

## ***Design Requirements of Wireless Telephones for Power Management***

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### ***Abstract***

*Wireless telephones of this day and age are more than merely an instrument of voice transfer. They come with loads of features and use up their battery quickly. In this paper, we present the subsystem design requirements for optimizing use of power in these phones. Smartphones, as many wireless telephones are popularly called, come integrated with global position system (GPS), music player, digital camera, and other features. Without power optimization, it would be difficult for a smartphone to retain power for running the different applications installed in it. Integration of different technologies in a handheld phone requires power optimization for each of its subsystem.*

***Keywords:*** *Wireless Telephone Design, Power Optimization In Smartphones, Technology Integration In Smartphones*

### **INTRODUCTION**

Trends in power management of wireless telephones or smartphones are driven by a demand for products loaded with features. Convergent wireless devices, such as smartphones that combine the features of cell phones, PDAs, digital still cameras (DSCs), music players (MPs), and global positioning systems (GPSs), stretch many technology boundaries, including those of power. This section discusses the latest power management products being used in

today's most sophisticated cellular phone designs.

### **Smart Phone Subsystems**

A state-of-the-art smart phone system (with handset and AC adapter charger) can be divided into up to five main board constituents: display board, baseband main board, keypad board, Li' in-battery board, and AC adapter board. Additional modules may be present for DSC, Bluetooth, or other functions. Accordingly, power management breaks down along

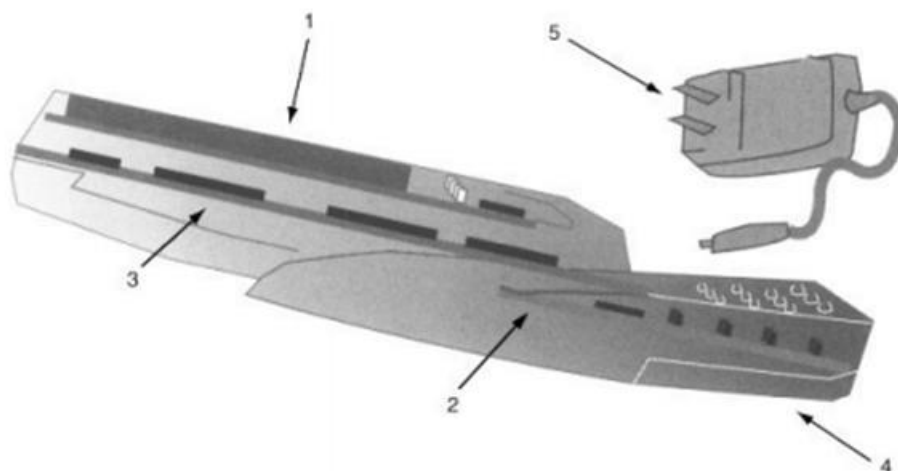


Figure 1 System partitioning of a state-of-the-art smart telephone system

these five subsystems. Figure 1 illustrates such system partitioning. We will review these subsystems with respect to their power management chips' content, both integrated and discrete, including Light Emitting Diodes (LEDs). These power management chips are:

- LED driver ICs and four white LEDs in the display board
- LED drivers and eight white or blue LEDs in the keypad board
- Power management ICs in the main board
- Lithium-Ion protection and fuel gauge ICs and MOSFETs in the battery pack
- Offline regulator ICs in the AC adapter board

Figure 2 shows the corresponding block diagram for a cell phone in the class of Nokia's 7650, which integrates a digital camera.

