Understanding Power Management Design Issues for Handheld Wireless Devices

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Presentation Overview

- “System” Power Management Defined
  - How Does It Differ from Component Level Power Management?
- Hardware Design for Power Management
  - Design-Time and Run-Time Features
- Software-Based Run-Time Power Management
  - Performance Adjustment, Energy Sharing, and Event Reduction
- Summary
General Definition of Power Management

- **Definition:**
  - The intelligent supervision and manipulation of energy sources and energy loads in wireless devices, so as to extend usable life (without affecting perceived performance)

- **Why?**
  - Because improvements in batteries (energy sources) are not keeping up with the requirements of devices (energy loads)
Power Management – The Good News

- Power management is a growing business
- Major semiconductor and system software vendors are making a significant push to reduce the energy consumption of their products and are making their products more energy-aware
- Major hardware/software development tools suppliers are incorporating features to allow designers to better manage and limit energy consumption
- Results at the component level:
  - Handling of leakage current in silicon
  - Use of power islands to make energy control more granular
  - Provision for power modes in CPU hardware and OS software
The “System” Power Management Challenge

- These innovations at the semiconductor and system software level must be orchestrated into device designs
  - How a component’s power management features are used is highly dependent on the system design of the device itself
  - Many items impact how components are combined into a complete device design
    - Feature requirements
    - Usage scenarios
Hardware Design for Power Management

- High-efficiency power supplies
- Support for multiple low-power modes
- Partitioned power control for peripherals
- Battery management
- Voltage adjustment
- Peripheral performance enhancers
- Peripheral power measurement
- Peripheral performance measurement
Hardware Design – System Block Diagram
Hardware Design – Power Measurement

[Diagram showing the structure of a computing system with various components such as RISC CPU Core, SDRAM, NOR Flash, NAND Flash, Expansion Interface, Card Interface, Memory, Power Supply, and Battery. The Legend box indicates Power Measurement, Connector (off-board), and CPU Sub-System.]
Hardware Design Summary

- High-efficiency power supplies
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- Partitioned power control for peripherals
- Battery management
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- Peripheral performance enhancers
- Peripheral power measurement
- Peripheral performance measurement

To design a truly low-power device, you must expand on “functional” debug hardware to include “power” debug hardware.
Software-Based Run-Time Power Management

- Performance Adjustment
- Energy Sharing
- Event Reduction
Performance Adjustment

- A device’s software tasks have varying performance requirements
- Most of today’s CPUs for wireless devices can operate at different clock frequencies
- Proper adjustment of clock frequency can greatly impact battery life
- This is an area of significant business interest right now
Clock & Voltage Scaling

- The internal performance level of a CPU core is directly proportional to its clock frequency.
- The power consumed by a CPU core is directly proportional to its clock frequency.
- The power consumed by a CPU core is directly proportional to the square of its supply voltage.

\[ P = K \times F \times V^2 \]
Reducing a CPU’s clock frequency by 50% without reducing voltage cuts power consumption for the core by about 50%.

However, because internal performance is reduced by 50%, a task can take twice as long.

The result is that energy consumption is approximately the same.

However, if voltage is dropped too, overall energy consumption is reduced.
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*We call this a “just-in-time” clock/voltage adjustment algorithm.*
“Just-in-time” algorithms do not analyze Run mode; rather they just minimize Idle.

“Saturation” algorithms analyze the system and adjust clock frequency and voltage, even when the CPU is not Idling.

- Saturation algorithms search for periods when performance is independent of clock frequency.
  - Example scenarios include peripheral activities such as wireless or disk I/O.
  - Energy consumed during these scenarios can drop by 50% or more, depending on the combination of peripheral activity.
  - The challenge is determining when performance is independent of clock frequency.

“Saturation” algorithms can also incorporate other system factors such as battery performance issues.
The graph shows low-level microprocessor “relative” throughput for loading of data from cached and uncached locations.

- Throughput of cached loads is directly proportional to clock frequency.
- Throughput of uncached loads is not proportional to clock frequency, and if detected unobtrusively, can be used to reduce energy consumption with minimal performance effects.
Clock & Voltage Scaling

- The graph shows high-level throughput and energy consumption for file access to a Compact Flash storage device.
- A halving of clock frequency drops throughput only 2.5%.
- A halving of clock frequency drops energy consumption 11%.
  - Total “system” energy consumption
  - No voltage adjustment
Energy Sharing

- Devices have multiple internal loads with differing characteristics
- Different batteries have operational features that define how well they handle different types of loads
- Correct matching of batteries to loads can increase a device’s operational life and lengthen a rechargeable battery’s life
Energy Sharing – Load Distribution

Load distribution networks direct the flow of energy from multiple sources to multiple loads.

The goal is to “match” source and load characteristics.
Energy Sharing – Hybrid Sources

- To achieve the most efficient release of energy, an energy source must operate as close to its optimal regime as possible
  - Batteries are non-linear and provide optimum energy release only in a very narrow range of operation (supply current, temperature, etc.)
  - Run/Idle modes create highly variable peak-to-average power and energy consumption
  - A single energy source is not efficient for all modes
- A hybrid energy source incorporates multiple sources and hardware/software to distribute energy from the sources in real-time as a function of load changes
  - Hybrid gasoline/electric automobiles have a similar philosophy
  - Devices with widely variable power modes – such as cell phones and smart sensors – can benefit greatly from properly managed hybrid sources
The graph shows a standard battery source (red) and a hybrid source (black).

At a 1% run/idle duty cycle, the hybrid source increases battery life by 20% (without altering volume or weight).
Event Reduction – Defined

- Reducing the number of events (interrupts) to allow the CPU to spend more time in lower-power modes, without necessarily affecting performance
Event Reduction Concepts

- Direct memory access (DMA) is a well-known feature that takes on new meaning in wireless devices, because it allows the number of events to be reduced, thereby increasing Idle time and consequently battery life.
  - Software developers should incorporate hardware-assisted DMA whenever possible, avoiding polling and interrupt-driven I/O.
  - The result is a win-win: reduced CPU core performance requirements and lower power consumption.
- Many embedded operating systems now implement intelligent time-slicing, eliminating the standard 1ms thread-switching interrupt and replacing it with variable time-slices.
  - Software developers need to understand their software’s process/thread structure and adjust accordingly.
Summary

- Battery technology is improving at a linear rate and new energy source technology (e.g., fuel cells, radio isotopes) is not yet mass-producible, while energy requirements for devices are increasing at an exponential rate.
- Many silicon, software, and tools providers are now making their products energy-aware.
- Innovations in system-wide power management technologies are now taking advantage of the energy-aware features of new components, thereby reducing the gap between energy sources and energy loads.