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SmartReflex™ Power and Performance Management Technologies: reduced power consumption, optimized performance

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Introduction

Wireless mobile devices are approaching an impasse. With the convergence of new computing, communication and entertainment applications on wireless handsets, power demands are increasing rapidly, yet battery capacity cannot keep up. At the same time, consumers want sleek, compact mobile devices they can slip into a pocket. Integration at the chip level – often combining multiple processing cores in the same device – and smaller, submicron fabrication processes help to reduce the size of wireless handsets while enabling added functionality. Unfortunately, smaller submicron processes exacerbate the problem of standby leakage power.

Wireless handset and other mobile device manufacturers are challenged to reduce power consumption while enhancing system performance; in other words, do more for less. SmartReflex™ power and performance management technologies from Texas Instruments (TI) – now significantly improved with second-generation SmartReflex 2 techniques – have product-proven, intelligent and adaptive capabilities that aggressively meet these challenges and provide a pathway to future solutions.

New SmartReflex 2 power and performance technologies:

- Dynamically adjusts transistor performance versus leakage
- Dynamically lowers voltages for idle memory banks
- Automates the application of SmartReflex™ technologies in the design process

Holistic power management approach

Managing power budgets for wireless mobile devices, both today and moving forward, will be an unprecedented challenge that can only be resolved by an aggressive, holistic power management approach. This approach starts with process technologies and moves upward to hardware, system-on-a-chip (SOC) architectures and software.

Wireless carriers clamor for increased capabilities in handsets so that they can develop new applications that will increase their average revenue per user (ARPU). Subscribers welcome the increased functionality. As a result, video, mobile digital TV, high-fidelity audio, 3-D video games, digital photography, strong security applications and other functions could soon jeopardize the long-held industry minimum of four hours of talk time and 120+ hours of standby on a single battery charge. Battery capacity simply cannot keep pace with the exciting new functionality on mobile handsets. While consumers demand new applications, they also want smaller, sleeker mobile devices, accelerating the trend toward higher levels of silicon integration and smaller submicron process geometries.

Key benefits

- TI's SmartReflex™ technologies combine intelligent and adaptive silicon, circuit design and software to solve power and performance management challenges at smaller process nodes. OEMs can offer sleeker, multimedia-enabled mobile devices with long battery life and less heat dissipation.
- SmartReflex technologies enable high performance at low power.
- SmartReflex technologies embed intelligence to adaptively adjust voltage, frequency and power based on device activity, modes of operation and temperature for maximum power reduction.
- With SmartReflex technologies, you can add new multimedia applications to mobile wireless devices without sacrificing standby time, talk time or battery life.
- SmartReflex technologies cross traditional boundary lines in systems, managing multiple processing cores such as DSPs and other functional blocks.
- SmartReflex technologies solve the chip-level leakage power challenge that is exacerbated at smaller, deep-submicron process geometries.
- TI has shipped more than 1 billion devices with SmartReflex technologies.

Traditional power management techniques such as low-power modes, clock gating and dynamic voltage and frequency scaling (DVFS) have commonly been implemented in wireless handsets, personal digital assistants (PDAs), laptop computers and other power-sensitive devices.

Designers will continue to apply these techniques, of course, but the industry's current trends necessitate comprehensive and aggressive solutions that address both power and performance.

For high-performance, power-sensitive applications, power reduction is only half the challenge. Providing higher performance while consuming less energy per function is imperative. The sophisticated applications coming to mobile handsets operate at much higher frequencies than voice communications. For example, simple audio on a wireless mobile device typically operates at less than 20 MHz, whereas a video application may require a frequency of 200 MHz or more.

Just managing the hundreds of thousands of pixels in a high-resolution video display generates a tremendous number of power-consuming processing cycles. Only creative new power reduction techniques that cross functional blocks and include multiple processing cores will allow systems to adapt dynamically and achieve high performance with less power.

In addition to dynamic power (the power that is consumed when transistors switch), wireless mobile devices are encountering new standby leakage power challenges caused by shrinking component geometries. Smaller, more highly integrated components are needed to fit more functionality into the compact new form factors consumers demand. Unfortunately, moving down the process scale from 90 to 65 to 45 nanometer (nm) has an exponential effect on leakage power; leakage thus becomes an increasingly significant percentage of a device's total power.

