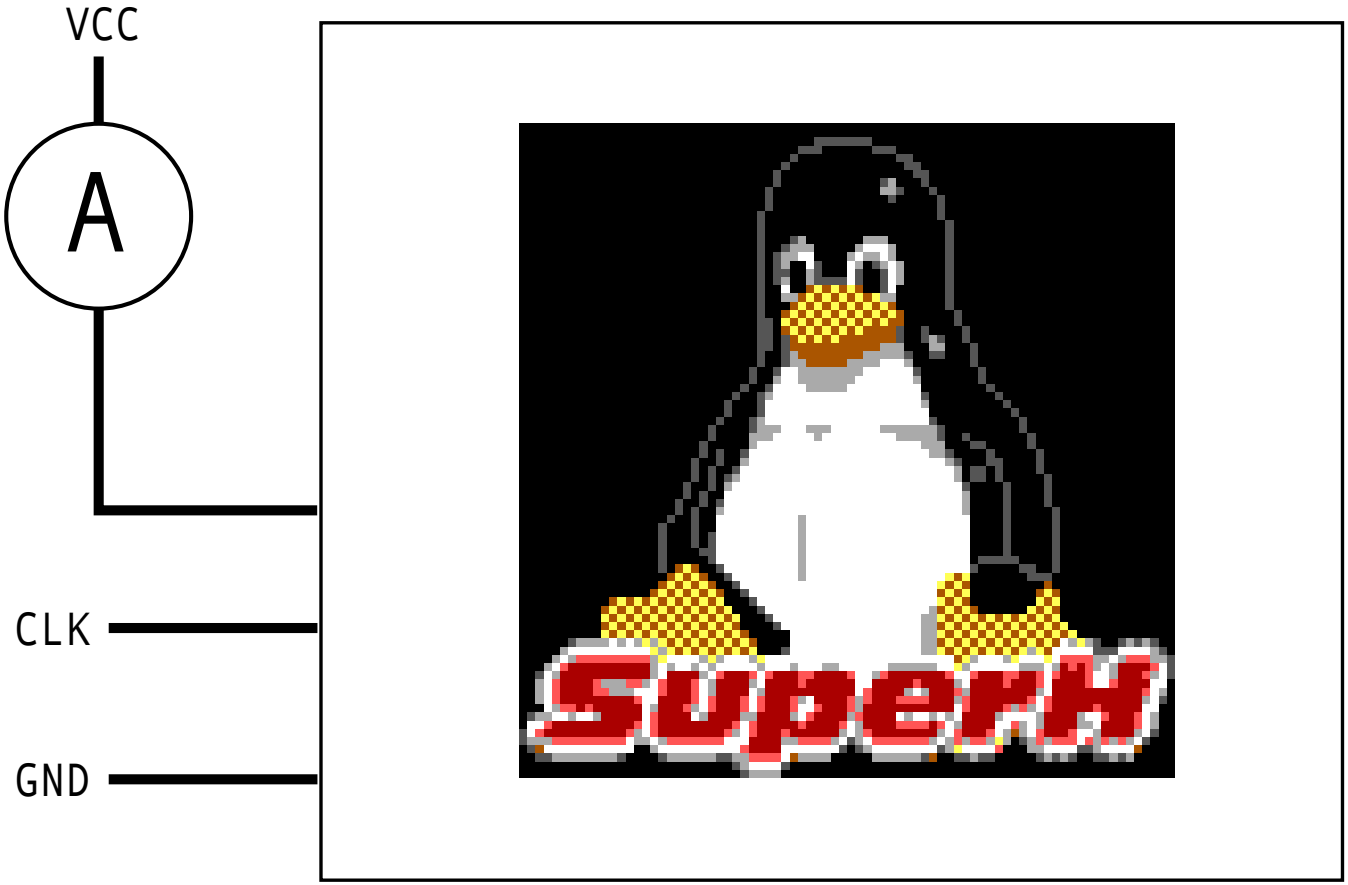
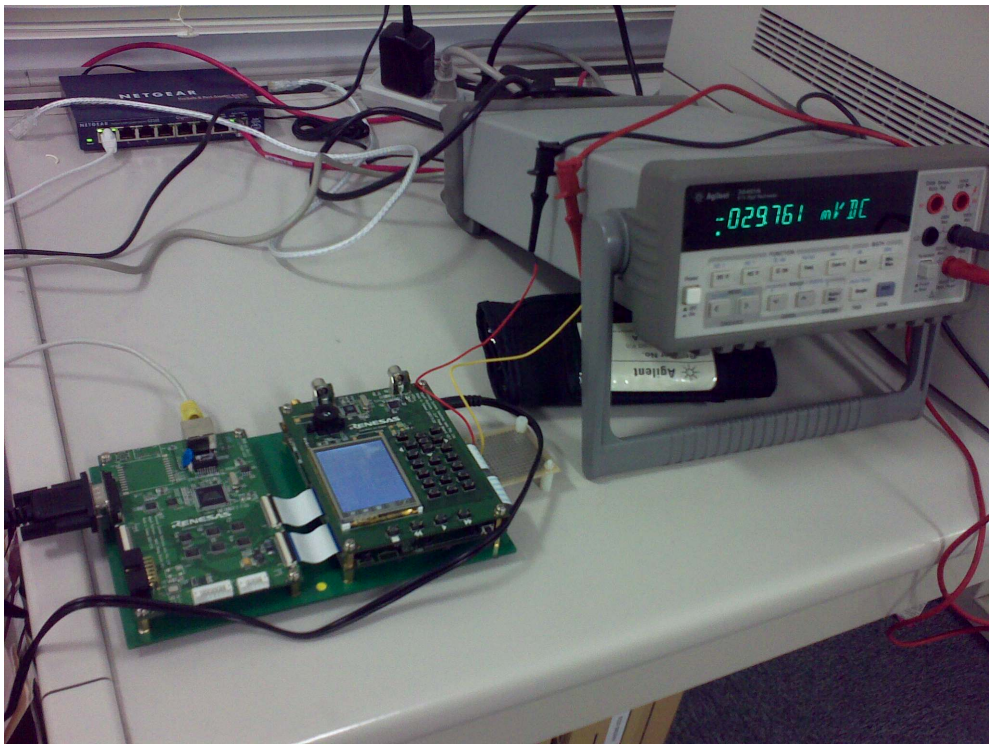
Hardware - Introduction