### Display Board

In monochromatic displays, the backlight can be made up of different colors, which generally are obtained with four LED lamps of the same color. In smart phones the color, Thin-Film Transistors (TFT) Liquid-Crystal Display (LCD), necessarily requires only white backlighting. White LED diodes have low forward voltage (around 2.7 V) and require a simple DC current to produce light. Accordingly, a low DC power source as low as 3.1 V, is necessary to bias these devices. Thanks to such low bias voltage, the four LEDs can operate directly off a single cell Lithium-Ion, the power source of choice in cellular

telephones. A monolithic quadruple LED driver, such as Fairchild Semiconductor's

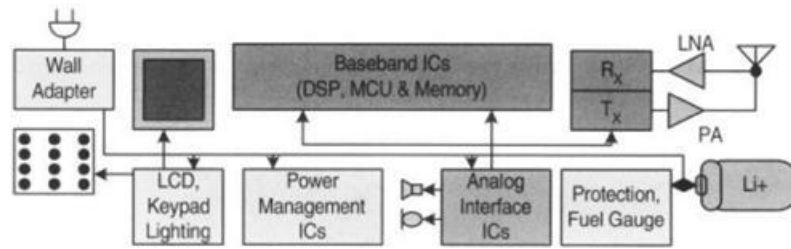


Figure 2 Block diagram of a smart phone system

FAN5613, can be housed in a tiny MLP 8-lead package and provide up to 40 mA bias for each diode. As continuous-time current control may result in poor color consistency, the LEDs can be excited with a pulse width modulated source via the ON/OFF pin to achieve higher color fidelity.

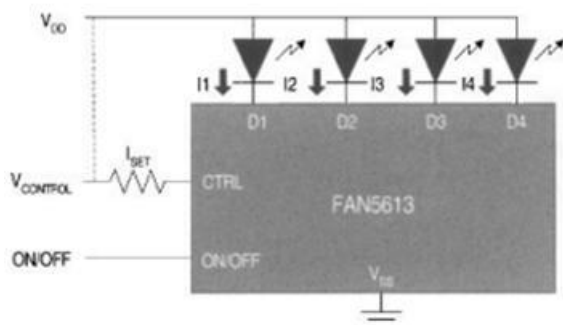


Figure 3 Bias scheme for White LED driver with FAN5613

### Keypad Board

Similar to the display configuration, the keypad is also illuminated by LED lamps. In this case, eight white or blue LEDs generally are utilized. For blue backlight,

eight QTLP601 C-EB InCaN/Sapphire surface mountchip LEDs (shown in Figure 4) can be used, with two FairchildFAN5613 LED Driver ICs driving them.



Figure 4 QTLP601 C-EB low VF blue LED lamp.

### Main Board

The main board contains the vast majority of the electronics, from the baseband DSP and application MCU to the transceiver and analog interface. Each of these blocks is powered by a dedicated voltage regulator. The growing complexity of smart phones requires strict management of the power source. This is obtained by means of a “power manager” inside the baseband processor, communicating to the

outside world via logic signals. On the power source side, the voltage regulators are able to receive such logic signals and react accordingly.

In some instances, all the regulator is required to do is to enter into a light load operation or sleep mode or into a shutdown mode via direct logic signals. In other instances, such as in powering the baseband processor, power management is more sophisticated and requires a voltage source that varies with the task at hand, delivering just enough power as necessary and no more.

In this case, a voltage regulator, coupled with a DA converter and a serial bus with the ability to communicate with the host microcontroller, is required. While this technique may sound exotic, such power

management schemes are commonplace in notebook computing, battery operated devices that long ago crossed the threshold of complexity that today's smart phones have just now reached. (Examples of popular power management techniques in notebooks are SpeedStep™ from Intel and PowerNow™ from AMD.)

Figure 5 illustrates an example of distributed power management on the main board. The combination of a simple buck converter and an SMBus serial-to-parallel interface, such as the FM3570 by Fairchild, allows the CPU to drive the Vcore supply with a 5-bit D-A converter resolution. A combination of switching and linear regulators assures a good compromise between simplicity and performance, and all the devices can be shut down via a dedicated logic pin.

