

The "Energy Aware" Appliance Platform: A New Approach to Energy Control

By integrating Altia's Design and DeepScreen GUI development tools suite, Echelon's Power Line Smart Transceiver and ShortStack API, and the Altera Cyclone III FPGA and Nios II embedded processor, developers have a powerful platform for developing cost-effective, yet robust energy aware solutions. These solutions allow homeowners to monitor appliance energy use via a home area network, appliance manufacturers to provide improved service to customers, and utility companies to lower energy consumption via the Internet.

Introduction

Fears of global climate changes and limited resources have increased energy awareness and conservation by both consumers and utilities. This trend will have a dramatic impact on consumer products as homeowners search for electrical appliances that are both energy efficient and cost effective. Given the lengthy development cycles for new products, now is the time to build energy awareness directly into next-generation products.

Energy Awareness

Electric utilities around the world are investing in smart grids, which are advanced electricity transmission and distribution networks that use two-way communications to improve the efficiency, reliability, and safety of power delivery and use. The backbone of the smart grid involves the installation of smart meters that read electricity consumption remotely, detect outages, identify electricity theft, remotely connect and disconnect service, and deliver prepaid electricity to customers who require this service.

Smart meters give utilities immediate access to data so that they can better project electricity demand from the grid. When demand is high, typically on hot or humid days, the grid becomes strained, forcing utilities to make difficult decisions such as increasing energy production with environmentally unfriendly coal-fired plants or by reducing electricity consumption among its customers. Utilities deploying smart meters typically introduce two new programs to consumers: time-of-use (TOU) pricing and demand-response (DR) programs.

- *TOU pricing programs* provide differential pricing for peak and off-peak use of electricity. The obvious goal of such programs is to discourage electricity consumption during peak periods, while encouraging consumption during off-peak periods. The implementation of such programs requires a certain level of energy awareness by consumers who will need to know when prices change. While many utilities are focused on the adoption of in-home displays to notify consumers, the most practical way to create awareness is by providing the information directly in the appliance itself.
- *DR programs*, which have become a key component of energy-management policies, ensure a balance between supply and demand while simultaneously reducing greenhouse gas emissions. In an electricity grid, any significant imbalance between electricity consumption and production can cause grid instability or severe voltage fluctuations and failures within the grid. A DR program involves a utility notifying its customers of a pending electricity shortfall and asking them to reduce energy use in order to place usable megawatts back on a region's energy grid. This eliminates the need to run coal-fired plants and reduces generation costs. In exchange, end-users are offered reduced electricity prices or other financial incentives.

DR programs can be automatic, with utilities having the right to reduce or turn off certain energy-consuming appliances for a short amount of time at customer sites, such as air conditioners, pool pumps, and hot water heaters. Signals are transmitted from the utility to the smart meter, and from the smart meter to network-connected consumer products.

So, why is this important to manufacturers and consumers of home appliance products? Simply put, over 100 million smart meters slated are to be installed worldwide over the next five to seven years. This "tidal wave" forming in the horizon will have a dramatic impact on consumer products as homeowners search for cost-effective solutions for managing their energy. Given the lengthy development cycles for new products, now is the time to build energy

awareness directly into next-generation products. In addition, utilities are likely to implement economic incentives for consumers. Many utilities today offer rebates to consumers who purchase Energy Star appliances, and the same will hold true for the new Energy Aware products.

Electronic Displays Move Beyond Traditional Products

In many consumer products, touch-screen displays rapidly are replacing dials and push buttons as the user interface of choice. Several trends are influencing the adoption of displays, including declining costs, GUIs, future-proofing, and consumer interest.

Costs continue to decline, thanks to advanced circuits that combine display controllers and multiple microcontroller units (MCUs) into a single integrated circuit. With rising consumer demand and increased production capacity, LCD prices are continuing to fall, as does the total bill of materials (BOM) cost.

GUIs can improve the consumer human-machine interface experience by supporting larger fonts, buttons, colors, and multiple languages. Manufacturers of multiple brands can leverage a single investment across multiple product lines because changes are supported easily via software in both the integrated circuits and software interface.

Investments in future-proofed designs will allow manufacturers to integrate new features such as displaying utility price signals from the electricity meter, notifying consumers about current or future DR events, and running system diagnostics to debug problems in the field or remotely through an Internet connection.

