



Research on Power Management Strategies for Low Power Electronic Systems Targeting Intelligent Terminals

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Abstract

The power management strategy is the core element of low-power design for intelligent terminals, and its effectiveness directly determines the overall energy efficiency performance of the system. The electronic systems in smart terminals usually have the characteristics of diverse functions and dynamic changes in workload, which puts high demands on the adaptability and flexibility of the power supply system. At the same time, the development of advanced integrated circuit technology also brings new opportunities for low-power design of intelligent terminals, making it possible to carry out refined power management at the chip level. On the other hand, the trend of heterogeneous intelligent terminal processors is becoming increasingly evident, integrating multiple types of computing units, which poses new challenges for power management and requires differentiated power consumption control based on the characteristics of different computing units. In addition, the introduction of hybrid power architecture also opens up new avenues for energy-saving optimization of the system, but at the same time requires the development of intelligent scheduling algorithms and reliable power management mechanisms. In view of this, it is of great significance to explore in-depth the power management strategy of low-power electronic systems for intelligent terminals.

Keywords

Intelligent terminal; Low power electronic systems; Power management; Strategy exploration

The low-power design of intelligent terminal electronic systems is a complex system engineering that involves multiple levels, such as chips, circuits, devices, algorithms, etc., posing severe challenges to power management strategies. Efficient power management requires in-depth optimization from dynamic adjustment mechanisms, heterogeneous resource management, intelligent management of hybrid power sources, and is closely related to chip technology, system architecture, and application scenarios. Exploring low-power electronic system power management strategies for intelligent terminals is related to the battery life, user experience, and sustainable development of intelligent terminals [1]. In view of this, this article aims to explore low-power electronic system power management strategies for intelligent terminals, sort out key technologies for power management of intelligent terminals, analyze low-power optimization approaches, and provide new ideas and methods for energy-saving design of intelligent terminals.

1. Principles of Power Management for Low Power Electronic Systems

The power management of low-power electronic systems in smart terminals needs to follow a series of basic principles to minimize the overall power consumption of the system while ensuring performance and reliability. Efficient power management cannot be achieved without comprehensive consideration of multiple aspects such as chip technology, circuit design, and application scenarios. It is necessary to start from the perspectives of energy consumption perception, demand forecasting, power scheduling, and heterogeneous resource collaboration, and build a globally coordinated and dynamically optimized control mechanism. By implementing real-time monitoring of the working status and load requirements of each functional module, the power management system can establish accurate energy consumption models and then minimize unnecessary energy losses through strategies such as dynamic voltage and frequency regulation, task allocation and migration, and power switch standby [2]. For intelligent terminals using heterogeneous computing architectures, power management also needs to fully utilize the differences in energy efficiency characteristics of different processor cores, intelligently match task types and computing resources, and strive for optimal power consumption while meeting performance constraints.

For the increasingly popular hybrid power architecture, intelligent terminal power management should focus on the collaborative complementarity of multiple power sources, comprehensively utilize the advantages of multiple energy sources, and maximize energy utilization efficiency and extend system endurance time through energy routing optimization, dynamic priority adjustment, and other methods. This requires strict control of power management at different levels and stages, and the development of strategies tailored to local conditions. It is necessary to plan and build an energy consumption control loop from top to bottom, as well as perform fine-grained optimization based on the characteristics of different devices and tasks from bottom to top [3]. Only through the coordination of software and hardware, and the consideration of chip-level and system-level, can the optimal energy efficiency balance be achieved in complex application environments, promoting the sustainable development of intelligent terminals.

2. Low Power Electronic System Power Management for Intelligent Terminals

2.1 Systematic Construction of Dynamic Adjustment Mechanism and Energy Efficiency Improvement

The dynamic adjustment mechanism is the core of intelligent terminal power management, and its systematic construction and energy efficiency improvement are key to achieving low-power electronic systems. Power management for intelligent terminals requires comprehensive consideration of multiple levels, such as chips, devices, circuits, algorithms, etc., collaborative optimization of software and hardware resources, and maximizing the energy-saving potential of the system. By constructing a comprehensive dynamic adjustment mechanism system, the working status and resource allocation of the system can be adjusted in real time according to application requirements and environmental changes, minimizing energy loss while ensuring performance, thereby significantly improving the overall energy efficiency level [4].