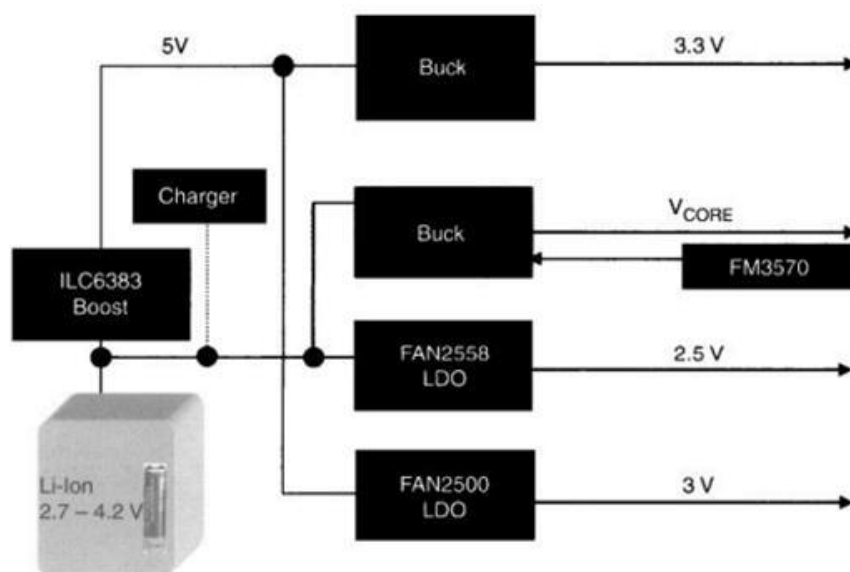


Figure 5 Example of distributed power management system for the main

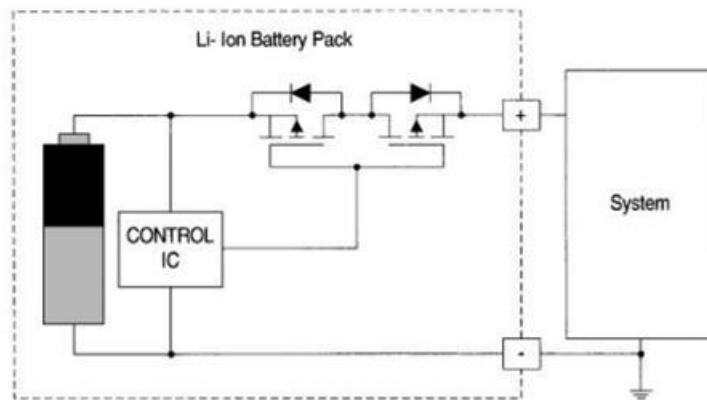


Figure 6 In-battery fuel gauge and protection with FDW2508D

### Battery Pack

The power management inside the battery pack consists mainly in the Lithium-Ion protection and fuel gauge ICs and MOSFETs. The protection electronics measures the battery voltage and opens a pass transistor as soon as the charge voltage threshold is crossed. Fuel gauging is necessary to display the battery's state of charge and to predict the residual time of operation in battery mode. Figure 6 shows an example of in-battery electronics that uses Fairchild's dual MOSFET FDW2508D as the pass transistor for the protection section.

### AC Adapter

The AC adapter board rectifies the AC line and converts it down, either to a low

DC voltage manageable by the main board, or directly to a constant current/constant-voltage charging algorithm required by the single Lithium-Ion cell, in which case it performs both the functions of adapter and charger. A charger on the main board will be required only in the first case.

In Figure 7 the AC adapter charger is based on an offline switching architecture for the best efficiency. In this example, the high voltage product called the FSDH0165 is powered directly by the AC line and integrates the power into the DMOS transistor for minimum complexity.

In this paper, we will also discuss in more detail the AC adapter charger subject.