Moreover, while process technologies shrink, the extra on-chip memory added to support new applications becomes a prime source of standby leakage power. Power dissipation translates to heat, and in mobile wireless devices heat is more than just a discomfort to users: it can have considerable negative effects on performance, eroding the reliability and durability of the system itself.

SmartReflex power and performance management technologies

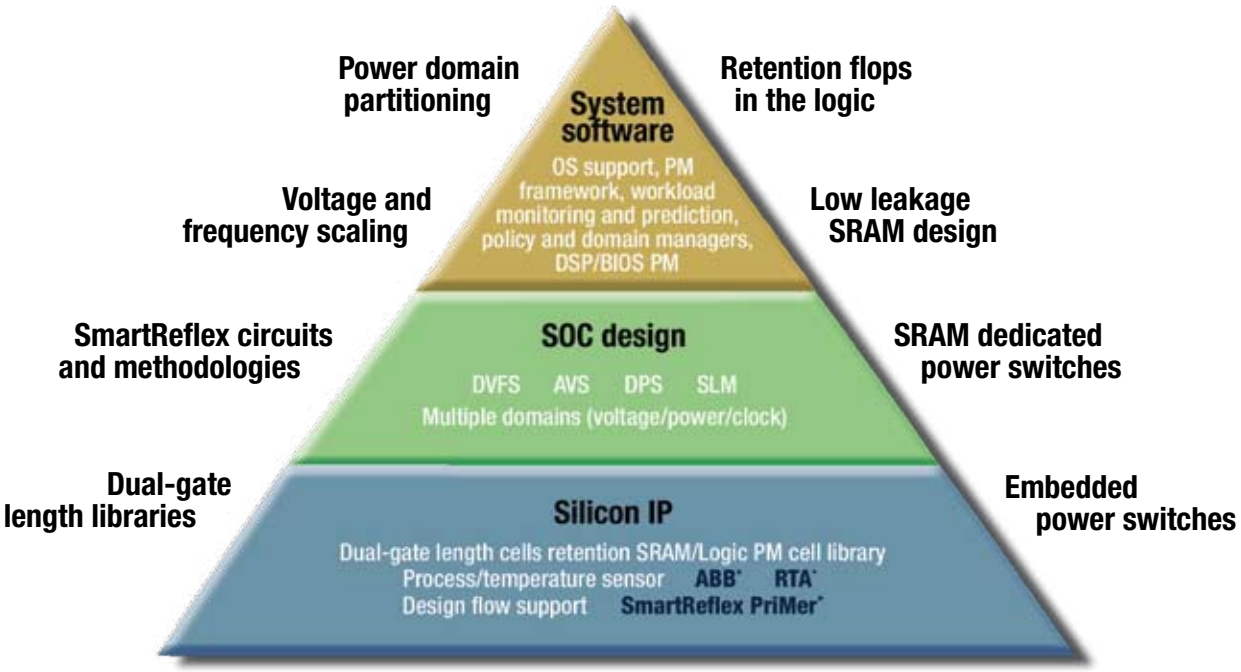
Traditional power strategies have focused on dynamic power reduction, but the holistic approach of TI's rich, product-proven SmartReflex technologies takes a more comprehensive system-wide perspective on the interrelated issues of power and performance, addressing both dynamic and standby leakage power. The SmartReflex portfolio of power and performance management technologies addresses today's mobile device challenges with a pathway to future solutions.

SmartReflex technologies comprise silicon intellectual property (IP); techniques that you can apply at the system-on-a-chip (SOC) design level; and system software that manages many of the hardware-enabled SmartReflex technologies and interfaces seamlessly to other power management techniques based in operating systems (OS) or third-party software subsystems. SmartReflex 2 adds the automatic application of key power management techniques in the design flow to these capabilities. TI is leveraging SmartReflex technologies for industry-leading power and performance management in custom and standard product devices.

