

# System-Level Display Power Reduction Technologies for Portable Computing and Communications Devices

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**Abstract**-This paper narrates a set of technologies that are integrated in Intel's graphics controller chipsets, offering platform-level power consumption reduction for the display subsystem of the portable computing and communications devices, thereby significantly enhancing their battery life.

## I. INTRODUCTION

Portable computing and communication technologies are undergoing exciting and rapid advancements, driven by a vision of "internet access anytime, anywhere" coupled with ever increasing demand for high-bandwidth access to information. Intel is at the forefront of the mobility wave, leading with power-performance optimized mobile platforms with high bandwidth wireless connectivity, ushering in the era of "personal internet on the go". This makes extended battery life achieved via reduction of power consumption an important requirement towards enhancing the mobility of the portable computing and communications devices.

As an example, Figure 1 shows the average power consumption breakdown by the components of a typical Thin & Light notebook PC. The system consists of a 14.1" XGA LCD panel, 2.26GHz Intel® Pentium® M Processor, Intel® 915GM Integrated Graphics chipset, 60GB Hard Disk, 512 MB DDRII-533 Memory, CD/DVD Drive, and Microsoft\* Windows\* XP SP2 Operating System.

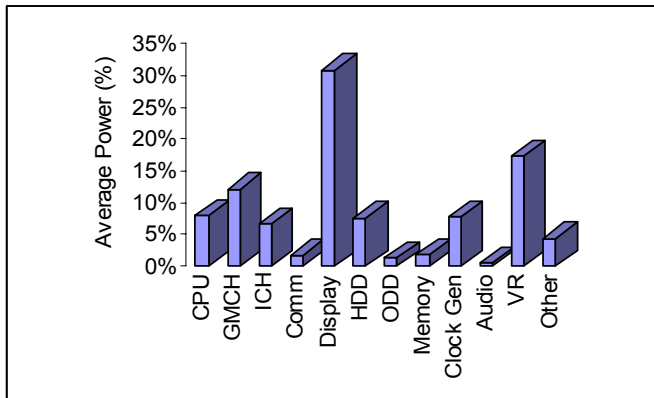


Fig. 1 Average power consumption breakdown for a typical *Thin & Light* notebook computer.

The power consumption for the components were measured using the BAPCo\* MobileMark\* 2005 Office Productivity Workload. The display brightness is set at 60nits, and the power consumption data for the display consists of both the backlight and the panel electronics. It can be seen that the display subsystem in this typical notebook platform is by far the largest power consumer of all the components.

In this paper, we present a set of technologies that are integrated in Intel's graphics controller chipsets for platform-level power optimization of the display subsystem of notebook and ultramobile computers. The results demonstrate that substantial power savings are achieved by employing these technologies, thereby enhancing the battery life of these portable computing and communications devices.

## II. DISPLAY POWER OPTIMIZATION

### A. Intel® Display Power Saving Technology (DPST)

The largest power consuming component within the notebook LCD panel is the backlight. For example, the backlight of a typical notebook LCD panel that we measured accounts for as much as 80% of the total panel power consumption at 200nits brightness, and 67% at 60nits brightness, while the rest of the display power consumption is due to the panel electronics. Intel® Display Power Saving Technology (DPST) is a power reduction technique that dynamically enhances the images being displayed and correspondingly modulates the backlight brightness, resulting in up to 25% savings in backlight power consumption [1]. The technology, integrated in Intel's integrated graphics chipsets, analyzes the image to be displayed, modifies the image luminance by altering the pixel values, and simultaneously adjusts the backlight brightness to adapt to the enhanced image. The image modifications and backlight adjustment occur for every frame of a video playback. Figure 2 shows the schematic diagram for the DPST processing and adjustment path, involving image analysis, image adaptation, and backlight modulation. Figure 3 illustrates the image adaptation and backlight adjustment process by using an example image. In the platform implementation, various levels of aggressiveness is made available, ranging from no backlight modulation for maximum quality to the highest level of backlight modulation for maximum battery life, in order to provide flexibility to the user.

