



On-Demand Power® Technologies:
Application and Technical Brief for a PDA

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.

The technologies in this document may be 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.

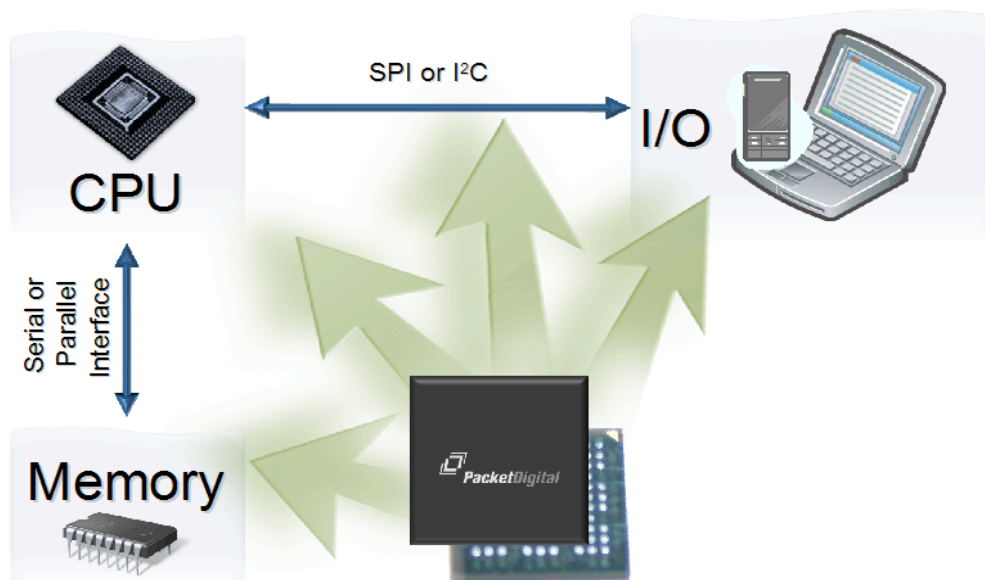


Figure 1: PowerSage monitors signals to dynamic adjust power delivery.

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 shows 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.

- 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 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 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.)

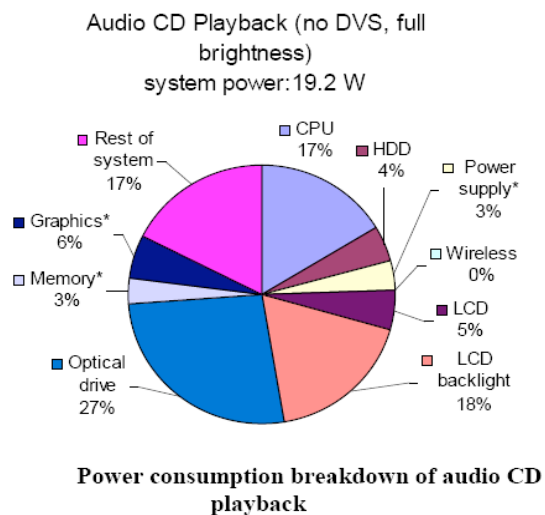


Figure 2. Energy demands of a laptop computer by function

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:

$$P_D \propto V_{DD}^2 \cdot f \cdot C_L \cdot N$$

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 – Personal Digital Assistant

Personal digital assistants (PDAs) combine many functions into a single portable device: address book, calendar, media player, and calculator, as well as hosting wired and wireless communication devices, games, and large databases for applications. PDAs can also play multimedia clips and movies, connect to Global Positioning Satellite (GPS) systems, and accept flash memory cards for larger data storage and retrieval.

Packet Digital used an OMAP Starter Kit (OSK) from Texas Instruments with the OMAP5912 processor, running standard PDA applications, with a Mistral LCD for touch screen input and display. The OSK uses a Texas Instruments TPS65010 Power Management Unit (PMU) to provide supply voltages for the multiple rails in the system.

