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APPLICATION NOTE 5383

Adding Intelligence to LED Lighting

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Abstract: How smart is your LED lighting system? While LED lighting holds the promise of reducing energy consumption and maintenance costs, smart LED lighting designs improve system performance in both areas, achieving higher performance per watt and reducing cost in the long term. Energy measurement, ambient light sensing, and communication serve as the cornerstones of smart LED lighting design. Energy measurement provides system health and consumption information. Ambient light sensing reduces an LED's on-time, conserving energy and extending diode lifetime. Communication links together each luminaire for identification of maintenance and system level coordination. The contribution of components to the overall system performance will be explored.

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Introduction

Imagine a marathon on a very hot, dusty day when saving every ounce of energy matters to the outcome. This race isn't half over, but the winner seems certain. The lead looks insurmountable, because this runner can do more with less energy. This runner shines brighter. In the face of heat and competition, this runner stays cool. So far, so good. Yet, will this competitor set the pace and hold the lead in the second half of the race? In a world of athletes who all train and compete intelligently, talent and potential only go so far. Great—and wasted—potential litters the road to success. Will the current leader dig deep, run a smart race, respond to the elements, and live up to expectations? Time, and intelligence, will tell.

Now you ask me, "What does a marathon have to do with LEDs? Do you really know what you're talking about?" I think so. Like a strong runner leading a marathon, LEDs hold promise in the world's race to produce more energy-efficient lighting. A major technological advance over both incandescent and fluorescent lighting, LEDs use less energy, last longer, and allow more control of color and direction of light.

In 2010, lighting consumed an estimated 19% of U.S. electricity.[1] By the year 2030, lighting could consume a full 767 terawatt-hours (TWh) annually.[2] What an opportunity for that lead runner in our fanciful marathon! LEDs for lighting could reduce that electricity consumption by 25% by 2030.[2]

Moreover, LEDs could ease the quantity and type of solid waste generated by lighting, because they last up to five times longer than other lighting solutions and contain no toxic materials. Eventually replacing LEDs will not necessarily occur because of lamp failure, but simply as the result of architectural style. Furthermore, the ability to fine-tune color with red, green, and blue (RGB) LEDs adds new options for performance and creativity. Ultimately, LEDs will function well beyond illuminating a space. They will simply look and fit better with new styles and fixtures.

LED Intelligence—Essential for Winning the Race

How will LEDs fulfill their tremendous potential? Undoubtedly, the first hurdle is price. LEDs currently cost an order of magnitude more than existing lighting solutions. Saving energy is often not enough to convince price-conscious businesses and consumers to make the more expensive purchase. Manufacturing savings and volume production will likely reduce prices over time, but will costs drop enough and can it come fast enough to win over users? Those trends are uncertain and entirely debatable. Admittedly, they are beyond the scope of this article. Consider also availability, which affects price. Go to any two hardware stores and try to find the same LED lamp. It's tough. Many retailers do not stock sufficient variety or quantity of LED lamps to pull in the casual consumer. Why? It comes back to price and efficient inventory turns. So where does that leave us, as engineers, innovators, and creative thinkers? How do we enable LED lighting to reach its potential? To win the marathon?

Let's give LED lights intelligence, make them smart. Let's give these lights eyes, a voice, and the ability to count. Designing high-value semiconductors into lighting applications will optimize energy efficiency, maximize lamp lifetime, and reduce maintenance costs. Then LEDs will run the rest of the race, hard and strong, and they will win the race by running smart.

Essential Elements of LED Intelligence

Ambient light sensing, communications, and energy measurement make up the critical components of an intelligent lighting system. Ambient light sensing allows lights to dim when other sources of light already light a space sufficiently. In addition, sensors that detect the color of ambient light permit color tuning of advanced RGB LED lighting systems. Communication permits remote control and central networking of both small and large lighting installations. Energy measurement provides accurate accounting of consumed power and system insight for predictive maintenance. All of these features—ambient light sensing, communication, and energy measurement—translate into energy conservation and lower operating costs. In this application note, I explore the critical design considerations of adding ambient light sensing, communication (both wireless and powerline), and energy measurement to LED lighting systems. Reference design examples are presented.