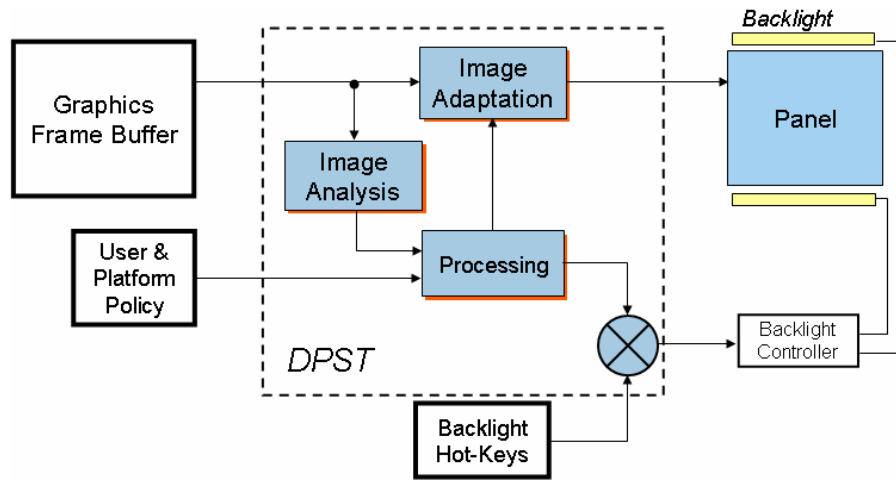


Fig. 2. Schematic diagram illustrating DPST processing and adjustment path, involving image analysis, image adaptation, and backlight modulation.

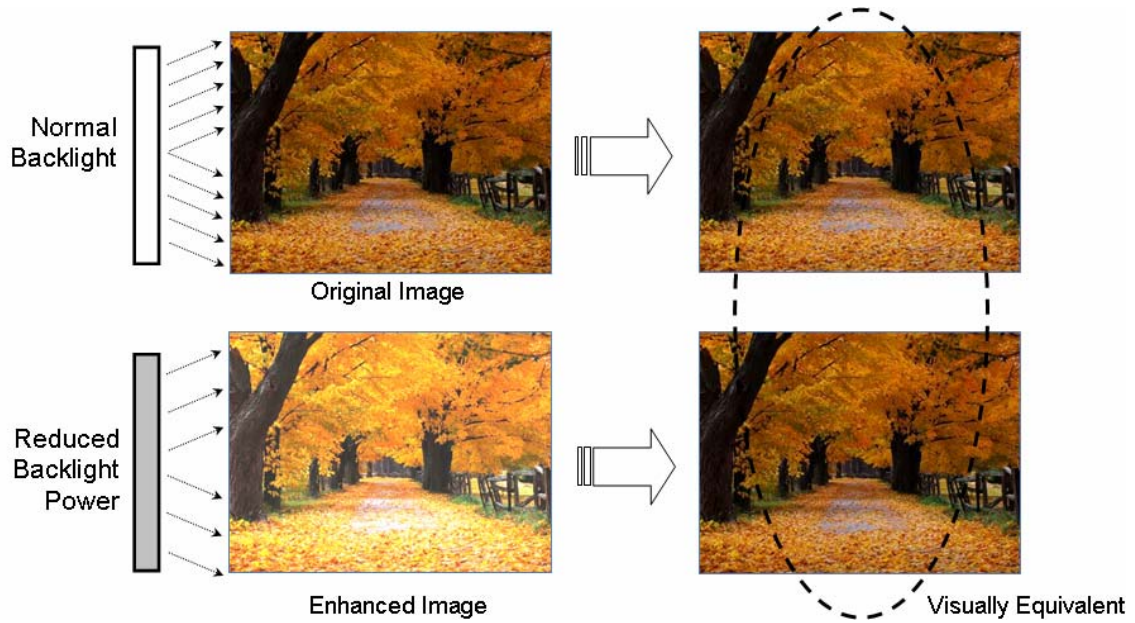


Fig. 3. Illustration of the image adaptation and backlight adjustment process for DPST. The image is digitally enhanced and the backlight is dynamically modulated on a per frame basis.