TI SmartReflex™ 2 Technologies

Aggressive power management involving all system components - silicon technology, SoC design and software

Reductions in both active and static power



*New SmartReflex 2 Technologies

Silicon IP

At the silicon level, TI has a track record as an industry pioneer in sophisticated power and performance capabilities, many of which have transitioned into SmartReflex technologies. One major emerging challenge that SmartReflex technologies address is standby leakage power, which becomes a significantly greater part of a device's total power at smaller process nodes. You can apply several SmartReflex technologies to drastically limit leakage from a device. For example, SmartReflex technologies combine to reduce standby leakage power in the OMAP3430 processor by as much as three orders of magnitude. Today, many of TI's 90-nm and all of its 65-nm wireless components implement SmartReflex technologies to reduce leakage power. In the future, all new devices at the 90-, 65-, 45-nm and smaller process nodes will incorporate these breakthrough technologies.

New with SmartReflex 2 technology – SmartReflex 2 enhances these silicon techniques with forward body biasing (FBB) and reverse body biasing (RBB), unique techniques that modulate the body voltage of transistor cells or blocks dynamically to gain performance and reduce leakage. For several CMOS process nodes, TI has employed transistors with short and long gate lengths in order to increase switching speed or reduce leakage. FBB and RBB carry this technique a step further by enabling small modifications in transistor threshold voltages after the device has been manufactured and is in operation. Tests indicate that FBB can increase performance by as much as 15 percent and RBB can reduce leakage by as much as 40 percent depending on device operating temperatures.

Another SmartReflex technology at the silicon level is a library of power management cells that enable power switching, isolation and voltage shifting, thus facilitating a granular approach to partitioning a device's power domains. By structuring the device with multiple power domains, functional blocks can be powered down or put into a standby power mode when they are not active, thus reducing power consumption while ensuring optimal performance. To simplify chip-level integration, SmartReflex technologies feature an easy-to-use, nonintrusive design flow.

New with SmartReflex 2 technology – As power management techniques become increasingly complex, it becomes important to simplify their implementation in the design process. SmartReflex 2

	Silicon IP
Technology	**Description**
Retention SRAM and logic	SRAM and logic retention cells support dynamic power switching without state loss, lowering voltage and reducing leakage
Dual gate lengths	Longer gate length for lower leakage and shorter gate length for higher performance
Power management cell library	Switching, isolation and level shifters support multiple domains in SOC implementations
Process and temperature sensor	Adapts voltage dynamically in response to silicon processes and temperature variations
Design flow support	Complete, nonintrusive support for easily integrating SmartReflex technologies
Adaptive body biasing	Modulates transistor bias voltages dynamically in order to optimize switching speed versus leakage FBB and RBB together are called adaptive body biasing (ABB) (SmartReflex 2)
SmartReflex PriMer	Automates the implementation of SmartReflex power management techniques in the design and provides a UPF-compliant specification (SmartReflex 2)
SRAM retention til access (RTA)	Reduces leakage while retaining contents in SRAM arrays by lowering the voltage on idle memory blocks (SmartReflex 2)

technology addresses this issue with SmartReflex PriMer, a user-friendly tool that simplifies design, reduces development time, and improves verification without compromising the flexibility needed to meet different product requirements. SmartReflex PriMer automatically generates a Universal Power Format (UPF)-compliant specification, complete with power management features that include RTL descriptions of power domain insertion and protocol control, FBB/RBB and SRAM power management controllers, and a full suite of power management verification and assertion checks. By providing these details automatically, SmartReflex PriMer conserves power and improves design reliability while speeding time to market.

New with SmartReflex 2 technology – SmartReflex 2 technology adds SRAM retention 'til access (RTA), a technique of reducing power leakage in memory arrays by automatically lowering the voltage in memory banks when they are not being accessed. When the entire chip is idle, the entire array is put into a low-leakage state. Memory access logic also runs on a lower voltage to conserve power.

SOC design

In addition to established hardware techniques such as DVFS and clock gating that address dynamic power, SmartReflex technologies also include new innovative techniques at the architectural level of SOC design to address standby leakage power. For example, adaptive voltage scaling (AVS), dynamic power switching (DPS) and standby leakage management (SLM) are creative new technologies in the SmartReflex portfolio.