An ambient light sensor (ALS) detects the amount of light in the proximity of the sensor. These simple devices become the "eyes" of an LED lighting system, and also the throttle. When there is already light in the room, lighting is completely unnecessary. The lamps can be dimmed or turned off completely, reducing power consumption and increasing lamp lifetime. Features critical to an ALS include current consumption, lux range, and IR and UV blocking. These sensors must quietly exist in the system; they cannot pull excess energy that defeats their purpose of conserving system energy. Excellent ALSs perform with less than 1µA of current. Lux range must exceed typical ranges of lux for a given outdoor application. A range from 0.1lx to 100,000lx generally encompasses most applications. A slightly higher band may be necessary for system robustness. IR and UV blocking remove any unwanted light in the nonvisible spectrum from the actual system readings.

Light Sensing

Figure 1[3] shows the placement of an ALS in a luminaire. The sensor must reside beyond the light of the lamp itself to prevent artificial light from affecting the ambient measurement. In this design, the ALS resides on a separate board and receives shade from the beam supporting the lamp. This straightforward design enables the ALS to turn off the lamp when morning light exceeds a preprogrammed value. RGB sensors can add even more "character" to a lighting application. LED systems like the one pictured here that are equipped with RGB LEDs and ALSs can dynamically tune their color output for application-specific requirements, such as mood lighting on a terrace or department store lighting for a display.

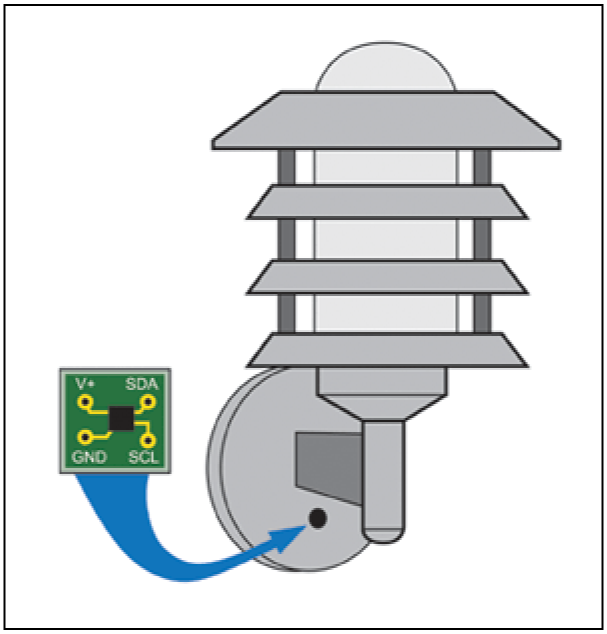

Figure 1. The ALS is mounted on a separate PCB and placed underneath the shadow of the luminaire's support beam. This prevents the sensor from reading light from the lamp itself.

Communications

Now let's talk about smart communication in LEDs. Ears and a voice are the next most critical features to make an LED light intelligent. By simply networking lights, you can turn them on and off, or dim them, via the network. This operation alone will reduce energy consumption. Communication also provides quick feedback for outages, necessary maintenance, and emergency situations. This information will save overall system maintenance costs. Both wireless and wired communication methods work effectively in various situations, depending on the network size and geography. Wireless works well in small indoor and larger outdoor applications with a continuous line of sight, available frequency bands, and sufficient headroom for transmission power. Powerline communication (PLC) uses the existing power lines to provide the communication. PLC works extremely well in large municipal-style lighting installations, tunnels, and indoor parking garages where line of sight is not possible because of geography or building walls. In all communication applications, reliability and robustness are critical. If communication fails, the system provides no benefits.