State of the art power management techniques are used to reduce the energy consumption. Devices are placed in low-power modes, light emitting diodes are turned off, and the Linux operating system provides on-chip frequency scaling on the OMAP processor. Figure 3 shows the power consumption of the OSK board, while performing audio playback for an MP3 file (for approximately one minute), using the calculator function, and playing a WAV file.

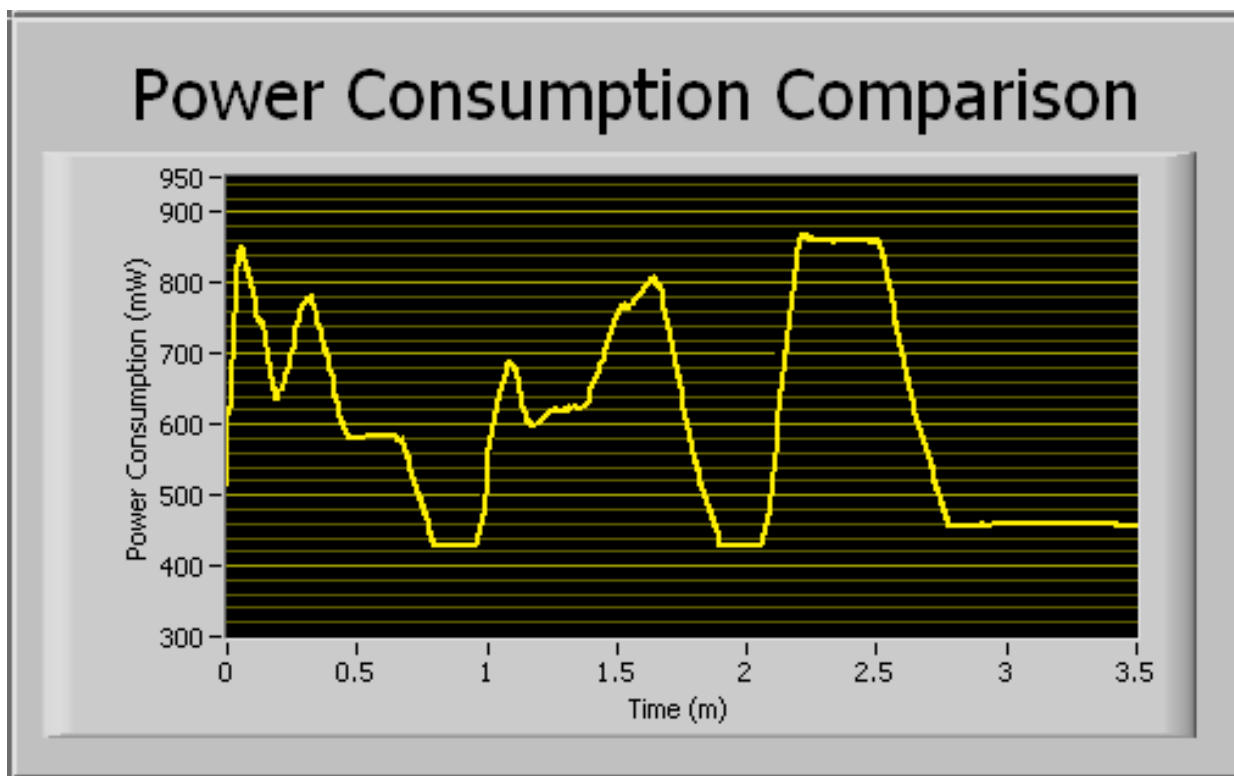


Figure 3. Power Consumption of the TI OSK for benchmark applications.

