On-Demand Power™ Technologies: Laptop Applications and Case Study

Packet Digital, LLC

Scope

This document details the monitoring and assessment capabilities of the Packet Digital PowerSage™ advanced power management controller for embedded systems. PowerSage™ is based on Packet Digital's patented On-Demand Power™ technologies, delivering just-in-time, just-enough energy based on real-time system demands.

Specifically, Packet Digital presents a case study of PowerSage™ technology, demonstrating our innovations in monitoring and system level assessment for autonomous. The information within this document is specific to the development platform used at Packet Digital, and may be directly tailored to laptop computers, ultra-mobile PCs, portable media players, and cellular handsets.

The technologies in this document are patent pending and/or covered by one or more of the following US patents: 7228446, 7312646, and 7337335.

Power Management Approach

The fundamental approach of On-Demand Power is to monitor critical signals of communication from the microprocessor and between the microprocessor and peripherals. The intent is to correlate the activity of the circuitry to the system's demand for energy. An accurate correlation between activity and system demand allows the PowerSage autonomous power management unit (PMU) to dynamically adjust system voltages and clock frequencies unobtrusively, without interrupting operation or requiring specific software commands. Figure 1 illustrates the monitoring of communications by the PowerSage PMU.

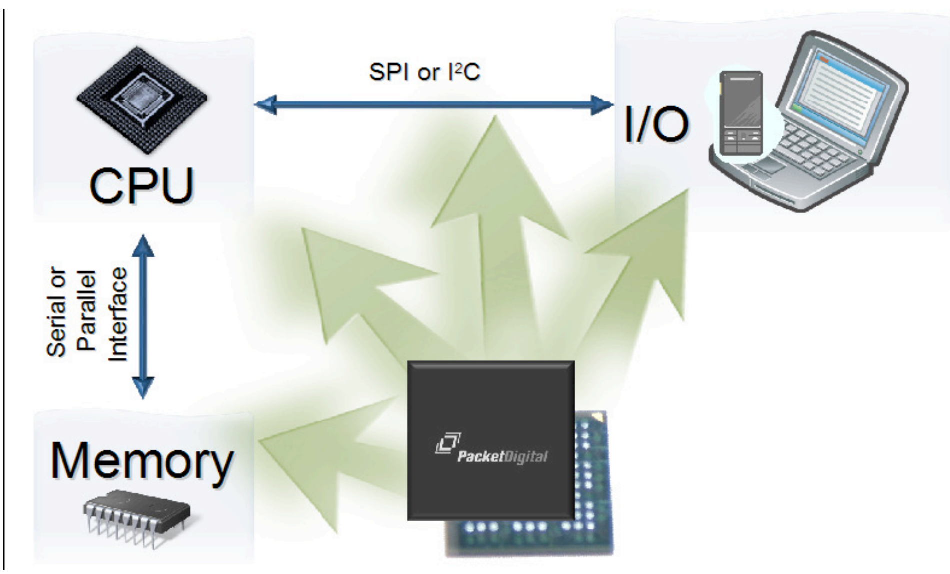

Figure 1: PowerSage monitors signals to dynamically adjust power delivery

This approach differs from other power management technologies that are inherently processor-centric. Conventional power management technologies focus on the processor as the target for dynamic voltage and frequency scaling. A review of available processor-centric dynamic power management methods show commonalities that inherently limit the effectiveness. These trends include, but are not limited to:

- The processor may not be the dominant energy user. Even substantial savings of energy on the processor have little overall improvements to the system. In smart phone applications, the display and power amplifier circuitry often use far more energy than the applications processor. Figure 2 illustrates the energy consumption by major functional block by a laptop computer during the playback of an audio compact disc. In this application, the processor uses approximately 3.25W, whereas the rest of the system uses nearly 16W. A system level power management method has 6x the effectiveness of a processor-centric power management method.