Hardware - Introduction



SuperH Mobile Migo-R board with Aglient 34401A multimeter

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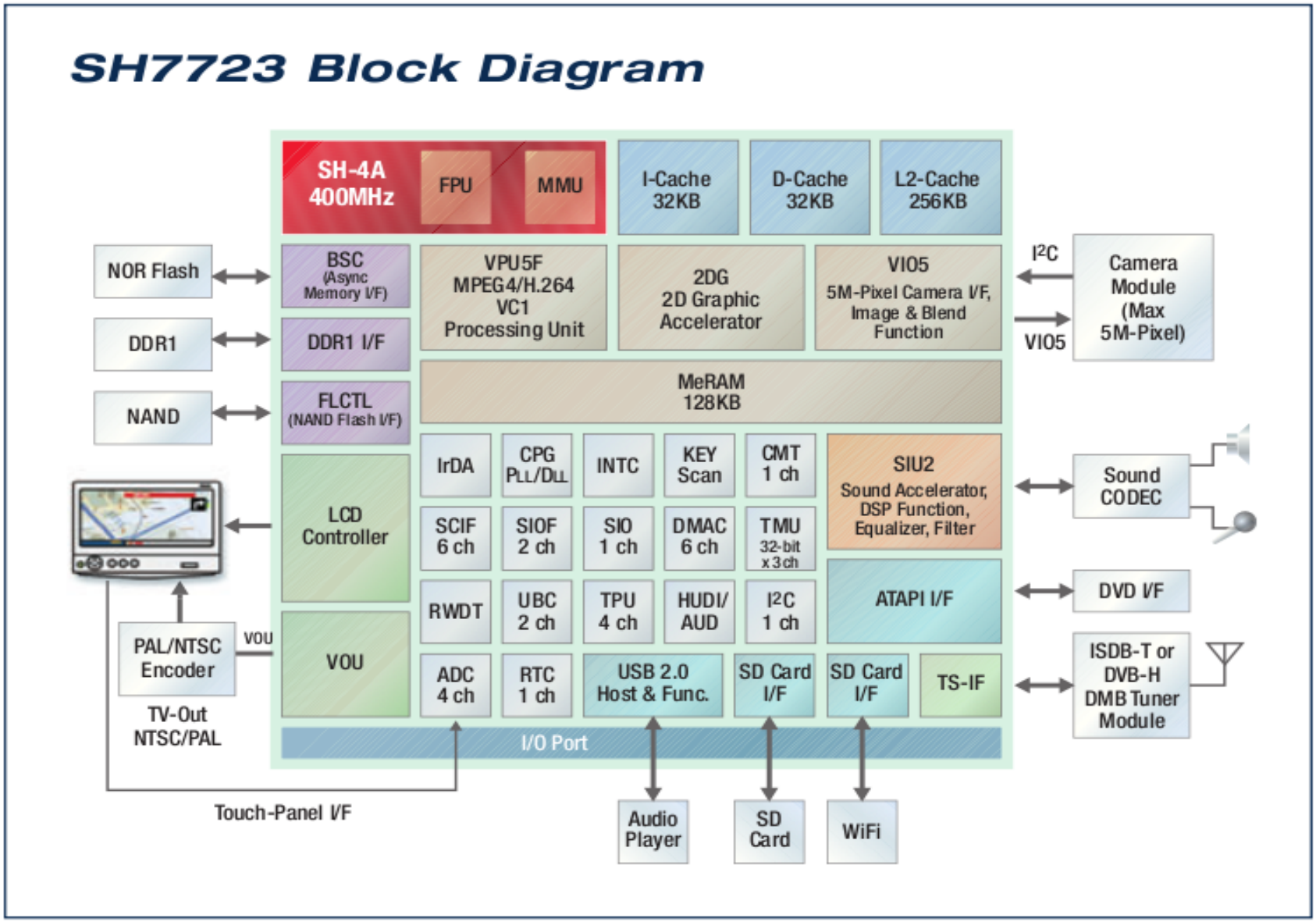
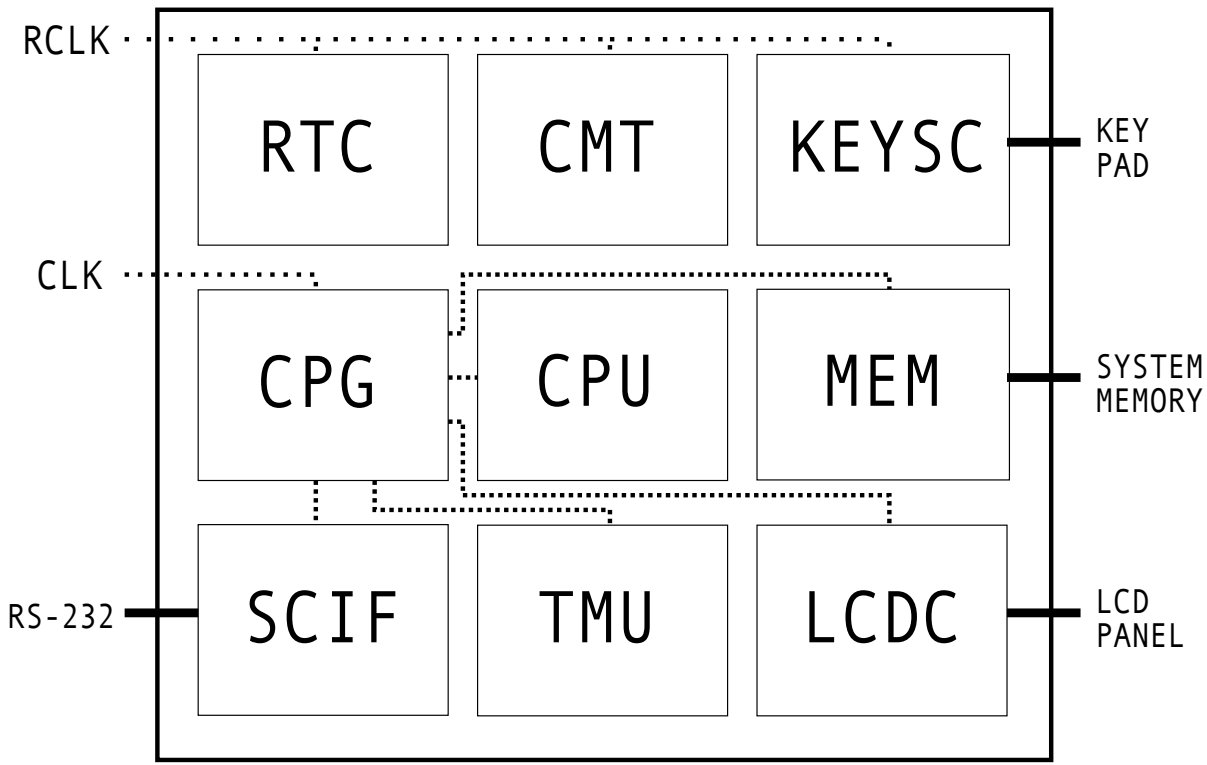
SuperH Mobile Hardware - SH7723