The ODP circuitry monitors the serial communication between the OMAP processor and peripherals on the I2C serial bus, and the parallel communication between the OMAP processor and flash memory. The ODP circuitry that monitors the system activity drives the TPS65010 circuitry to dynamically modify the supply voltages. In this case, **not only does ODP circuitry work seamlessly with processors, but also improves the performance of commercially available PMUs.**

The same application mix is executed with ODP circuitry enabled, with figure 4 illustrating the power dissipation of the OSK board. Table 2 illustrates the reduction in power management **in comparison to the best results using the advanced features of the OMAP and the TI PMU**. Figures 5 through 8 show the effectiveness of ODP circuitry for specific PDA applications. The PowerSage PSG3258 circuit provides autonomous system level power management for portable media applications, with two clock frequency outputs (from 1 Hz to 64 MHz) and multiple LDO/switching regulator supply rails.

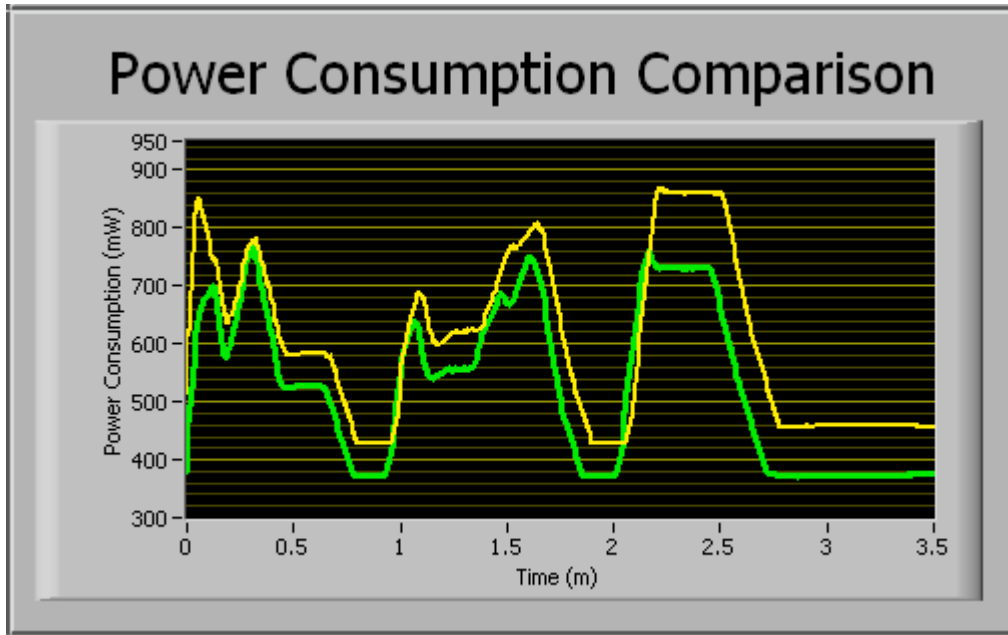


Figure 4. PDA applications without (yellow) and with (green) ODP power management

Table 2. Power Dissipation of the OSK for PDA applications

Power Dissipation, without ODP	Power Dissipation, with ODP enabled
396.13 mW	315.58 mW 20.33% Reduction