Displays will play a vital role in homes as consumers seek tools to interact and manage devices in their home. In-home displays are already supported by utilities who want their customers to alter energy consumption behavior based on electricity availability. Several premium home appliances such as refrigerators, washers and dryers, dishwashers, and air conditioners are now sold with touch-screen display capability included.

A number of non-traditional GUIs are emerging such as wireless routers, DSL modems, and network-attached storage devices for scheduling events, creating scenes, and sharing energy data. DVRs, DVD players, set-top boxes, and media centers make ideal interfaces for consumers preferring to interact with their homes through their televisions. Of course, communication tools such as telephones, mobile phones, MP3 players, and other wireless devices are also excellent candidates. Finally, there are utility-oriented products such as thermostats and in-home displays that can extend functionality to include device management.

Connecting Everyday Devices

People typically think of a home network in terms of a local area network (LAN). A new type of network is rapidly emerging called a home area network (HAN), which is used to connect consumer products together such as appliances, thermostats, pools and spas, light switches, electrical outlets, and other energy-consuming devices via the home's electrical power lines. Devices in the HAN may connect to a LAN or computer network to allow consumers to monitor electricity consumption, manage schedules, and remotely access the home, but the computer typically does not control all of the devices in the network.

In a true "press and play" environment, HAN-enabled devices such as appliances can be connected to the HAN simply by plugging in the appliance to the electricity outlet and then pressing a button on the device. This represents a significant paradigm shift in the idea of control systems requiring a central computer or controller to manage all devices. By embedding intelligence in every device, there is no need for expensive controllers to manage devices. This approach eliminates the extra cost, complexity, and unreliability of traditional home automation systems.

The presence of a HAN brings hidden benefits to consumers and manufacturers, such as enabling remote diagnostics and troubleshooting capabilities that are commonly used with equipment in LANs today. The HAN's connection to the meter typically is implemented in parallel with a connection to the home's high-speed Internet connection. This connection, while initially installed for energy awareness, provides the service lifeline to allow greatly improved customer-care programs such as remote diagnostics to eliminate multiple service visits, imminent failure notice to

service companies directly from appliances, new or improved software and firmware upgrades to deliver improved functionality or new features, or even eliminate a service visit altogether.

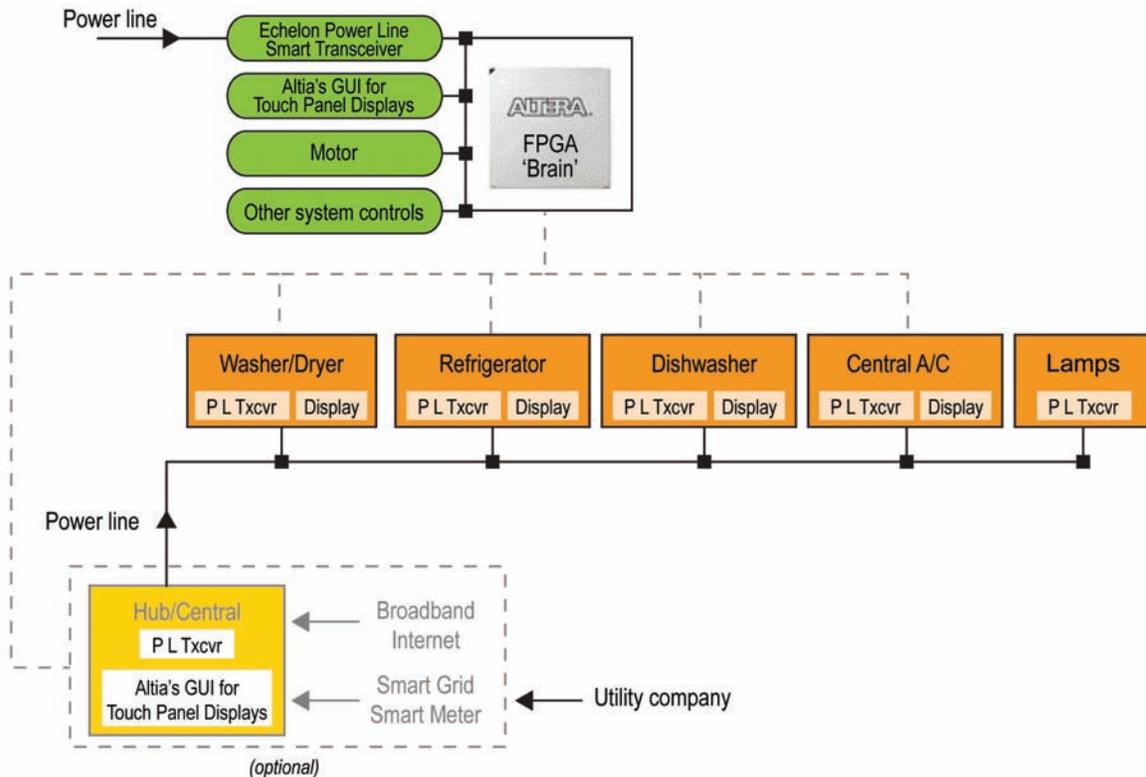
However, a power line is a very challenging communication channel. Intermittent noise sources, impedance changes, and attenuation make the power line a hostile signaling environment. Echelon's Power Line Smart Transceivers incorporate a variety of technical innovations to insure reliable operation:

- A unique dual-carrier frequency feature automatically selects an alternate secondary communication frequency should the primary frequency be blocked by noise.
- A highly efficient, patented, low-overhead forward error correction (FEC) algorithm can overcome errors induced by noise.
- Sophisticated digital signal processing (DSP), noise cancellation, and distortion correction algorithms correct for a wide variety of signaling impediments, including impulsive noise, continuous tone noise, and phase distortion.
- A high-output, low-distortion external amplifier design delivers 1A into low impedance loads, eliminating the need for expensive phase couplers in typical residential applications.

Reducing Cost Through Integration

Manufacturers are constantly seeking ways to reduce the BOM cost for their products. Figure 1 shows how Altera, Echelon, and Altia have collaborated to provide a highly integrated solution to address this demand.

Figure 1. Altera, Echelon, and Altia's Integrated Energy Aware Solution



One of the often-overlooked solutions for cost reduction lies in the integrated circuits themselves. FPGAs combine several components into a single integrated circuit that can be programmed in the field after manufacture. The chip is composed of an array of configurable logic cells (also called logic elements (LEs)) that can be configured or programmed to perform one of a variety of simple functions, such as computing the logical AND of two inputs. FPGA logic cells can be used as building blocks to implement any kind of functionality desired, from low-complexity state machines to high-performance microprocessors.

Traditionally, developers used FPGAs to verify design concepts and build initial product prototypes. However, with the recent advancement in the semiconductor submicron technology, low-cost FPGAs have made their entrance into many of the high-volume, consumer household products such as digital TV, set-top boxes, DVRs, and personal media players. By using the Altera® Cyclone® III FPGA with Nios® II soft processor core, it is possible to replace multiple MCUs with a single FPGA. Custom functions can be created with software libraries from Altera or third parties. This future-proof solution supports new features, last-minute changes, and rapid adaptation to changing market requirements.

Based on the TSMC 65-nm low-power process technology, Cyclone III FPGAs offer a flexible, reliable, and cost-effective solution to consumer appliances and home automation manufacturers. In conjunction with Nios II embedded processors, Cyclone III FPGAs enable designers to produce highly integrated systems, thereby reducing BOM cost, power consumption, and design complexity.

Echelon provides a software interface called the ShortStack® API to connect the Nios II processor to the Power Line Smart Transceiver. This API allows communication to take place between the host (Nios II processor) residing within an appliance display and other devices connected to the same HAN, such as lighting fixtures, dishwashers, refrigerators, pool pumps, and water heaters.

In addition to Echelon's ShortStack API, the Nios II processor also interfaces with the Altia Design and DeepScreen tools. These tools work together as a platform-independent embedded systems GUI technology suite, enabling highly interactive branded applications on any type of device. It allows homeowners to interact with all devices that are connected to the HAN.