TABLE I  
MEASURED DPST POWER SAVINGS FOR TWO AGGRESSIVENESS  
LEVEL SETTINGS FOR A MAINSTREAM NOTEBOOK

Workload	MobileMark* 2005 Office Productivity		MobileMark* 2005 DVD Playback
	4	6	6
Aggressiveness Level	4	6	6
Backlight Power Savings	6.5 – 14.5%	15.5 – 25%	17 – 27%

### B. Dynamic Display Power Optimization ( $D^2PO^*$ )

The circuit power consumption of an LCD panel can be shown by the following formula in general:

$$P_{circuit} = P_{dynamic} + P_{static} \quad (1)$$

where  $P_{dynamic}$  is the AC component and  $P_{static}$  is the DC component.  $P_{dynamic}$  can be shown by the following formula:

$$P_{dynamic} = kCV^2f \quad (2)$$

where  $k$  is a proportionality constant,  $C$  is the parasitic capacitance of the circuit,  $V$  is the driving Voltage, and  $f$  is the driving frequency.  $P_{static}$  in Equation (1) is due to the power consumed by the power supply and losses in the DC-DC converter, whereas  $P_{dynamic}$  is due to the LCD Drivers, Array lines, LCD Timing Controller, and the PCB. The dynamic component of the circuit power consumption is much larger than the static component.

Intel and Toshiba Matsushita Display Technology Co., Ltd. have jointly developed the Dynamic Display Power Optimization technique that substantially reduces the power consumption of a notebook LCD panel electronics, graphics controller, memory, and display link [2]. This involves a multi-field driving (MFD) technology that reduces the AC component of the panel electronics power consumption by decreasing the effective frame frequency. The MFD technology first divides a frame into multiple fields, and then writes the image in each field by an interlaced scanning technique. This decreases the effective driving frequency of the panel electronics and thus reduces its power consumption. In addition, the combination of voltage polarity of pixels is carefully selected in order to eliminate any panel flicker to below perceptible limits.

As an example, Figure 4 depicts a 1:2 multi-field driving scheme, where one of every two gate lines are driven for every field, thereby reducing the effective driving frequency per frame by a factor of two. In this case, every frame is divided into two interlaced fields, where an odd line is driven in an odd field and an even line in an even field.

The support for the Dynamic Display Power Optimization technology is implemented with the next-generation Intel® Centrino® Duo mobile technology platform, based on Intel® GM965 Express Graphics Chipset, in conjunction with LCD panels employing multi-field driving method, as shown in Figure 5. The system platform selects the appropriate driving scheme from the progressive mode and multi-field drive mode to optimize the system-level power-performance metric without impact to the display image. This is accomplished by dynamically and seamlessly switching between the two modes depending on the content that is being displayed on the screen at a given time. In the multi-field drive mode operation, reduction in power consumption is achieved in the drive electronics of the LCD panel, system memory, and the graphics controller due to reduced memory access and data transmission. The system-level power savings per component in the multi-field driving mode relative to the traditional progressive driving mode, measured on a proto-type system using the BAPCo\* MobileMark\* 2005 Office Productivity Workload, is shown in Table II.

It is well known that hold-type displays such as LCD exhibit interlace artifacts in the form of jagged edges for moving image content. We have mitigated this issue in the system-level implementation by developing capability in the graphics controller to distinguish motion vs. static image content and dynamically select the appropriate mode of operation based on the displayed content. This allows maximum power saving for static or low-motion content by driving the display in the MFD mode and preserve superior image quality for high-motion content by seamlessly switching back to the progressive driving mode.