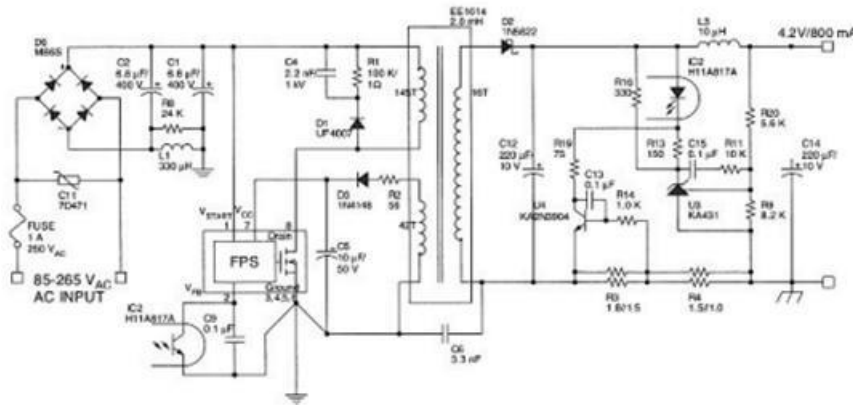


Figure 7 AC adapter for single cell Lithium-Ion

The power management of state-of-the-art wireless telephones typically breaks down along five main subsystems, each following its own integration dynamics. The main board requires many low voltage sources and lends itself to higher levels of integration.

At the opposite end is the AC adapter (or adapter/charger) with its requirement of high voltage (600-800 V) and galvanic isolation with respect to the low voltage side. The keypad board and display can be serviced by the same class of technologies, namely LEDs and LED drivers, while the in-battery electronics is another unique domain where true mixed signal technologies are needed for fuel gauging and protection.

It seems safe to say that the natural boundaries of these subsystems and the diversity of the technologies needed in

each of them will assure a plurality of technologies, solutions, and players in the power management of wireless devices.

### POWERING FEATURE-RICH HANDSETS

Market trends show that devices incorporating color screens, camera phones, and Personal Information Management (PIM) applications are growing steadily. For example, market data by major market research companies like Dataquest and iSuppli point to the possibility that in 2006 the number of smart phones will be larger than the number of the notebook computers shipped that year and will far outnumber single function devices like digital still cameras and PDAs.

With this in mind, we have little doubt that newly emerging applications in cell

phones and handhelds, such as video streaming and high quality digital media playback, will soon become legitimate in high-end handsets and will later be embraced by the mainstream. In this section, we will look at the challenges that such complex devices pose, with a special focus on power management. We will also discuss new solutions and future trends.

### **Growing Complexity and Shrinking Cycle Time**

Today's OEMs play in complex markets, spanning across different platforms-second generation or 2G platforms such as GSM, Time Division Multiple Access (TDMA), and CDMA, and 3G platforms such as W-CDMA and CDMA20G and each proposed in different models. You can review these acronyms.

For the best time to market, the reference design for a single platform typically will rely on a relatively rigid "core" chipset, while a more flexible periphery will accommodate a model's differentiation within the given platform. In other words, it takes time, sometimes up to a year, to develop new chips that incorporate new features. Consequently a product can go on the shelf faster if it can rely on a rigid core inherently undifferentiated with the differentiation-new features, better performance, etc.-that is accommodated with add-ons.

The resulting product may be less integrated and more bulky but goes to market faster. Hence, the final architecture of a product, like the one in Figure 8, is influenced by technical factors as well as by time.

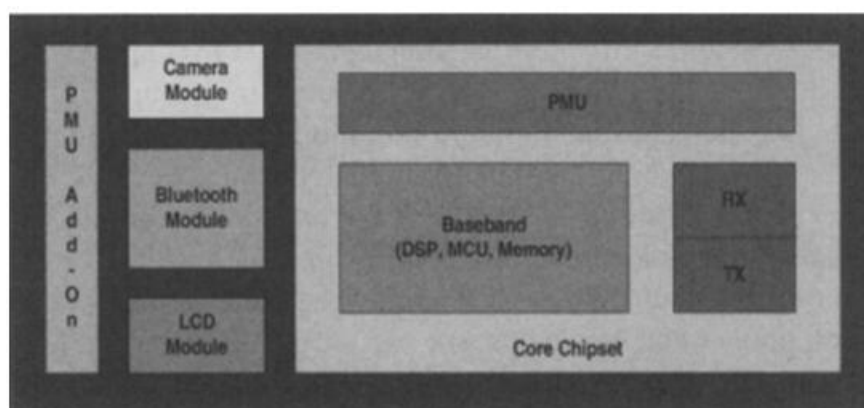


Figure 8 Block diagram of the handset mainboard.