SuperH Mobile Hardware - Simplified Version



Simplified version of SH7343, SH7722, SH7366, SH7723

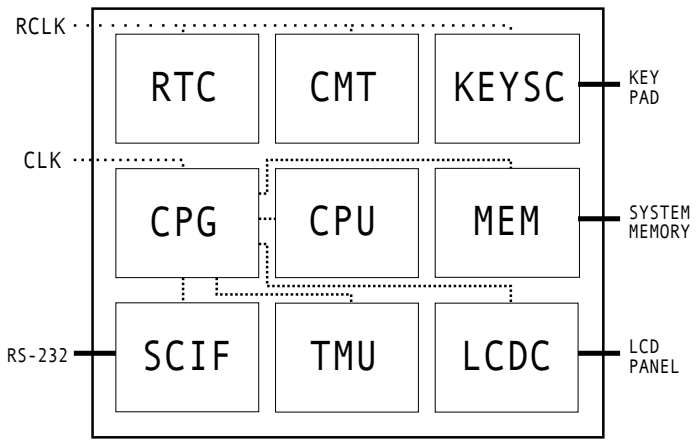
SuperH Mobile Hardware - Sleep modes

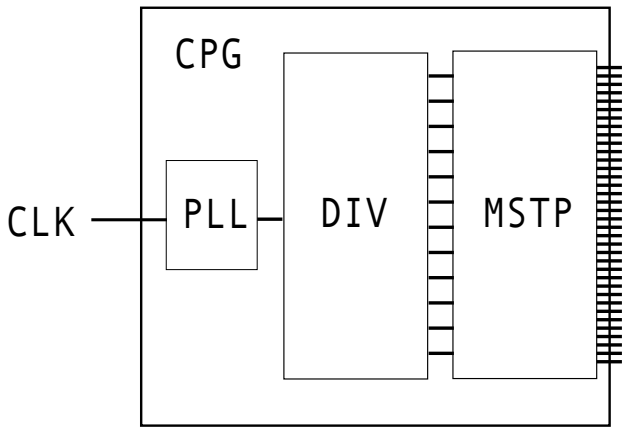
The `sleep` instruction controls system standby modes:

- “Sleep Mode” (CPU Core clock disabled only)
- “Software Standby Mode” (All system clocks off except RCLK)
- “R-Standby Mode” (Core power off)
- “U-Standby Mode” (Core power off, resume from reset vector)

Some processors support R-Standby only, some U-Standby only.

SuperH Mobile Hardware - CPG





Clock Pulse Generator:

- Simplified Version: 5 Clocks, 7 Module Stop Bits
- SH7723: 12 Clocks, 48 Module Stop Bits

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Clock Framework - API

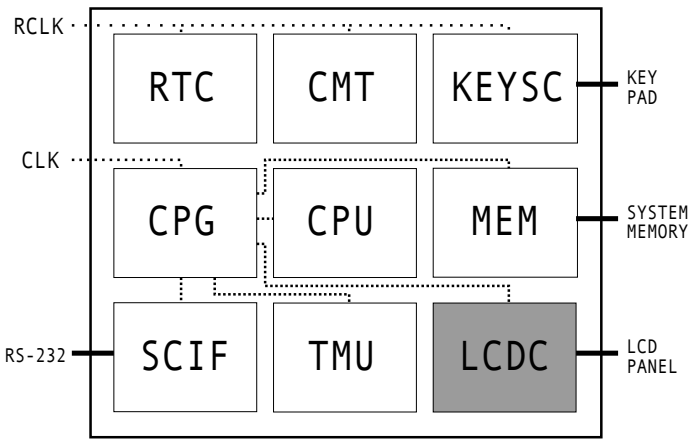
The architecture independent Clock Framework API:

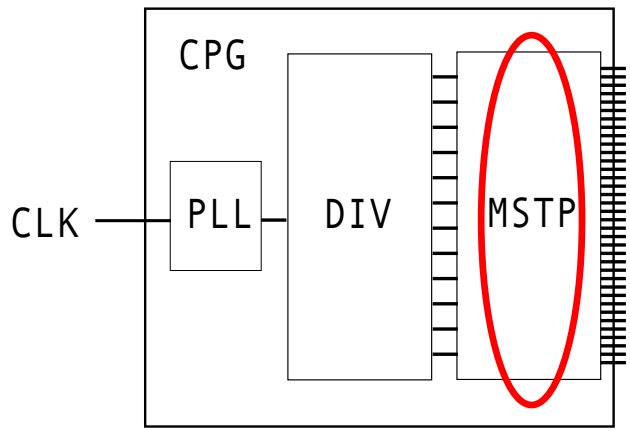
From `include/linux/clk.h`:

- `clk = clk_get(device, string);`
- `clk_enable(clk);`
- `clk_get_rate(clk);`
- `clk_disable(clk);`
- `clk_put(clk);`

Note: clk_get_rate() only valid after clk_enable()!

Clock Framework - SuperH Mobile





From `include/linux/clk.h`:

- `clk_enable(clk);`
- `clk_disable(clk);`

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Device Drivers - Overview

SuperH Mobile Device Driver Examples:

- i2c-sh_mobile.c - Clock enabled during I2C transfer
- sh_mobile_ceu_camera.c - Clock enabled during Camera capture
- sh_mobile_lcdcfb.c - Use deferred io with SYS panels
- sh_sci.c - Serial port receive needs clock enabled
- uio_pdrv_genirq.c - UIO device needs clock framework feature!

Device Drivers - PM Suggestions

For Energy Efficient Device Drivers...