In wireless applications, signals may run over Wi-Fi®, ZigBee®, or other standard and proprietary protocols often in, but not limited to, the industrial, scientific, and medical (ISM) radio bands. Limiting power consumption provides network flexibility and is critical if endpoints use batteries. **Figure 2** shows a unique application in which a light switch is equipped with an energy-harvesting RF transceiver. The system harvests the energy used to flick the switch, resulting in a usable DC voltage that powers the radio communication over < 1GHz RF to the light fixture. This switch can be placed anywhere in a room, provided that the signal reaches the luminaire. Without the need to wire the light switch, room design becomes more flexible and lighting control more dynamic.

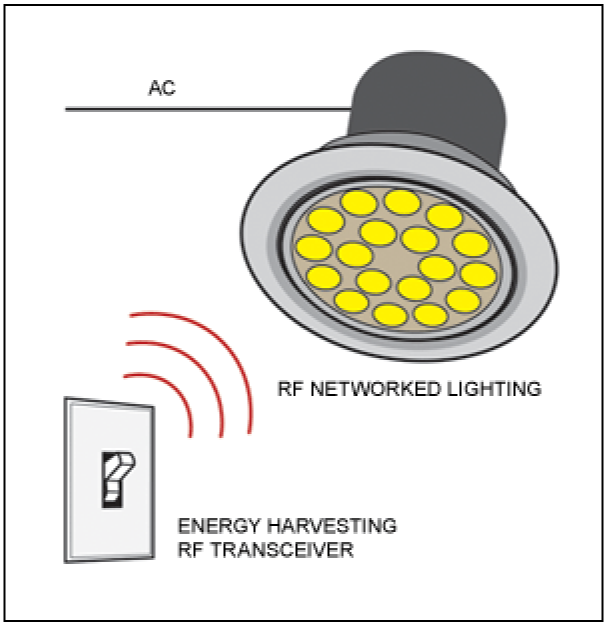

Figure 2. A building automation application in which the light switch contains an unwired, energy-harvesting RF transceiver that controls the LED lighting.

PLC control of lighting uses the existing lines that already deliver power, thus making this method a cost-effective choice. PLC eliminates concerns such as sharing communication frequencies, performance in bad weather, and network maintenance, because communication occurs over maintained lines already delivering power. Range, speed, and robustness are the critical design considerations with PLC.

Powerlines carry a tremendous amount of noise, which affects system robustness. G3-PLC™ communication is a new OFDM-based PLC standard that provides excellent communication over power lines. This standard allows for speeds up to 300kbps, mesh networking capability, and robust mode for high-noise situations. OFDM-based, PLC-controlled lighting networks similar to G3-PLC already exist.

Figure 3 shows the PLC installation for a tunnel lighting network by Nyx Hemera Technologies.[4] This system has already saved 25% in energy and 30% in reduction of maintenance. This large-scale installation supports up to 1022 lights on a single system and communicates over distances of up to 3km.