In the system illustrated in Figure 8, the power management-the section of interest for us-is accomplished with a core PMU tightly integrated inside the chipset and an auxiliary PMU servicing the add-on features.

Figure 8 illustrates the core chipset, with the baseband section, including the application MCU handling the data, the DSP for voice, FLASH memory, the RF section (with its receiving RX and transmitting TX blocks), and the power management unit section. A number of add-on modules, such as Bluetooth for untethered data transfer on a short distance, cameras, and LCD modules surround such a core chipset. These blocks require additional power provided by an auxiliary PMU, represented by the PMU add-on block in Figure 8.

### **Management Unit**

The increasing number and performance of smart loads supported by the power management unit demands an increasingly sophisticated PMU, capable of going well beyond providing the basic functions of voltage regulation, charging, and fuel gauging. In sophisticated systems, the PMU may need to be programmable in order to become platform-specific via software implementation of the protocol.

To this end the PMU must be capable of communicating with the host CPU via a serial interface (I2C Bus or similar). This is to adjust the power delivery mode to the load demand (heavy, light, or intermediate) and to take responsibility for many critical functions, such as power sequencing, at a time when the communication bus is disabled. Such PMU can be implemented with varying levels of integration, perhaps initially starting with a solution based on multiple chips for fast time to market, and subsequently up-integrating to a single package (Multi-Chip Package or MCP) or even a single IC, depending on the volumes and other considerations.

### **Low Dropouts (LDOs)**

In Figure 9, a microcontroller-based power management architecture provides all the hardware and software functions, as discussed above, in a multi-chip implementation. When defining this unit, many trade-offs need to be considered.

The Li+ low voltage (3 V typical) power source is conducive to a high level of integration on standard CMOS. However, this choice hits a snag if a charger, interfacing with an external AC adapter, needs to be integrated, in which case the process technology needs to withstand

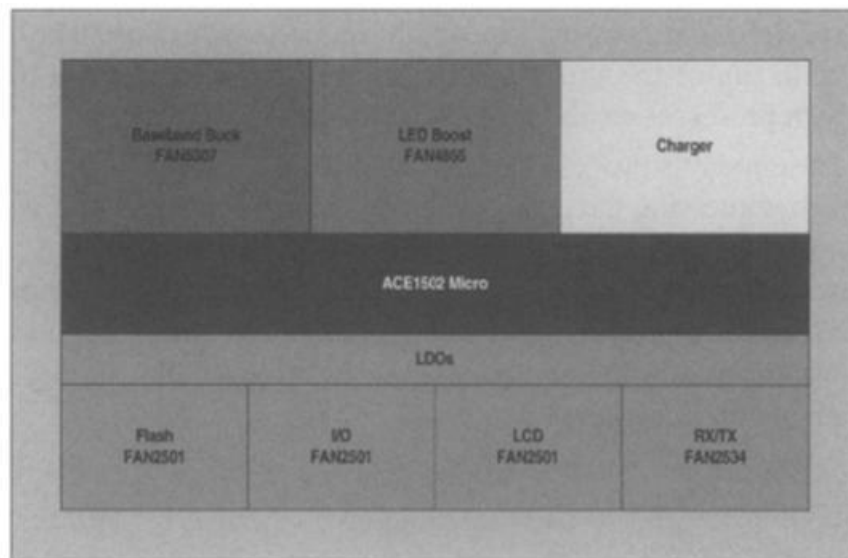


Figure 9 Power management unit

voltages well above the standard 5 V of CMOS. Ultimately, if the cost structure allows for its high mask count, a powerful mixed signal BCD process can enable a true single chip solution capable of handling high voltage, high current, and high gate count.