Benefits of Energy Aware

The "Energy Aware" appliance platform developed jointly by Altera, Echelon, and Altia delivers proven, reliable performance and rapid development solution for home energy control to consumers, home appliance and home automation manufacturers, and utility companies alike. The solution delivers benefits to homeowners in three ways:

- *The homeowner stays in control:* Upon receiving power-warning messages from the electric utility companies via the smart meters, homeowners can determine if, and how, their smart appliances will respond to the energy event. They can program certain home appliances not to operate during peak time, thus reducing household energy costs while avoiding blackouts.
- *The homeowner can be proactive:* By knowing how much energy is consumed by every household appliance (connected to the power-line network) in terms of watts and dollars, homeowners can take a proactive approach in dimming certain room lighting or programming the washer and dryer only to operate at certain times of the day. Giving homeowners the ability to fine tune their energy use is particularly important in situations where a homeowner has chosen a pre-paid energy plan.
- *The homeowner saves time with less hassle:* Communicating HANs mean that homeowners no longer have to endure wasted hours or even days while service technicians schedule multiple visits with the wrong part or bad software. Better reliability, software updates, and preventative maintenance combine to deliver peace of mind and a greater sense of comfort.

For home appliance, home automation, or in-home display manufacturers' standpoint, this solution delivers the following benefits:

- *Increases revenues and customer loyalty* by providing additional services such as regular appliance maintenance or malfunction fixes without the need for the customer to place a phone call. Instead, the smart appliance automatically sends a service request to manufacturers via the power-line network.
- *Improves margins on warranties* through remote diagnostics and repair, remote software updates to prolong or improve an appliance's operating modes to better match a consumer's use pattern, single visit repairs, and maximize truck roll effectiveness by scheduling proactive on-site preventative repairs before a product fails

- *Cuts service costs* by remotely upgrading new software or diagnosing a malfunction before sending a technician equipped with the right parts coming over to fix the problem.
- *Reduces total development cost* while improving time-to-market with product scalability so that multiple products share the same hardware platform, with software features added or subtracted to create end-product differentiation.
- *Beats competition* with the ability to react quickly: any last minute design change to accommodate bug fixes or new features can be accomplished even after production, thanks to the flexibility and programmability of FPGAs.

The utility companies also benefit, as this solution:

- *Remotely monitors and controls* consumer energy usage
- *Communicates alert messages* directly to homeowners in special circumstances such as outage detection or electricity theft identification

Complete Set of Tools to Jump-Start the Design Process

By integrating Altia's Design and DeepScreen GUI development tools suite, Echelon's Power Line Smart Transceiver and ShortStack API, and the Altera Cyclone III FPGA and Nios II embedded processor, developers have a powerful platform for developing cost-effective, yet robust energy aware solutions.

Altera

To give designers a quick start, Altera provides a suite of complete, easy-to-use tools. The Quartus® II design software is a comprehensive environment available for system-on-chip (SOC) design, encompassing all phases of the FPGA design process. A comprehensive design methodology based on SOPC Builder, a system generator tool, enables designers to quickly assemble a custom device tailored to their need in matters of minutes. Using SOPC Builder and Altera's library of intellectual property (IP) cores, designers can select the right component for their FPGA function and verify its functionality relatively quickly. Altera partners with several third-party companies to provide additional IP to end customers as needed.

A single Cyclone III FPGA with a Nios II embedded processor serves as a processor, IP host, digital signal processor, and touch-screen display driver. In addition to the software design tools, Altera offers the Nios II Embedded Evaluation Kit (NEEK) and a set of design examples to help the home appliance, home automation, and in-home display designers kick-start the process.

Echelon

Echelon Corporation's ShortStack API replaces four function-specific microprocessors with a single Cyclone III FPGA and a PowerLine Smart Transceiver. This reduces cost, complexity, and development time while simultaneously adding network communications to an appliance that enables utility companies, home appliance OEMs, and consumers to effectively manage and control energy consumption.

The ShortStack API works in conjunction with Echelon's Power Line Smart Transceivers to use a home's existing electricity wiring for communications, making the solution a "no new wires" approach. The Power Line Smart Transceiver features a highly reliable narrow-band power-line transceiver, an 8-bit processor core for running applications and managing network communications, a choice of on-board or external memory, and an extremely small form factor—all at a price that is compelling for even the most cost-sensitive consumer product applications.

The appliances on the power line network form the backbone of the HAN, serving the critical need to provide reliable communications across an entire home or property. Other devices, such as RF-based sensors, perform better by leveraging the power line backbone to span greater distances and RF signal blockers such as brick walls. The power line signaling technology and the communications protocol for the HAN incorporated into Echelon's Power Line Smart Transceivers utilize the ISO/IEC 14908 global standard to ensure longevity and enable interoperability among disparate manufacturers.