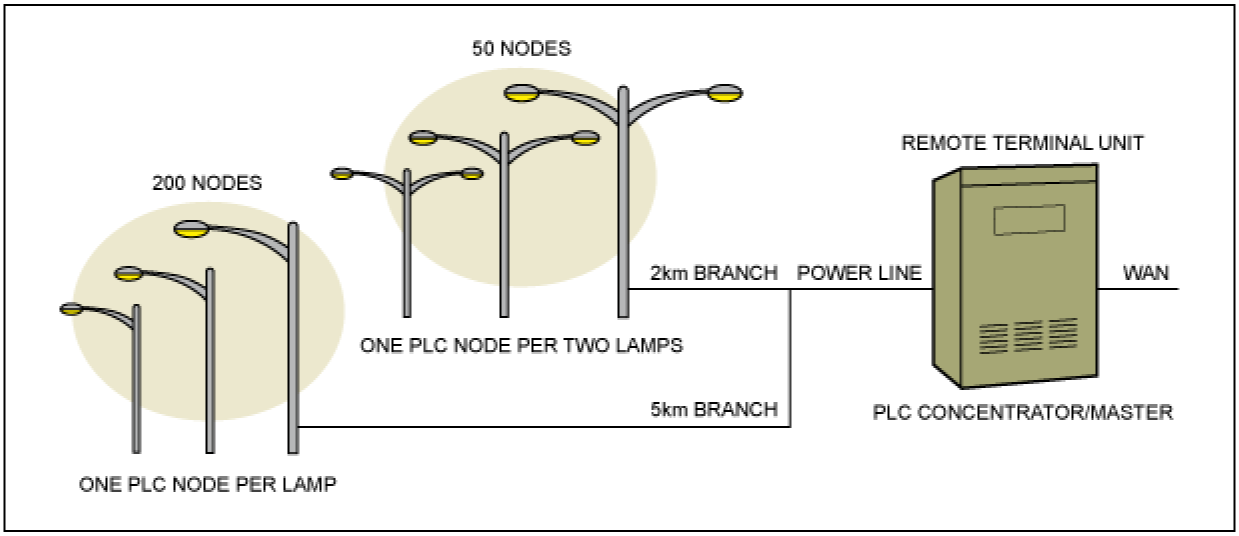

Figure 3. An example of a municipal streetlight network using PLC.[4]

Energy Measurement

Finally, smart LED lights need the ability to count watts. Each smart grid installation, from smart meters to voltage controllers to electric vehicle chargers, features energy measurement that gives utilities and customers accurate knowledge of power use in real time. Major lighting installations that report back their consumption provide finer granularity about building and municipal lighting situations. In this way, they can ensure that utilities only charge for the exact amount of energy used. By dimming or turning these lights off when not in use, they become responsive to user demand. Furthermore, variation in the energy consumption of specific lamps can signal a need for system repair, maintenance, or replacement. There is no doubt that with many lighting installations in areas difficult to access, optimizing maintenance will save money. To produce usable data in a smart grid, energy-measurement designs must provide a high level of accuracy across a wide current range. Furthermore, limiting or eliminating calibration time reduces overall system cost. **Figure 4** shows a flexible LED lighting reference design featuring energy measurement.[5] The energy-measurement chip also provides system dimming and a DALI interface.

Many municipalities are currently installing LED lighting without intelligent features. This will generate tremendous future opportunity for retrofit modules that enhance the performance of LED lights. To be upgradeable, these systems need interfaces that permit links to the intelligent lighting system. Given the cost and volume of LEDs, merely replacing relatively new and efficient LEDs will not be cost effective. Simple interfaces, such as DALI, will allow future addition of ALS, communications, and energy measurement.