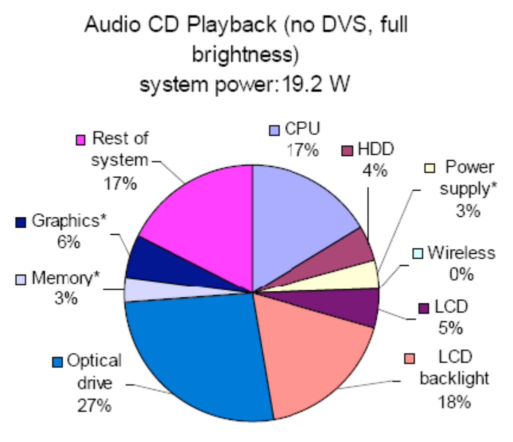

Figure 2: Energy demands of a laptop computer by function

- Processor-centric power management methods are not easily ported to new applications. New designs are limited by the ability for conventional power management circuitry to be integrated. If the capabilities are not added by the silicon designers, system developers are unable to add or modify areas to be managed.
- Processor-centric functions may be largely software based, which will always be slower and less efficient than hardware based solutions. Additionally, the software design requires design and validation, which may slow the time-to-market and decrease revenue opportunities.
- Processor-centric power management is largely based on usage models and predictions for operations, specifically in cellular handsets. If the usage models differ from actual operation, then the battery life suffers due to inefficiencies. Market research suggests that cellular handsets will have open access on applications, allowing users to add and remove applications from their smart phones much like they can add and remove software programs from their personal computers. In that model, usage models are completely ineffective, as there is no way to accurately predict the way that a consumer would use their phone if the types of functions and applications are unknown (and the amount of energy that each application may consume.)

Packet Digital's On-Demand Power technologies trace back to the fundamentals of electronic power management. Although different systems have radically different power management profiles and demands, the dynamic power dissipation, P_D of digital systems is governed by the equation:

$$P_D \, \alpha \, V_{DD}^2 \bullet f \bullet C_L \bullet N$$

where V_{DD} is the power supply voltage, f is the clock frequency, C_L is the load capacitance, and N is the number of gates switching. If we can reduce the frequency and the supply voltage, we reduce the dynamic power dissipation.

The supply voltage and clock frequencies are dictated by voltage regulation and oscillators. The control of the voltage regulation and oscillators can be moved to a system that allows adjustment of supply voltages and clock frequencies outside the processors and peripherals to control the dynamic power dissipation. Packet Digital has developed autonomous dynamic power management, by monitoring bus communications and system signals to determine the activity level (or N, in the previous equation) with the intent of scaling the supply voltages and frequencies accordingly.

Case Study – Laptop Computer

Conventionally, power management techniques on laptop computers have focused on the processor, adding dynamic voltage and frequency scaling commanded by the operating system. Additional power management features may include the ability for the operating system to power off peripherals on command. Power must be restored manually before the peripheral is used. This power management strategy is unfavorable due to negative impacts on the user experience.

Packet Digital implemented our On-Demand Power power management technologies into a Panasonic Toughbook CF51 with a Intel Pentium M (Dothan) 1.6GHz processor to dynamically manage the hard drive and optical drives. The laptop incorporates modern functions of a mobile computer such as wifi wireless networking, DVD/CD optical drive, and is powered from a 14V battery pack.

State of the Art power management techniques were used to ensure the baseline was operating at the lowest possible power. Software based control over CPU frequency and voltage scaling were enabled, hard disk drives were set to aggressive internal power management, and the OS kernel was optimized for low power.

Current sensors were incorporated into the study to track the real-time power usage of the drives and a standard suite of tests was run to determine power consumption throughout the test. Three tasks were tested, with a short idle time in-between. Automation was used to ensure that the test is always run exactly the same. First, a spreadsheet application was used while a MP3 audio file was being played. Second, a DVD video was played from the optical disk drive. Third a 3D video game was played. Figure 3 shows the baseline power consumption.

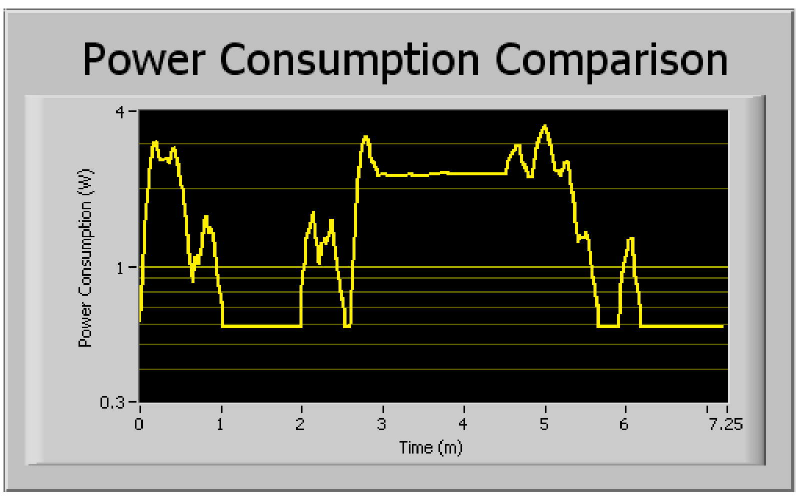

Figure 3: Power Consumption Through Test

After analyzing the baseline power consumption, On Demand Power (ODP) was applied to the hard disk drive (HDD) and optical disk drive (ODD). This represents a partial system solution and proves the scalability of On-Demand Power technology to peripherals. The ODP circuitry monitors the communication buses and reduces the power delivered to the peripherals when the devices are not in use. Immediately when needed, the ODP circuitry delivers additional power to the devices to perform tasks.