	SOC architectural and design technologies
Technology	**Description**
Adaptive voltage scaling (AVS)	Maintains high performance while minimizing voltage based on silicon process and temperature
Dynamic power switching (DPS)	Dynamically switches between power modes based on system activity to reduce leakage power
Dynamic voltage and frequency scaling (DVFS)	Dynamically adjusts voltage and frequency to adapt to the performance required
Multiple domains (voltage/power/clock)	Enables distinct physical domains for granular power/performance management by software
Standby leakage management (SLM)	Maintains lowest standby power mode compatible with required system responsiveness to reduce leakage power

System software

At the system software level, SmartReflex technologies include intelligent software that manages many of the lower level hardware-enabled technologies. For example, SmartReflex technologies include host processor power management, which features several capabilities deployed at the system level, such as a workload monitor, workload predictor, resource manager and device driver power management software. Additionally, the SmartReflex framework features the TI DSP/BIOS™ software kernel foundation.

SmartReflex technologies cross many traditional boundary lines, such as the distinction between processing cores. First- and second-generation power management solutions were by and large vendor-specific and limited in scope. They could only be applied to certain functional blocks or specific cores. As a result, these solutions only addressed a small portion of the device's power budget. In contrast, SmartReflex technologies support multiple cores, hardware accelerators, functional blocks, peripherals and other system components. In addition, SmartReflex system-level technologies are open to OS-based and third-party power management software so that you can develop a collaborative and cooperative environment with regards to power and performance.

	System software
Technology	**Description**
OS support	Provides an open environment for blending with operating systems and supports Symbian and Linux
Software power management framework	Intelligent control for power and performance management that is transparent to application programs and legacy code - Monitors system activity, not just processor activity
Workload monitoring and prediction	Determines system performance needs used to make intelligent power and performance management decisions
Policy and domain managers	Dynamically controls the system, providing the performance needed at the lowest power
DSP/BIOS software kernel foundation	Power and performance management software for DSPs

SmartReflex technologies: a holistic solution

TI's SmartReflex technologies embody a holistic, comprehensive approach to enable devices with the highest performance with the lowest power in the industry. This is possible because TI is one of the few semiconductor suppliers maintaining a broad-based and focused approach to its business, including advanced process technologies, its own silicon foundries, many years of system-level expertise and advanced IP.

The system expertise TI developed while working closely with wireless OEMs and manufacturers in other industries is an invaluable resource for SmartReflex technologies. With this extensive system-level knowledge, SmartReflex technologies work in unison, complementing each other and coordinating activities throughout the system. Only with this intimate knowledge and a thorough understanding of wireless mobile devices could SmartReflex technologies have the tremendous impact that they have already had on all facets of a system.

As a consequence of its extensive support over the years for handset manufacturers, TI has focused its research and development efforts to have an immediate effect on wireless mobile devices. TI's development of extensive product-specific IP is applied in SmartReflex technologies.