Altia

The new face of home appliances is the human-machine interface (HMI), which provides a rich, interactive experience for the consumer. By creating a graphical user interface (GUI), developed with Altia's Design and DeepScreen tools to support multiple languages, colors, varying size fonts, and resolution, as well as other potential features, appliance manufacturers can leverage a single HMI across multiple brands and multiple product lines. Through downloadable software, manufacturers can remotely change and update new versions of the GUI and new feature sets. With a development tool suite, GUI design and deployment happens in a cohesive and streamlined manner, thus eliminating development cycles, diminishing overall project risk, and reducing the high costs associated with the graphical application development.

Developing a GUI with Altia's Design and DeepScreen tools provides two important benefits:

- A platform-independent embedded graphics engine enabling rapid porting from the targeted hardware platform to the Windows simulation with identical APIs
- A WYSIWYG GUI-building tool leveraging highly optimized portable graphics that output complete C source code suitable for deploying on low- or high-end products

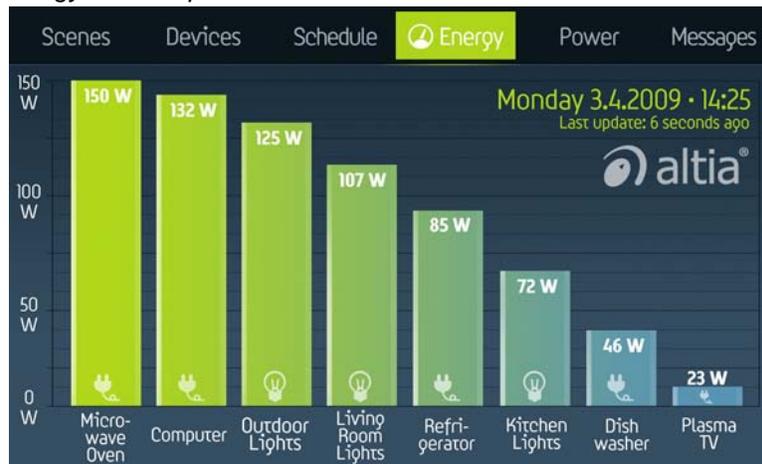
Electronic touch-screen displays are replacing dials and push buttons to become the primary HMI and product control mechanism for most of today's in-home consumer appliances. [Figure 2](#) shows how the Altia HMI provides homeowners with a single location to receive messages from household members, the local utility company, and appliances connected to the HAN.

Figure 2. Altia HMI Message Center



In-home appliance displays are supported by utility providers who want their customers to alter energy-consumption behavior based on electricity availability, as shown in [Figure 3](#). A flexible interface with upgradable features goes hand-in-hand to deliver greater service and higher value to consumers over time. Innovative, but as yet unrealized, programs from service providers are likely to take advantage of the design flexibility in the upgradable GUI for energy aware appliances.

Figure 3. Altia HMI Energy Consumption Interface



Conclusion

Altera, Echelon, and Altia have teamed up to provide a proven platform that delivers reliable performance and rapid development energy-saving solution for the home appliance, home automation, and in-home display manufacturers. The platform offers a simple approach to help homeowners increase awareness and effectively save household energy by monitoring and controlling each and every electrical appliance connected to the HAN. Moreover, it enables utility companies to remotely control and monitor consumer energy usage or directly communicate to homeowners under special circumstances. In short, it offers a new way of life devoted to a greener, better environment to everyone.

Further Information

Altera

- Cyclone III FPGAs:
www.altera.com/products/devices/cyclone3/cy3-index.jsp
- Nios II embedded processors:
www.altera.com/products/ip/processors/nios2/tools/ni2-development_tools.html
- Quartus II design software:
www.altera.com/products/software/quartus-ii/web-edition/qts-we-index.html
- Nios II Embedded Evaluation Kit, Cyclone III Edition:
www.altera.com/products/devkits/altera/kit-cyc3-embedded.html

Echelon

- ShortStack API:
www.echelon.com/products/development/shortstack
- Power Line Smart Transceivers:
www.echelon.com/products/transceivers/powerline

Altia

- Altia Design
www.altia.com/products_design.php
- Altia DeepScreen:
www.altia.com/products_ds.php

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