Specifically, at the chip level, advanced processes, optimized layouts, and reduced leakage can be used to reduce power consumption. For example, advanced processes such as using high dielectric constant gate dielectric materials and multi gate transistor structures can improve device performance while reducing power consumption; Optimizing layout and wiring, reducing the length of critical signal lines, and minimizing parasitic capacitance can help reduce dynamic power consumption; The use of high threshold transistors, gate bias, and other techniques can effectively suppress leakage current. In circuit design, technologies such as multiple power domains, voltage scheduling, clock gating, and dynamic frequency regulation can be used to achieve fine-grained control of power supply and clock. For example, dynamically migrating between different voltage domains based on task load to reduce unnecessary charge loss; Using adaptive voltage scheduling strategy to appropriately reduce voltage amplitude while meeting performance constraints; Gate control non critical path clock signals to reduce dynamic power consumption; Dynamically adjust the main frequency according to the working status of the chip, and automatically switch to low-power mode when idle or under low load.

In terms of system architecture, the energy efficiency advantages of heterogeneous multi-core can be leveraged to build fine-grained energy consumption awareness and task scheduling mechanisms. For example, integrating high-efficiency processor cores and low-power co processors, and flexibly adjusting them according to application characteristics; Introducing an energy aware operating system kernel to achieve real-time monitoring and intelligent

regulation of power consumption and performance; Design optimal scheduling strategies for different task types to balance the load distribution among multiple processor cores [5]. In addition, energy-saving optimization can also be carried out at the algorithmic and software levels. For example, designing efficient data compression algorithms to reduce energy costs for data storage and transmission; performing instruction-level optimization on key code segments to improve code execution efficiency; developing adaptive energy-saving scheduling algorithms to predict future load trends based on system status and user behavior, and making energy management decisions in advance.

In short, the power management of low-power electronic systems for intelligent terminals needs to start with the systematic construction of dynamic adjustment mechanisms, and comprehensively, multi-level, and fine-grained exploration of energy-saving optimization space. Collaborative design of software and hardware, matching of upper and lower layer protocols, and consideration of local and global aspects can maximize energy efficiency, meet increasingly stringent power constraints and continuously growing performance requirements, and promote the sustainable development of intelligent terminals.

2.2 Fine-Tuned Power Consumption Control of Heterogeneous Computing Resources

The refined power consumption control of heterogeneous computing resources is a key optimization strategy for low-power electronic systems targeting intelligent terminals. With the increasingly diverse application scenarios of intelligent terminals, their processor architectures are showing a trend of heterogeneous development, integrating various types of computing units such as central processing units, graphics processors, digital signal processors, neural network processors, etc. The power consumption characteristics and energy efficiency ratios of different computing units vary significantly, so it is necessary to finely control power consumption according to their characteristics, fully leverage their respective energy efficiency advantages, and minimize the total system power consumption while meeting application performance requirements.

Specifically, the refined power consumption control of heterogeneous computing resources can be approached from the following aspects. At the hardware level, it is necessary to comprehensively model and analyze the power consumption characteristics of various computing units, obtain their energy consumption data, and provide a basis for upper-level power management. This requires a built-in power consumption detection circuit in chip design to monitor real-time parameters such as current, voltage, and power of each core module. At the same time, corresponding low-power design techniques should be adopted based on the characteristics of different types of computing units, such as clock gating, voltage and frequency regulation, and functional module partitioning.

At the system software level, it is necessary to build a heterogeneous resource energy consumption perception and management framework to unify the energy consumption information of each computing unit and provide standardized power consumption monitoring and control interfaces. The operating system needs to integrate power consumption statistics and analysis modules to achieve visual evaluation of heterogeneous resource energy efficiency. On this basis, intelligent task scheduling strategies should be developed based on application load characteristics and energy constraints, taking into account the energy efficiency advantages of each computing unit, dynamically allocating tasks, balancing performance and power consumption. For example, for computationally intensive tasks such as multimedia encoding and decoding, they can be prioritized for execution on energy-efficient graphics processors or dedicated accelerators. For control and event-driven tasks, lower power central processing units can be prioritized for processing. At runtime, the system also dynamically adjusts the working mode and frequency voltage configuration of each computing unit based on changes in task load and battery level, intelligently balancing energy efficiency and performance. When the load is light, the operating frequency can be reduced or even non-essential computing components can be turned off, while in high load scenarios, performance requirements can be met by increasing the frequency voltage. For predictable load changes, adjustments can be made in advance through task prefetching, task migration, and other methods to avoid frequent mode switching and reduce additional power consumption overhead.

2.3 Intelligent Management Technology for Hybrid Power Architecture

The intelligent management technology of hybrid power architecture is another important development direction for low-power electronic systems targeting intelligent terminals. Traditional intelligent terminal power systems usually use a single battery power supply method, which is difficult to meet the increasing demand for battery life and

power consumption constraints. The hybrid power architecture integrates multiple energy sources, such as lithium batteries, supercapacitors, photovoltaic cells, wireless charging, etc., to provide a more flexible and reliable power supply for smart terminals. At the same time, the hybrid power architecture also requires intelligent management technology to dynamically schedule multiple power sources based on energy availability and load demand, optimize energy utilization efficiency, and maximize system operation time.