### C. Intel® Display Refresh Rate Switching (DRRS)

The Intel® Display Refresh Rate Switching technique involves dynamic selection of the display refresh rate for traditional LCD panels with progressive-scan driving mode [1]. This technology offers significant power savings in the panel electronics, graphics controller, memory, and the display link, while maintaining excellent visual experience as well. For LCD panels that support multiple refresh rates, a variable refresh rate can be employed within a power policy to save power when in battery mode.

TABLE II  
POWER SAVING FOR MFD MODE RELATIVE TO PROGRESSIVE  
MODE MEASURED ON A PROTOTYPE SYSTEM

Component	Panel electronics	GMCH	Memory
Power saving for 60i vs. 60p	27%	4.4%	28%

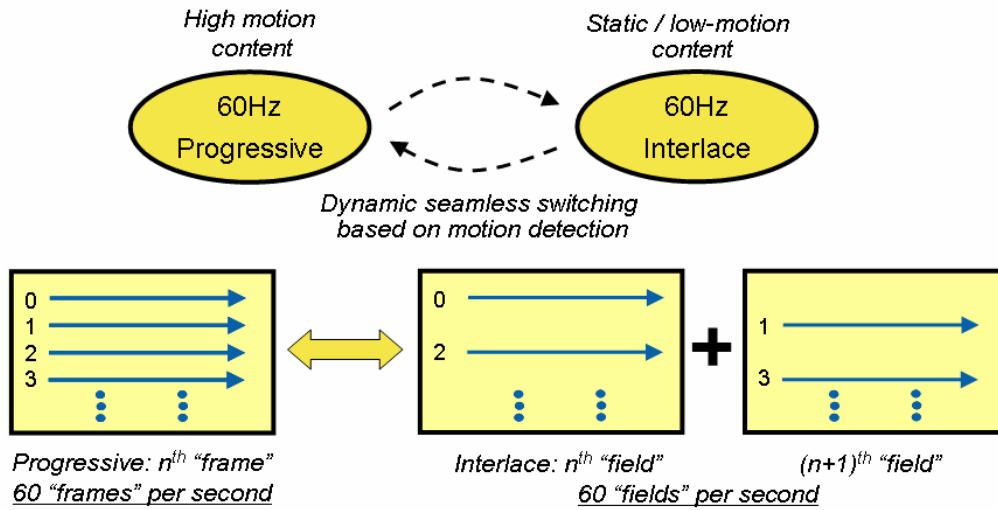


Fig. 4. Depiction of a 1:2 multi-field driving scheme, where one of every two gate lines are driven for every field, thereby reducing the effective driving frequency per frame by a factor of two.

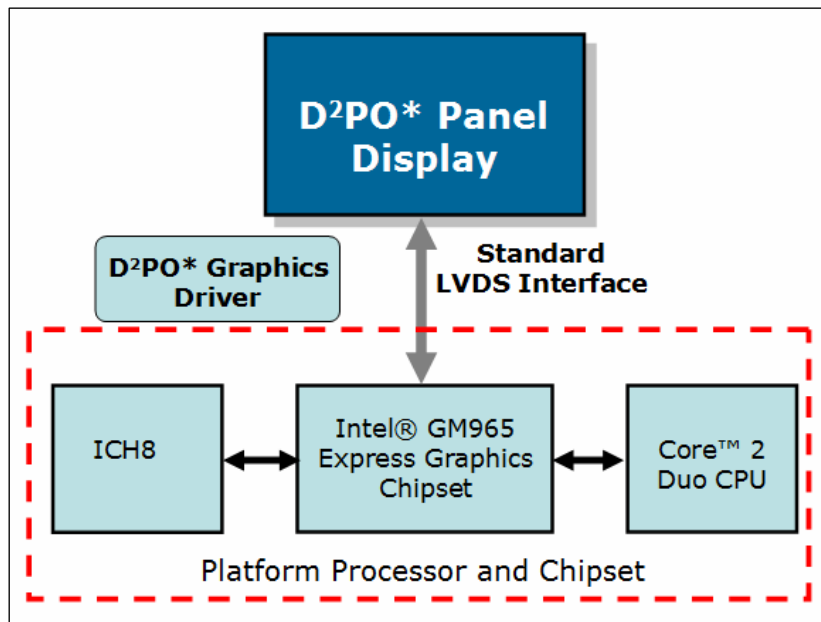


Fig. 5. Dynamic Display Power Optimization implementation with next generation Intel® Centrino® Duo mobile technology based platform.