- Use clock framework for System Clocks / Module Stop Bits
- Disable clocks when hardware is unused
- Avoid software polling

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Sleep Modes - Overview

Architecture independent overview:

- Light: Low latency - Few dependencies - Basic Power Savings
- ...
- ...
- ...
- Deep: High latency - Many dependencies - Good Power Savings

Theory: For best power savings, enter as deep mode as possible!

Sleep Modes - Self-Refresh Limitations

Self-Refresh...

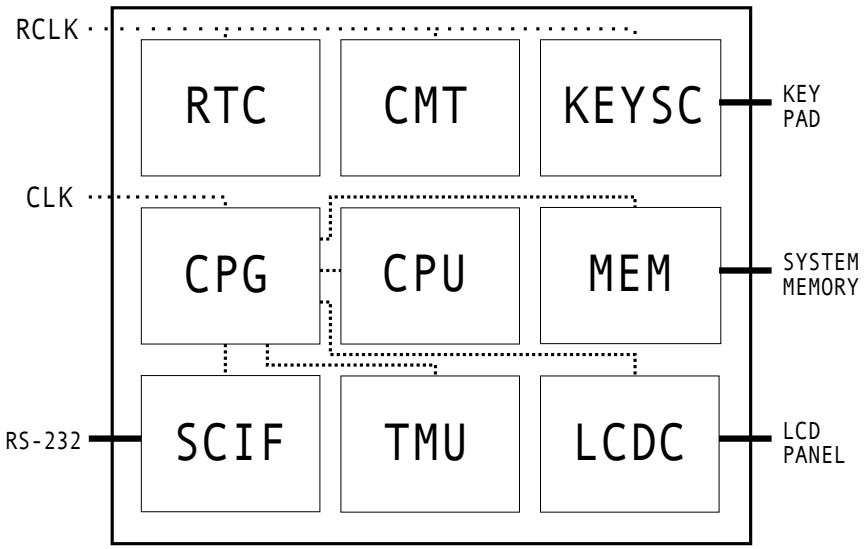
- is a must when System RAM clocks are stopped
- means System RAM may not be accessed
- requires Sleep code in cache or on-chip RAM

SuperH Mobile Sleep code is...

- Implemented in relocatable assembly code
- Relocated to on-chip RAM and executed there

In the future sleep code may use a simple in-kernel code generator

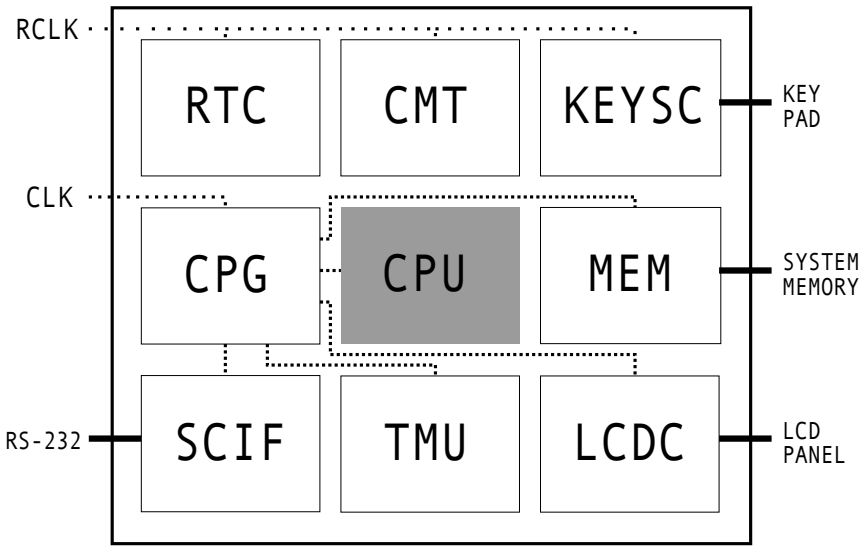
Sleep Modes - SuperH Mobile Software



SuperH Mobile Software Sleep Modes:

- “Sleep Mode”
- “Sleep Mode” + System RAM in Self-Refresh
- “Software Standby Mode” + System RAM in Self-Refresh
- “U/R-Standby Mode” + System RAM in Self-Refresh