The ODP circuitry monitors the system in real time and controls the regulators to dynamically modify the supply voltages. Since the sensing and control is all done in hardware, the operating system is not aware that the devices are consuming lower power. No system latency is introduced and the burden of power management control is not required by the operating system. This allows the user to experience a system with the feel and operation of a system that is 'always on'.

The same automated set of applications was executed the ODP enabled. Figure 4 illustrates the real time power consumption of both the baseline and the OPD enabled tests. Comparing the total power consumed between the tests, it is shown that the ODP circuitry performs the same tasks and reduces power consumption of the hard drive and optical drive by over 25%. The PowerSage PSG5120 provides the autonomous system level power management for dual hard disk drives, optical disk drives, or solid state drives.

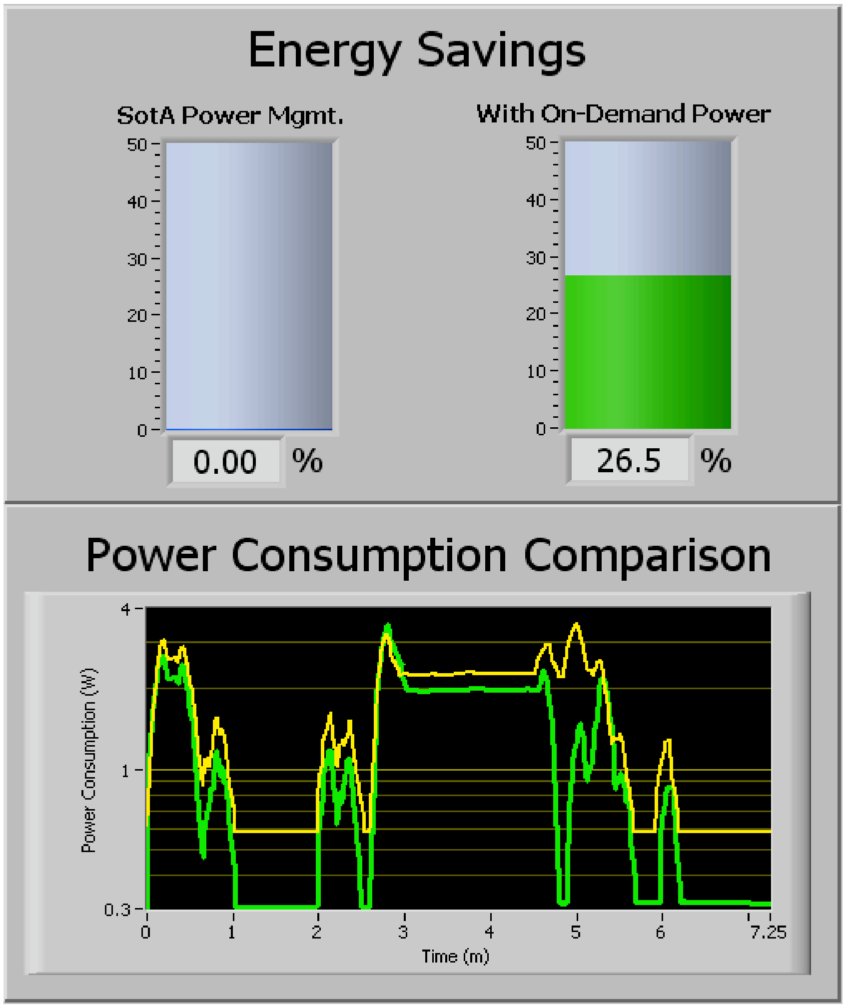

Figure 4: Power Consumption Comparison

Conclusions

On-Demand Power™ technologies build upon the best power management of conventional systems, but improve performance considerably over any other solution. The system level approach is critical to give the maximum operational life and enables additional features, greater miniaturization, or lower cost of design and operation.

The core concept of monitoring and assessing activity and demand is application, operating system, architecture, and packaging independent. ODP circuitry, and the PowerSage™ intelligent PMU, monitors serial and parallel communications buses to determine when to scale system voltages and clock frequencies. This approach is inherently scalable to new processors, transceivers, memories, and peripherals.

Packet Digital has demonstrated this on simple single-function devices and complex multi-function platforms with a wide range of applications. In all cases, power consumption is reduced with battery life greatly increased, to the point where consumers will choose ODP enabled components.