For example, when the panel supports two refresh rates, the higher frequency refresh rate can be used when the notebook is powered by AC, and the lower frequency refresh rate can be used to save power when the notebook is running on battery mode. Such a scheme offers power savings due to the principle explained in Equation 2. When three refresh rates are available, the two lower refresh rates can be used to save power when on battery: the higher of the two can be used during video playback and 3D gaming (where performance may have higher importance) whereas the lowest refresh rate can be used otherwise.

Display Refresh Rate Switching allows power savings to be realized not only when system is idle, but when system is active. The goal of this technique is to deliver power savings in the display panel while generating an equivalent end-user-perceived image quality for different refresh rates. Figure 6 illustrates the technique employed with panels that support progressive-scan image update with multiple refresh rates.

### III CONCLUSION

In summary, we have presented a set of technologies for platform-level power optimization of the display subsystem of notebook and ultramobile computers. These include: I) Intel® Display Power Saving Technology that involves dynamic and content-dependent backlight modulation and image adaptation, II) Dynamic Display Power Optimization, jointly developed with Toshiba Matsushita Display Technology Co., Ltd., that involves a multi-field driving technique, and III) Intel® Display Refresh Rate Switching technique that involves dynamically switching between multiple display refresh rates based on power policy and displayed content. These technologies are integrated in the graphics controller chipsets incorporated in Intel® Centrino® Duo mobile technology platforms, offering a significant enhancement of the battery life of portable computing and communications devices by reducing the power consumption of the display subsystem.

TABLE III  
SYSTEM-LEVEL POWER SAVINGS MEASURED WITH 40HZ  
PROGRESSIVE REFRESH RATE OVER THE TRADITIONAL 60HZ  
PROGRESSIVE REFRESH RATE.

Component	Panel electronics	GMCH	Memory
Power saving for 40p vs. 60p	10%	3%	18%

### REFERENCES

- [1] A. Bhowmik, "Display Power-Performance Optimization Technologies for Notebook Computers," in *Flat Panel Displays: Technology and Market Trends*, pp. 182 – 188, edited by H. Asakura, Nikkei Business Publications, Inc., Tokyo, 2005 (ISBN: 4-8222-1333-1).
- [2] H. Maeda, T. Hashimoto, A. Okazaki, M. Watanabe, and A. Bhowmik, "The Dynamic Display Power Optimization (D<sup>2</sup>PO™) Driving Scheme Enables Low Power TFT LCD Modules for Notebook Applications," *Proc. International Display Workshop*, 2006.

\* Other names and brands may be claimed as the property of others.

\*\* Actual measurement results may vary depending on the specific hardware and software configuration of the computer system measured, the characteristics of those computer components not under direct measurement, variation in processor manufacturing processes, the benchmark utilized, the specific ambient conditions under which the measurement is taken, and other factors.

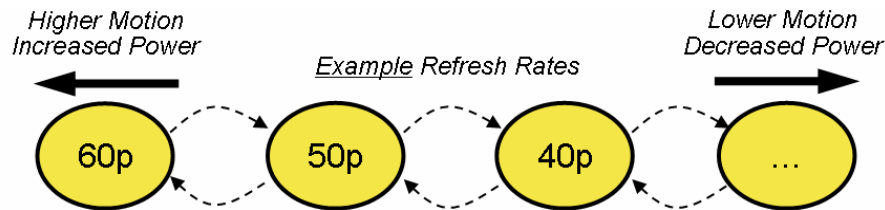


Fig. 6. Schematic diagram illustrating Display Refresh Rate Switching, employing multiple progressive update rates based on content and power policy.