As illustrated in Figure 9, each subsystem in the handset requires its own specific version of power delivery-low noise LDOs in the RF section and low power LDOs elsewhere. Each subsystem also requires an efficient buck converter for the power consuming processors, a boost converter in combination with LED drivers for the LED arrays, and a linear charger

interfacing the Li+ battery with the external AC adapter during charge.

### Microcontroller-Driven Illumination System

A complex LED based illumination system is illustrated in Figure 10. Typically, an array of four white LEDs is needed for the color display backlighting, while another array of four white or blue LEDs implements the keyboard backlighting. White LEDs, typically assembled in a quad package, are needed for the camera flash. And finally, an RGB display module provides varying combinations of red, green, and blue flashes for lighting effects. As mentioned earlier, the sequencing and duration of all

the illumination profiles are under micro control. Figure 11 demonstrates the lighting system described previously, with

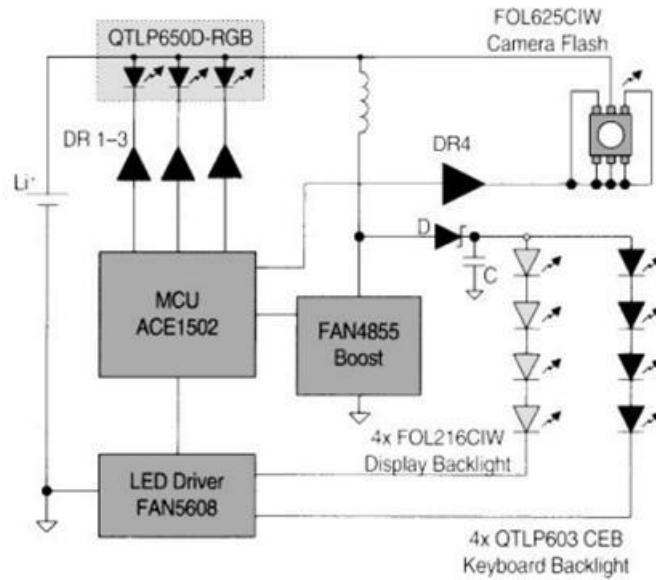


Figure 10 Handset illumination system



Figure 11 Lighting system demonstration

all the elements of the system excited at once. The back light and display light locations are obvious. The flash is the top light and the RGB is the one in the middle.

Figure 12 shows the typical waveform generated by the microcontroller to drive the lighting system. The oscilloscope waveforms are:

A1 FLASH LED cathode signal

A2 primary back light intensity control via 8-bit PWM signal

secondary back light intensity control via 8-bit PWM signal

RGB LED Module: Red channel controlled using 4-bit PWM signal

RGB LED Module: Green channel controlled using 4-bit PWM signal

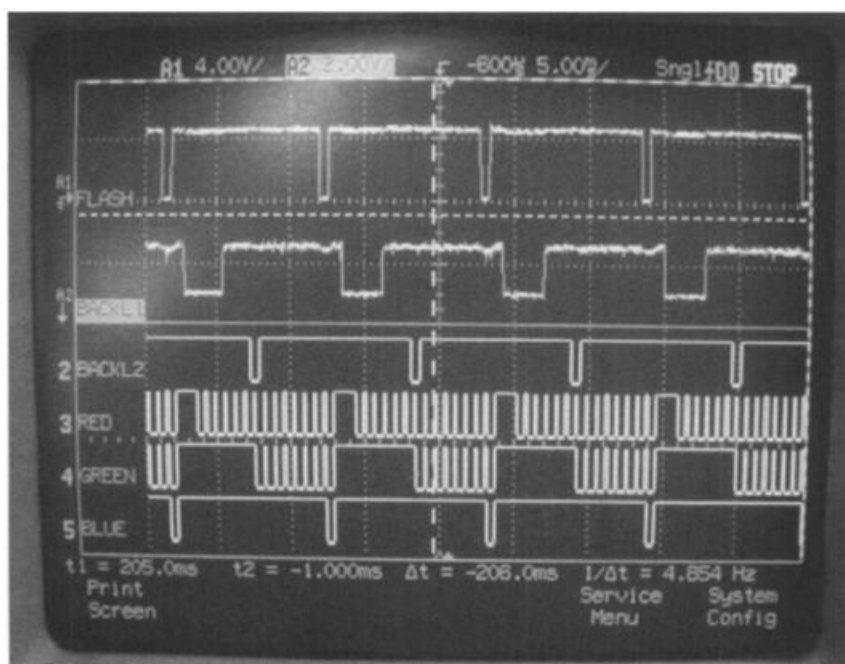
RGB LED Module: Blue channel controlled using 4-bit PWM signal

### Power Minimization

The battle for power waste-minimization extends to the signal path as well. The

logic gates, operational amplifiers, and data conversion devices used extensively in ultraportable applications are all

specifically designed for ultra low power dissipation and are housed in space efficient packages.



**Figure 12 Lighting system waveforms**

For example, the Ultra Low Power (ULP and ULP-A) TinyLogicO devices, such as Fairchild's NC7SP74, a D flip-flop, and the NC7SPOO dual NAND gate, operate at voltages between 3.3 V and 0.9 V and have propagation delays as short as 2.0 ns, consuming less than half as much power as existing high performance logic.

### **CONCLUSION: MOVING TOWARDS UNTETHERED OPERATION**

Recent high-end handsets exhibit amazing features such as dual color LCD displays,

camera, video on demand, and audio on demand. An 800 mAh Li+ battery (corresponding to a 2.4 Wh at 3 V average output) can sustain heavy-duty activities like playing games, taking pictures, or recording and viewing videos-assuming each activity consumes power at a rate of 1.4 W for less than two hours. Such figures of merit are getting better, thanks to the power management methods discussed previously, but they remain a far cry from the desired performance of 6-8

hours of untethered operation as in more basic handsets.

The two technologies on the horizon promising to improve this situation are organic LEDs, which do eliminate the power consuming backlights, and fuel cells; electrochemical devices capable of extracting electricity directly from fuels like methanol. Fuel cells already promise to flank Li', for example as untethered chargers, and then to progressively substitute Li' technology. Alternative power sources, such as fuel cells, will require even more sophisticated power management. This increased management will necessitate further proliferation of local intelligence to manage tasks (i.e. additional microcontrollers,; including sophisticated mixed signal capabilities to perform supervisory functions. Digital still cameras with OLEDs are already commercially available and this technology is expected to take a wider hold in the next three to five years.

Fuel cells are a proven technology but difficult to miniaturize and they may come to larger devices like notebooks before trickling down to handsets. Prototype handsets, some powered by, and others simply charged by fuel cells, have been demonstrated and are expected to become

commercially viable in the same timeframe as OLEDs. Power management techniques are adapting and evolving to keep up with the increased complexities of today's systems. These techniques include traditional cell library regulation elements as well as untraditional digital functions, such as bus interfaces, data converters, and microcontrollers.

Feature-rich handsets and smart phones are clearly the devices pushing the edge of every technology, including power, and more features will be coming in the future. For example, it is conceivable that a series of "plug and play" standards will be debated and then adopted to allow for mix-and-match of add-on peripherals (camera, GPS modules, etc.) from various sources, as well as promote the re-use of peripherals that a user already owns.

The addition of microcontrollers in power management applications will become an increasingly important theme in the ICs that provide system power for these platforms. This "smartening" of power management electronics, combined with the increasing maturity of new technologies for energy storage and displays, promises to keep these feature-rich devices on a steep growth curve for the foreseeable future.

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