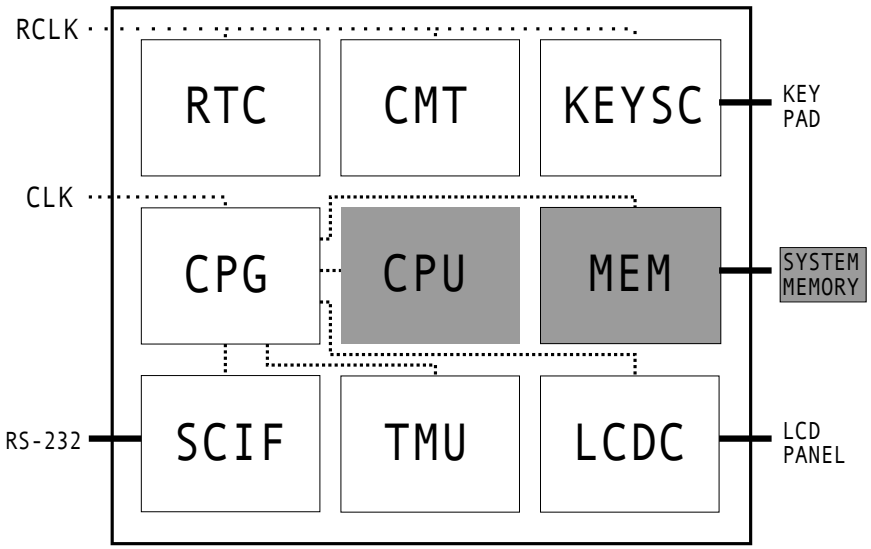
Sleep Modes - “Sleep Mode”



SuperH Mobile “Sleep Mode” properties:

- Stops CPU Core clock
- Wakeup from interrupt or reset
- Low latency, few hardware dependencies
- Basic power savings

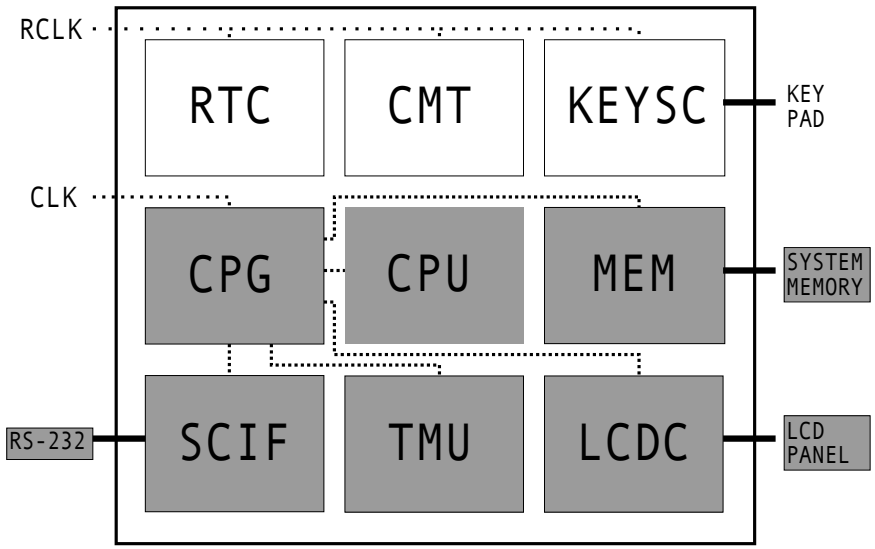
Sleep Modes - “Sleep Mode”



“Sleep Mode” may be combined with System RAM Self-Refresh:

- Special Linux-only software sleep mode
- Saves System RAM power
- May only be used if System RAM is inactive
- Must check bus master activity

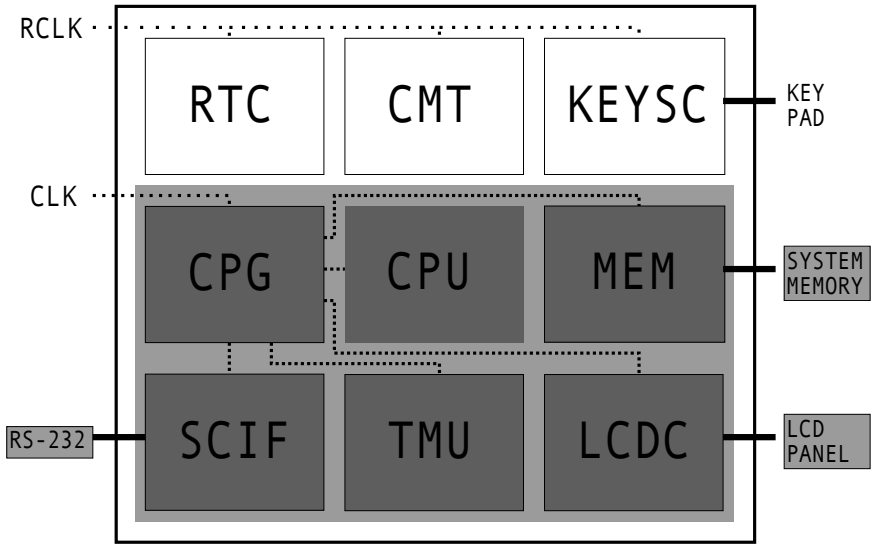
Sleep Modes - “Software Standby Mode”



SuperH Mobile “Software Standby Mode” properties:

- Stops all system clocks except RCLK
- System RAM must be put in Self-Refresh mode
- Wakeup from interrupt or reset
- Around 2 ms latency, many hardware dependencies

Sleep Modes - “U/R-Standby Mode”



SuperH Mobile “U/R-Standby Mode” properties:

- Powers down SoC Core area
- Wakeup from interrupt or reset
- “U-Standby Mode” resumes from reset vector
- Most hardware blocks need re-init on resume

Sleep Modes - Upstream Status

Queued for 2.6.30:

- “Sleep Mode”
- “Sleep Mode” + System RAM in Self-Refresh
- “Software Standby Mode” + System RAM in Self-Refresh

Future work:

- “U/R-Standby Mode” + System RAM in Self-Refresh

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Hibernation and Suspend - Overview

Easy theory:

- Suspend System
- Wait for Wakeup Event
- Resume System

But in practice:

- Suspend and Hibernation are quite different
- Per-device `struct dev_pm_ops` contains 14 callbacks
- Few in-tree architecture implementations

Hibernation and Suspend - Hibernation

Suspend-to-Disk (`CONFIG_HIBERNATION`):

- Freezes system activity, suspends drivers
- Saves image to swap, turns power off
- Power on, boots kernel, loads image from swap
- Resumes drivers, continues system activity

Generic SuperH implementation, tested on a sh7785lcr board

Hibernation and Suspend - Suspend

Suspend-to-Ram (`CONFIG_SUSPEND`):

- Freezes system activity, suspends drivers
- Enters Sleep mode, waits for wakeup event
- Resumes drivers, continues system activity

On SuperH Mobile..

- Sleep mode translates to “Software Standby Mode”
- RTC and KEYSC drivers support `device_may_wakeup()`
- CONFIG_PM_TEST_SUSPEND is known to be working

Hibernation and Suspend - CONFIG_KEXEC_JUMP

`CONFIG_KEXEC_JUMP`:

- Hybrid approach using kexec
- Suspends and resumes drivers like CONFIG_HIBERNATION
- Enters secondary kernel
- Can be used for suspend to disk or sleep mode.

Hibernation and Suspend - Upstream Status

- Hibernation and Standby are queued for upstream 2.6.30
- Kexec Jump is queued for upstream 2.6.30 as well
- Latest kexec-tools git has SuperH kexec jump support
- “U/R-Standby” and wakeup dependencies need more work

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Timers - Overview

The Linux kernel manages time using:

- Clockevents (Schedules next timer event)
- Clocksources (Keeps track of elapsed time)

Available SuperH Mobile Timers:

- CMT (Driven by RCLK, can be used to wake up from deep sleep)
- TMU (High resolution, stopped in “Software Standby Mode”)

Timers - Tickless

Classic jiffy-based system: (`CONFIG_NO_HZ=n`)

- Clockevent: `CLOCK_EVT_MODE_PERIODIC` mode
- Clocksource: Optional

Tickless system: (`CONFIG_NO_HZ=y`)

- Clockevent: `CLOCK_EVT_MODE_ONESHOT` mode.
- Clocksource: Required (!)