The intelligent management of hybrid power architecture for intelligent terminals first requires the construction of a multi-power collaborative power supply mechanism, which comprehensively utilizes the energy advantages of multiple power sources. For example, in high load scenarios, lithium batteries are mainly used for power supply to ensure sufficient power output; In low load scenarios, supercapacitors or photovoltaic cells can be prioritized to reduce the discharge depth of lithium batteries and slow down their aging rate. At the same time, power priority management strategies can be introduced to determine the optimal power supply usage sequence and switching timing based on parameters such as energy density, conversion efficiency, and charge discharge characteristics of different power sources.

Next is to develop intelligent energy scheduling algorithms to achieve on-demand allocation of power supply energy. Algorithms require real-time monitoring of the system's energy consumption requirements and power supply capabilities, dynamically matching power sources and loads, and reducing energy waste. For example, load forecasting technology can be used to anticipate energy consumption trends in the future and make power scheduling decisions in advance; Alternatively, based on the charging status and aging degree of the power supply, the charging and discharging currents of each power supply can be controlled to extend its service life. In addition, it is necessary to strengthen the fault diagnosis and fault tolerance capabilities of hybrid power systems. Due to the inclusion of multiple power modules in a hybrid architecture, its reliability challenges are greater. Therefore, it is necessary to establish a sound fault monitoring, isolation, and recovery mechanism, and improve the robustness of the system through power redundancy design and adaptive reconstruction technology. For example, when a power module fails, the system can automatically switch to a backup power source to maintain basic functional operation; Simultaneously start the fault diagnosis program, locate and isolate the problematic module as soon as possible, and avoid the spread of the fault.

2.4 Predictive Control Driven by Artificial Intelligence

The predictive control driven by artificial intelligence has brought innovation to the power management of intelligent terminals. Traditional power management mainly relies on pre-set rules and thresholds, which are difficult to adapt to complex and changing usage scenarios and user needs. By introducing artificial intelligence technology, dynamic and adaptive power management can be achieved by learning and predicting the energy consumption model and user behavior of the system. This method can minimize energy consumption while meeting performance requirements, and provide personalized optimization strategies based on users' usage habits and preferences.

In the implementation process, it is necessary to first collect and process various energy consumption-related data, such as device-level voltage, current, power, as well as system-level resource usage and task scheduling information. These data can be obtained through built-in sensors and monitoring circuits, as well as recorded through software layer logging and tracking mechanisms. After obtaining enough data, machine learning algorithms can be used to analyze and model it. Common algorithms include decision trees, support vector machines, neural networks, etc., which can automatically learn and extract energy consumption patterns and patterns from data. In the modeling process, it is necessary to select appropriate features and hyperparameters for different types of devices and tasks, and evaluate the generalization performance of the model through methods such as cross-validation. After obtaining an accurate and reliable energy consumption model, prediction and control can be based on it. On the one hand, it is possible to predict the energy consumption demand for a certain period of time in the future based on the current system status and environmental conditions; On the other hand, the working mode and parameters of each device can be dynamically adjusted based on the prediction results and optimization objectives, such as adjusting the frequency and voltage of the CPU, controlling the switching status of peripherals, etc. During operation, it is necessary to continuously monitor the actual energy consumption of the system and use it to update and optimize the energy consumption model, forming a closed-loop feedback control. In addition, reinforcement learning and other technologies can be introduced to enable the system to autonomously learn and optimize control strategies based on energy consumption feedback, continuously improving energy efficiency.

3. Conclusion

This article systematically explores the power management strategy of low-power electronic systems for intelligent terminals, and conducts an in-depth analysis from the aspects of dynamic adjustment mechanism, heterogeneous computing resource control, and intelligent management of hybrid power supply. By constructing an energy consumption perception loop, matching the energy efficiency characteristics of heterogeneous resources, and coordinating the scheduling of multiple power sources, the energy-saving potential of the system can be maximized, significantly reducing power consumption while meeting performance requirements. The proposed power management optimization method provides new ideas for low-power design of intelligent terminals, which is of great value for extending battery life and improving user experience. In the future, further research is needed in intelligent power management, energy acquisition and storage, and other areas to promote the continuous improvement of energy efficiency of intelligent terminals, and to assist their widespread application in fields such as the Internet of Things and artificial intelligence.

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