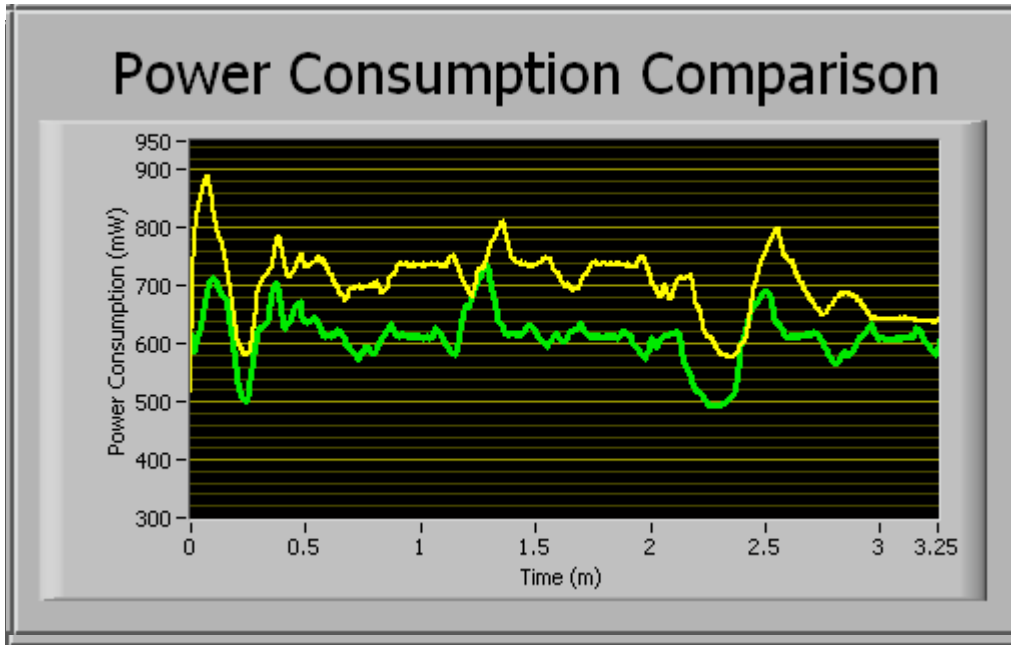


Figure 5. Calculator functions on the OSK without (yellow) and with (green) ODP power management

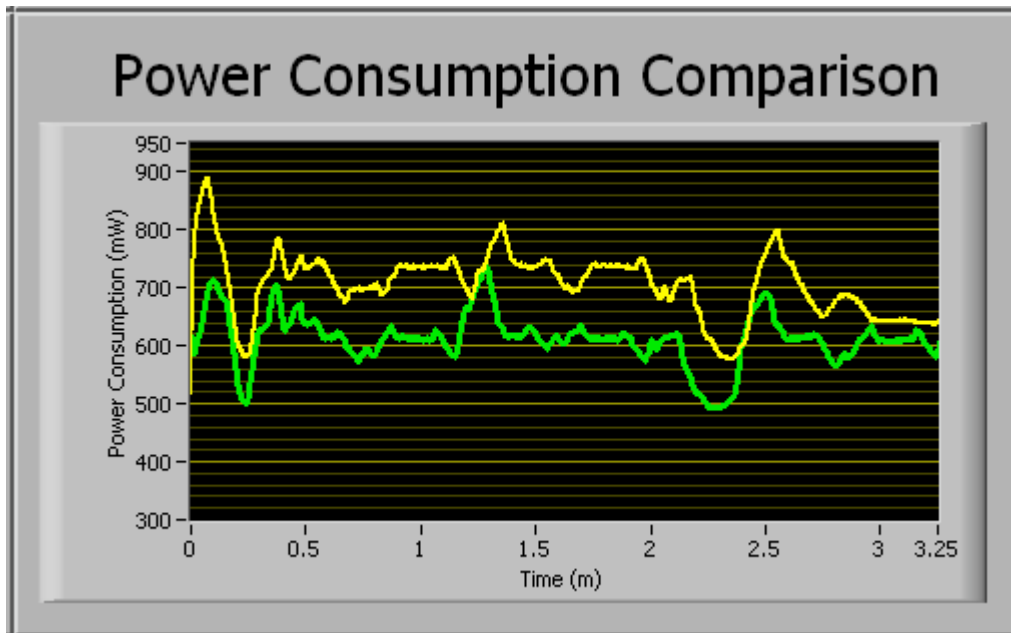


Figure 6. Address book functions on the OSK without (yellow) and with (green) ODP power management