Check wakeup with `CONFIG_TIMER_STATS` + `/proc/timer_stats`

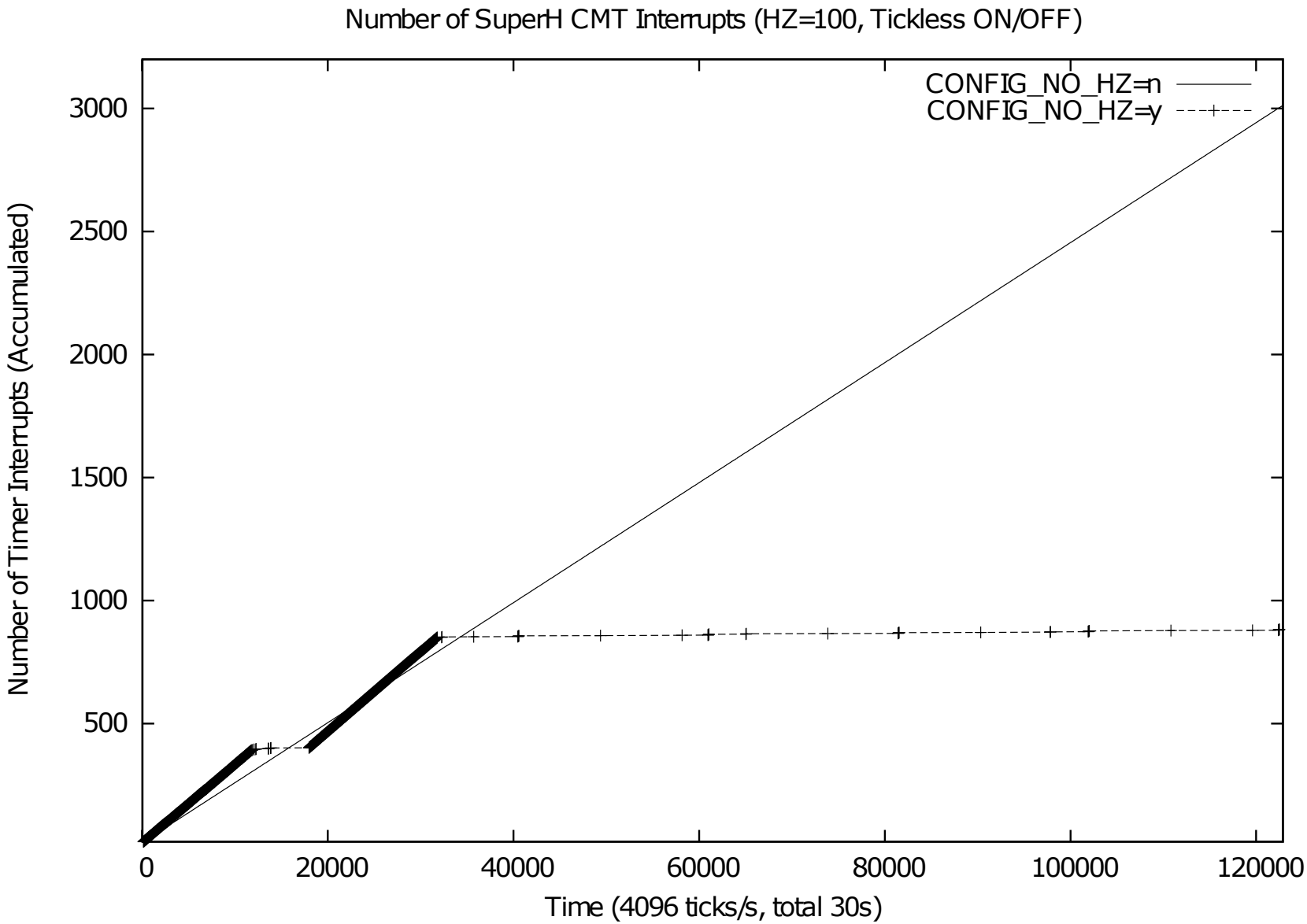
Timers - SuperH CMT

Problem: Only one CMT Timer available in deep sleep

Solution: SuperH CMT driver...

- Clockevent and Clocksource with a single timer channel
- Timer hardware counting up, wraps to 0 on match
- Match register reprogrammed, software accumulates time
- Provides a low resolution clocksource
- Supports `CLOCK_EVT_MODE_ONESHOT` clockevent mode.
- Allows tickless operation with a single timer!

Timers - Tickless SuperH CMT



Timers - Upstream Status

Timer changes queued for 2.6.30:

- SuperH CMT driver (clockevent only)
- Clockevent set_mode() delta patch
- setup_irq() and remove_irq() patches

Timer changes submitted upstream:

- Clocksource patches (power management, callback args)
- Early Platform Driver patches
- SuperH CMT driver updates (clocksource/early platform)
- SuperH CMT early platform data

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Idle loop - CPU Core Power Management

CPU Core power is managed by the idle loop:

- Works well with light sleep
- However, deep sleep comes with latency costs

Cpuidle..

- Keeps track of sleep modes and their latency
- Makes use of SuperH Mobile Software Sleep Modes
- Tries to enter as deep sleep mode as possible

Idle loop - Upstream Status

2.6.30 status:

- Regular SuperH idle loop is using “Sleep Mode” already

Cpuidle status:

- Prototype supports “Software Standby Mode”
- Needs clock framework for dependencies
- Tickless timers needed for good performance

Outline

Outline

Performance

Typical Processor Power Consumption [SH7722 @ 266/66/133 MHz]:

- No Power Management: ~0.6W
- “Sleep Mode”: ~0.2W
- “Software Standby Mode”: ~0.01W

Migo-R System Power Consumption (Without LCD board):

- Loaded CPU or “nohlt” idle: ~0.6W
- “Sleep Mode” when idle: ~0.4W
- “Software Standby Mode” when idle: ~0.2W
- External Ethernet chip consumes ~0.6W (!)

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Upstream Status

2.6.30:

- Timer patches
- “Sleep Mode” and “Software Standby Mode”
- System RAM in Self-Refresh
- Suspend-to-Disk (CONFIG_HIBERNATION)
- Kexec Jump
- Suspend-to-Ram (CONFIG_SUSPEND)
- Driver wakeup updates (RTC/KEYSC/Touchscreen)

Future Work

Future Work:

- Improved clock framework support
- Cpuidle integration
- Frequency scaling
- “R-Standby” support
- Driver updates
- UIO Clock framework support