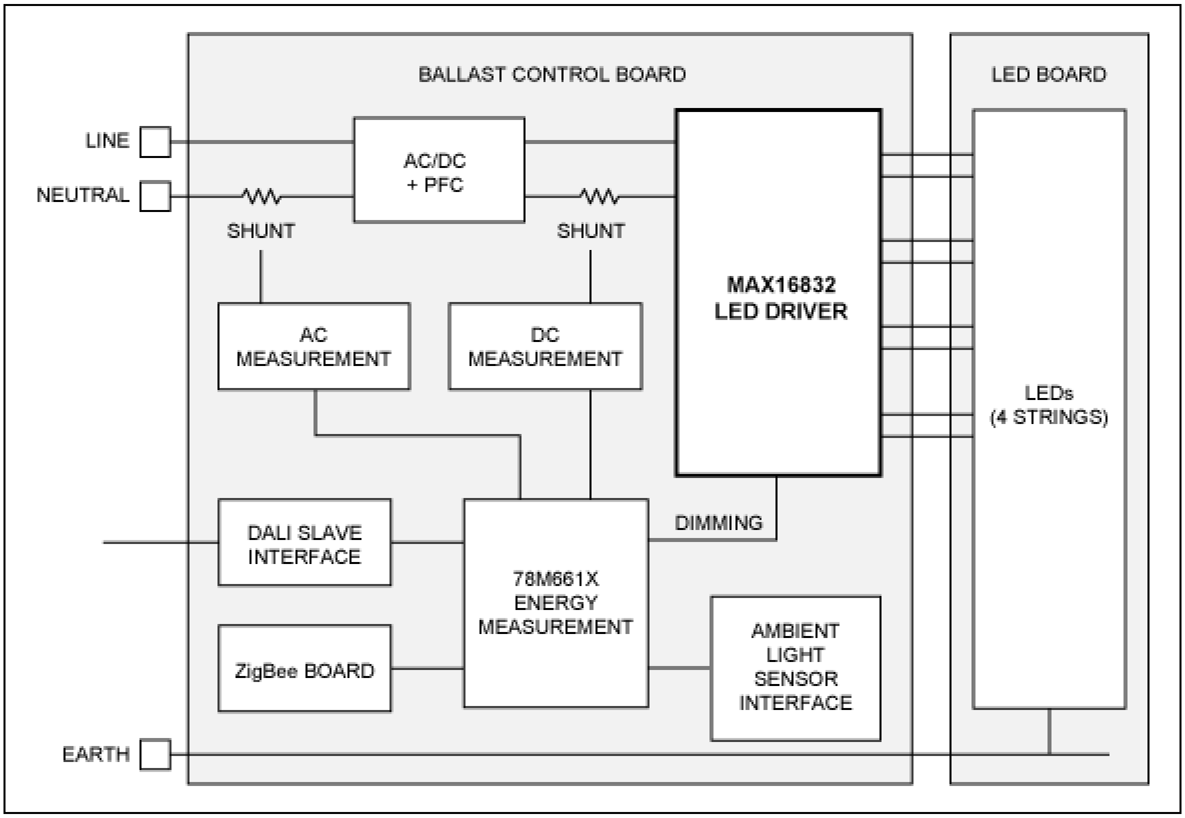

Figure 4. A complete smart LED lighting reference design, featuring energy measurement, ambient light sensing, and communication.

The Finish Is Most Promising

Where does this leave us? The race for industry and consumers to transition to LEDs will be a long one. It is clear that LED lighting holds the potential to transform lighting and save tremendous amounts of energy. Adding the critical elements of "intelligent" lighting—ALS, communication, and energy measurement—will make LEDs far more useful and appealing. The measurement data supplied by smart LEDs will further reduce the energy consumption of that lighting system. It will lower operational and maintenance costs. With intelligence, LEDs can reach their full potential and beat out traditional forms of lighting in the race that is already being run every day.

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Wi-Fi is a registered certification mark of Wi-Fi Alliance Corporation.
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Related Parts		
78M6612	Single-Phase, Dual-Outlet Power and Energy Measurement IC	Free Samples
78M6613	Single-Phase AC Power-Measurement IC	Free Samples
DS1340	I²C RTC with Trickle Charger	Free Samples
MAX16832	2MHz, High-Brightness LED Drivers with Integrated MOSFET and High-Side Current Sense	Free Samples
MAX16910	200mA, Automotive, Ultra-Low Quiescent Current, Linear Regulator	Free Samples
MAX2990	10kHz to 490kHz OFDM-Based Power Line Communications Modem	Free Samples
MAX2991	Power-Line Communications (PLC) Integrated Analog Front-End Transceiver	Free Samples
MAX2992	G3-PLC MAC/PHY Powerline Transceiver	Free Samples
MAX44000	Ambient and Infrared Proximity Sensor	
MAX44009	Industry's Lowest-Power Ambient Light Sensor with ADC	Free Samples
MAX6958	2-Wire Interfaced, 3V to 5.5V, 4-Digit, 9-Segment LED Display Drivers with Keyscan	Free Samples

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