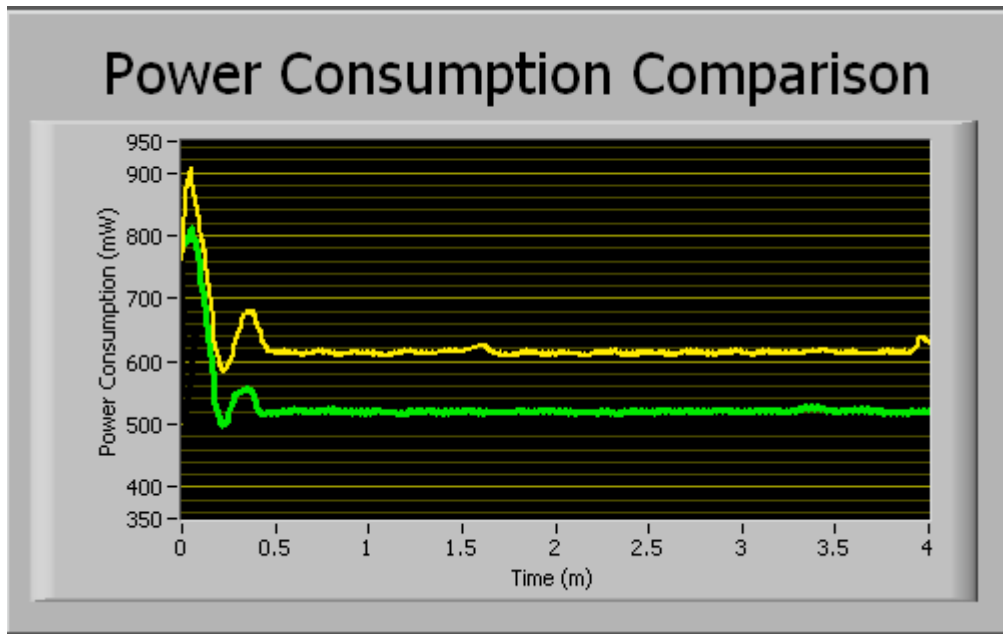


Figure 7. Notepad functions on the OSK without (yellow) and with (green) ODP power management

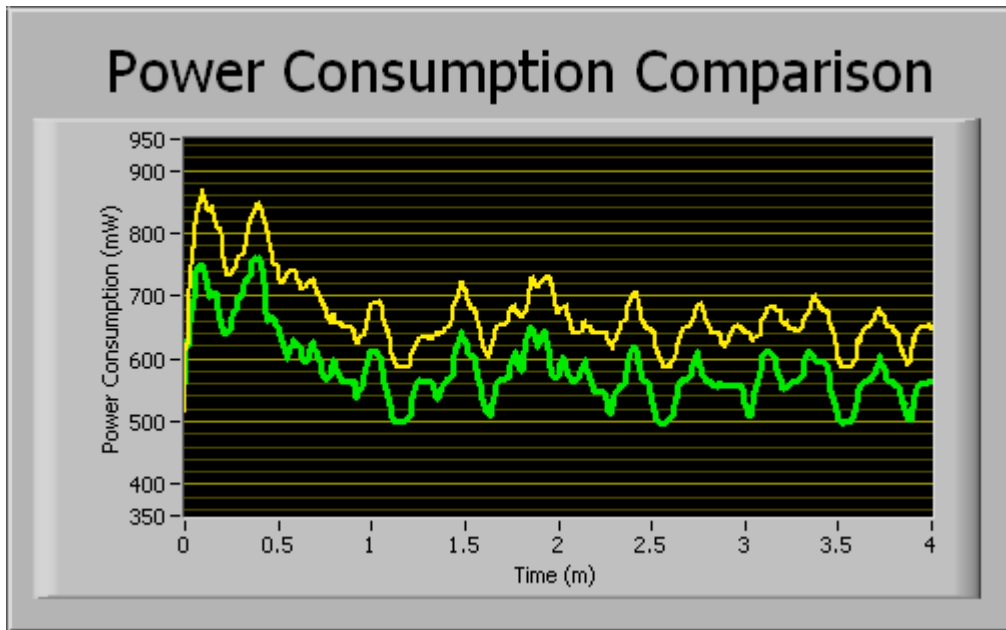


Figure 8. Photo retrieval and viewing on the OSK without (yellow) and with (green) ODP power management

Conclusions:

On-Demand Power technologies expand upon the best power management aspects 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 independent of the application, operating system, architecture, and packaging. 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, battery life is greatly increased, helping meet consumer demand and improve competitive advantage.