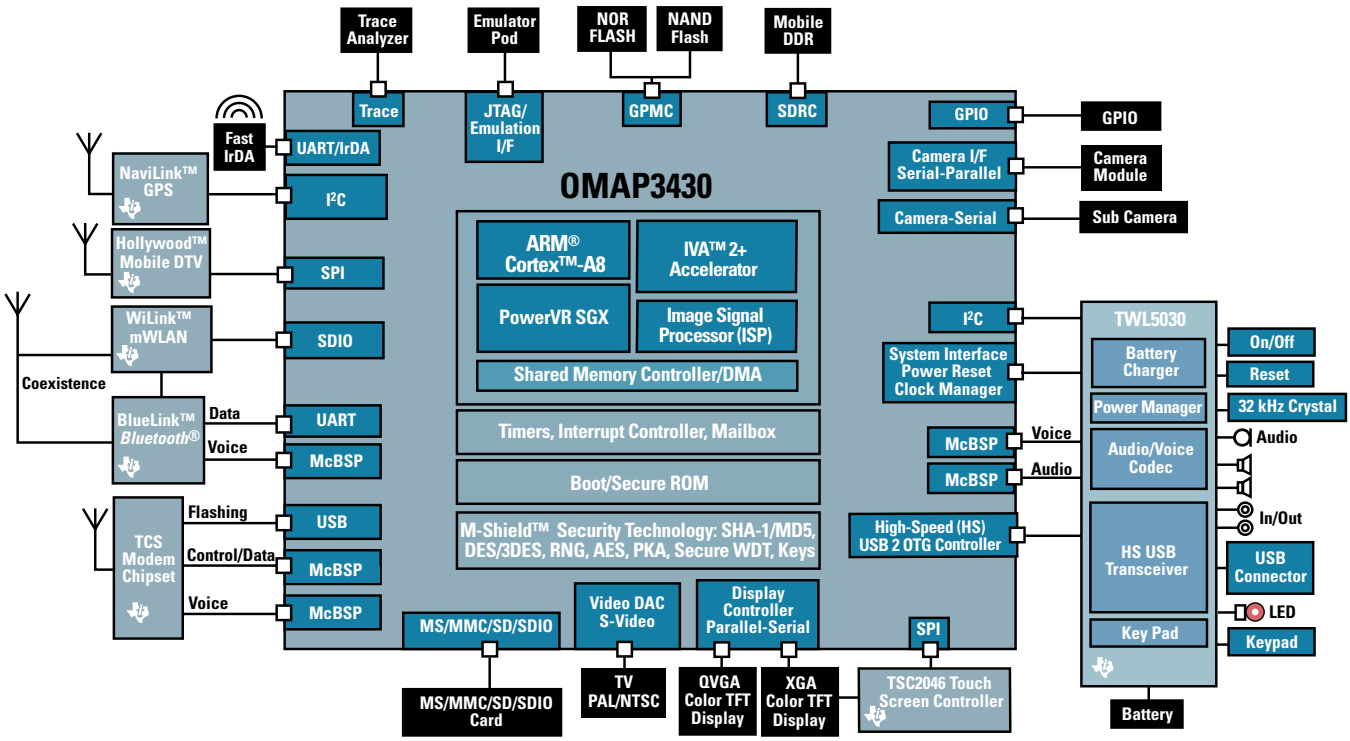
TI's leadership in chip fabrication technologies means that the company can develop SmartReflex technologies within the context of the process technologies used to produce the chips. As a result, SmartReflex technologies can address the issue of leakage power head-on. And because TI operates its own foundries, it is able to monitor, control and ensure the production quality of each device.

The OMAP3430 processor with SmartReflex™ technologies

The multi-core OMAP3430 mobile multimedia applications processor provides an excellent example of SmartReflex technologies used to reduce power consumption at the SOC level. With more than 150 million on-chip transistors, the 65-nm OMAP3430 processor features aggressive power management techniques that enable multi-standard video encode and decode in handheld applications.

The SmartReflex technologies employed by the device include multiple voltage domains with multiple discrete operating/performance points (OPPs) for cores and peripherals; 11 major power domains for fine-grained leakage control throughout the device; split-rail memories separating memory logic from arrays (allowing voltage rescaling for active power reduction or faster response); SRAM RTA; AVS to compensate for circuit temperature changes as well as changing levels of activity; and core logic designed with full power-down in standby mode.

TI designers also used SmartReflex PriMer in creating the OMAP3430 processor, ensuring power design reliability and helping TI bring the complex device to customers more quickly. The OMAP3430 processor's successful power management implementation results in an active power reduction of 66 percent and a reduction in leakage power of two to three orders of magnitude.



The future of power and performance management

The effects of SmartReflex technology on power consumption and system performance are constantly demonstrated in the vast number of mobile wireless devices that feature these innovative solutions. Indeed, TI has already shipped more than 1 billion components with embedded SmartReflex technologies.

The solid foundation for SmartReflex technologies now extends outward with the second-generation features of SmartReflex 2: dynamic adjustment of transistor performance versus leakage, lower voltages for unused memory banks and the automatic application of power management techniques in the design process. TI's roadmap for such capabilities stretches far into the future, penetrating deeper into wireless mobile devices while at the same time leveraging the application of SmartReflex technologies into other high-performance, power-sensitive industry segments.

The forces of the marketplace do not rest. Wireless mobile devices and other battery-operated systems must aggressively add new functionality and applications to attract users. New styles and popular industrial design will change the form factors that mobile devices come in, driving chips toward higher integration and smaller process geometries where new SmartReflex solutions await. As SmartReflex technologies continue to evolve, they will remain on the critical path for mobile applications well into the future.

For more information

www.ti.com.smartreflex

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